

Reversing the role of the customer: the new 'customer-as-a-supplier' supply chain principle for the circular context

Jonathan Gosling, Nadine Leder, Mohamed Naim, Lucy Hoggins & Jane Hall

To cite this article: Jonathan Gosling, Nadine Leder, Mohamed Naim, Lucy Hoggins & Jane Hall (09 Oct 2026): Reversing the role of the customer: the new 'customer-as-a-supplier' supply chain principle for the circular context, Production Planning & Control, DOI: [10.1080/09537287.2026.2742183](https://doi.org/10.1080/09537287.2026.2742183)

To link to this article: <https://doi.org/10.1080/09537287.2026.2742183>



© 2026 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 09 Oct 2026.



[Submit your article to this journal](#)



Article views: 56



[View related articles](#)



[View Crossmark data](#)

Reversing the role of the customer: the new 'customer-as-a-supplier' supply chain principle for the circular context

Jonathan Gosling^a , Nadine Leder^a, Mohamed Naim^a, Lucy Hoggins^b, and Jane Hall^c

^aLogistics Systems Dynamics Group, Cardiff Business School, Cardiff University, Cardiff, Wales; ^bResilience Sustainable Solutions Ltd, Cardiff, Wales; ^cGreen Edge Applications Ltd, Chepstow, Wales

ABSTRACT

This paper evaluates the relevance and sufficiency of a suite of six established supply chain principles for uncertainty reduction in circular supply chains, focusing on plastics in the construction sector. Using a structured intervention-based research approach, two trials with industry consortia designed and implemented closed-loop models for mortar tubs and aggregate packaging, incorporating higher recycled content and new reverse logistics arrangements. Findings confirm that original principles remain relevant but insufficient in circular contexts. We propose an additional principle 'Customer-as-a-Supplier (CaaS)' to address uncertainties in quality, timing, and volume of returned materials, and the changing role of customers in closed loop supply chains. CaaS emphasises communication, incentives, convenient return logistics, contamination control, and retailer engagement to enable high-quality material recovery. This extends the existing framework and highlights the active, and changing, role of customers. Future research should test the generality of CaaS and existing principles across diverse closed-loop supply chains.

ARTICLE HISTORY

Received 21 November 2025
Accepted 21 September 2026

KEYWORDS

Circular supply chain;
plastics; construction

Introduction

Global plastics production has almost reached 400 million metric tons with only about 14-15% being kept in the material loop e.g. by recycling (Alves 2024; King and Locock 2022). An increased public perception towards single-used plastics and a growing pressure from policymakers via the introduction of new schemes and regulations (e.g. the UK Environment Act 2021 and the Environment Protection (Single-use Plastic Products) Wales) Act 2023), is forcing organisations to reconsider their handling of plastics (Stumpf et al. 2023). New schemes, such as Extended Producer Responsibility (EPR), where organisations are expected to cover the full costs of recycling and disposing of their plastics packaging are further levers to support the movement towards a sustainable plastics economy (UK Government 2021). Hence, there are increasing pressures and drivers to reduce the environmental impacts of plastics. However, this has proven very challenging given the pervasive use of plastics in industrial and consumer products.

It is argued that a fundamental shift is needed to move the focus from a traditional linear supply chain to a more circular supply chain (Ding, Wang, and Zou 2023; Govindan and Soleimani 2017). Building on previous work, Batista et al. (2018) developed a circular supply chain archetype, based on the closed loop supply chain concept, incorporating sustainability augmented design complexity, downstream design

and value chain composition. However, several significant barriers to achieving such an archetype have been identified in the literature. This includes amongst others, volatility in quality and amount of returned material (den Hollander 2017; Kirchherr et al. 2018; Urbinati, Franzò, and Chiaroni 2021). On an organisational level, barriers include the involvement of top management, and a hinderance in strategic decision-making which seemed often to be linked to financial barriers such as low initial capital to make investments (Bouzon, Govindan, and Taboada Rodriguez 2018). In a B2C environment barriers included the 'loss of user control' over products, which can lead to further financial and operational risks (Bressanelli, Perona, and Sacconi 2019; Hahladakis and Iacovidou 2018; Tukker 2015).

The challenges are particularly pronounced in the construction sector, which is characterised by complex supply chains and long product life-cycles. Further, the sector is a major consumer of plastics and significant generator of waste. Currently, plastic value chains in the construction sector are predominantly linear with recycling rates as low as 17% (World Economic Forum 2023). Therefore, the sector presents both a challenge and an opportunity to implement circular supply chains principles, especially by using recycled plastics and closed-loop material flows.

To tackle these barriers and to raise awareness for circularity within material-intensive sectors such as construction, with businesses and end-consumers alike, the UK

government has started a range of initiatives, such as the Circular Economy Taskforce and the Waste and Resource Action Programme (WRAP). These programmes are designed to support organisations and end-consumers in taking a proactive approach towards circularity and change the way how products are designed, produced, consumed and disposed of e.g. WRAP (2021). WRAP's activities are strategically focused across three priority areas, including Food, Textiles and Plastics Packaging (WRAP 2006a). Whilst plastics packaging has been identified as a source of waste which can be recycled, research often focuses on the chemical elements, rather than looking at resource efficiency and infrastructure for plastics value chains (WRAP 2006a). Governmental funding enables WRAP to translate national circular economy objectives into sector-specific projects hence satisfying industry needs. In doing so, WRAP Cymru's initiative on innovative supply chains, worked with local businesses, that have particular pains, to increase the recycled material content in products. This allowed design for circularity and to establish a closed loop supply chain that demonstrates financial viability. This provides a set of case studies (<https://www.wrap.ngo/what-we-do/case-studies>) that illustrate differing approaches and highlight their implications and potential applications across industry sectors.

Further motivations to reduce plastic packaging waste included the UK's plastic pact, which brought together over 200 businesses from different industry sectors to look at enhancing plastic value chains in the UK (WRAP 2006b). This study is based on two such projects, which aimed to design for circularity, to set up a financially viable closed loop supply chain and to explore the extent to which it is possible to incentivise the return process for such circular supply chains, specifically when working in a B2C environment (e.g. Batista et al. 2018; Bocken et al. 2014).

During the study the role of the customer became paramount in realising the circular supply chain. While some authors have questioned the role of 'linear' supply chain thinking in a 'circular' setting (e.g. Batista et al. 2018), we challenged this new thinking and determined that there are still some fundamental principles, namely, the Control system principle, Time Compression principle, Information Transparency principle, Echelon Elimination principle, Synchronisation principle and the Design for X (DfX) principle (Alfnes et al. 2023; Gosling et al. 2014; Towill 1997), that are relevant but may need to be adapted, moderated and/or augmented. Traditionally, the role of the customer has been viewed as 'select and pay for' production output (Sampson and Spring 2012), but in the circular context, this role may need to be reconceptualised, as the customer is needed to undertake additional activities, such as providing stable resource and material flows.

This study reports the findings of the aforementioned two Welsh Government funded trials. The trials build upon 'interventions', or intervention strategies (Chandrasekaran, Treville, and Browning 2020; Oliva 2019) to demonstrate how industry bodies can quickly adapt and change within their given business context to implement circular approaches which are often requested by governing bodies. As both

trials had moved on, the research developed from an intervention-based approach to a conceptual replication study (Hendrick 1990). Replication studies in general have still had little traction in operations management research (Pagell 2021). The first project trial, undertaken between 2018 and 2021, focused on hard-plastic tub re-use and recovery in the construction sector, while the second, undertaken 2022–2024, examines soft-plastics packaging for aggregate products in the same industry sector.

More specifically, we address two research questions:

- How does an original suite of linear supply chain principles need to be augmented to cope with uncertainties in circular supply chain management?
- What is the role of the customer in circular supply chain management, given that they become an integral part of the returns process and hence a source of material supply uncertainty?

The paper follows the C-building blocks, i.e. common ground, complication, concern, course of action, and contribution, for management theory development proposed by Lange and Pfarrer (2017). First, we establish the common ground by reviewing the relevant literature on circular supply chains and plastics recycling. We also highlight the complication associated with uncertainties, and the foundational supply chain principles that underpin our analysis but which do not account for the resulting uncertainties that result when the customer now becomes a supplier in the closed-loop supply chain. Hence, we indicate the concern that the complication has considerable implications for the performance of the closed-loop supply chain with respect to the timing, quantity and especially the quality of the final product that contains a percentage of recycled content. Next, we lay out our course of action by describing the intervention trials undertaken and the Population-Intervention-Comparison-Outcome (PICO) framework, which has been used extensively to learn from interventions (e.g. Huang et al. 2006; Nishikawa-Pacher 2022), explaining how we try to mitigate against the complication and hence the concern. Finally, we report the findings from each intervention before synthesising insights to articulate and discuss the need for a proposed 'Customer-as-a-Supplier' (CaaS) principle, thereby enhancing theoretical understanding of uncertainty in circular contexts and to show how the work moves the scholarly conversation forward.

Our substantive contribution is in identifying this new principle CaaS that needs to be included for due consideration of the circular economy context. To the best of our knowledge there are only a few papers where the concept, rather than a principle, has been noted in a service-sector context (Sampson 2000) where customers provide themselves (e.g. healthcare) and/or broken products (e.g. vehicle repair), a mobile-phone remanufacturing setting (van Nunen and Zuidwijk 2004) where intermediaries sort, grade, test, and sell returned products before supplying to remanufacturers, where customers are a source of supply in a system dynamics model of a recycling and reuse process, and a

circular economy source of uncertainty (de Lima, Seuring, and Sauer 2022, de Lima 2024). In addition, there is a growing body of knowledge suggesting that 'green' customers, and coordination of them, are a key component of circular chains (Guo et al. 2021).

The remainder of the paper is organised as follows. Section 2 reviews the literature on circular supply chains, plastics recycling, uncertainty, and established supply chain principles. Section 3 outlines the intervention-based research design and the two intervention trials. Section 4 presents and evaluates the findings from the trials using the PICO framework. Section 5 discusses the implications of the findings and develops the proposed Customer-as-a-Supplier (CaaS) principle. Finally, Section 6 concludes the paper, highlighting contributions, limitations, and directions for future research.

Literature review

Circular supply chains in the plastics environment

The transition to a circular economy requires fundamental, systemic changes in business models and their supply chains. While the concept of circularity is not new, it offers a framework that enables material recovery in supply chains, helping them to become more circular (Batista et al. 2018; King and Locock 2022). In a circular supply chain, material can be either recovered in an open or closed loop system. In a closed-loop supply chain material is often returned to the original manufacturer with the intention of being reused for the same purpose. In contrast to an open-loop supply chains, in which material flows are being transferred to different manufacturers, or even across industry sectors, for the purpose of achieving an alternative usage (Batista et al. 2018). Uncertainty is already a well-established challenge in traditional linear supply chains, particularly from an end-customer demand perspective (e.g., Lima et al. 2021). However, in circular supply chains this uncertainty is amplified and transformed as the role of the customer shifts from being solely a consumer to also acting as a supplier of returned materials. This role reversal introduces new sources of risk, particularly related to the quality, quantity, and timing of returned materials, which complicates material availability and forecasting accuracy. As a result, circular supply chains face heightened uncertainty not only in demand management but also in reverse flows, posing additional challenges for planning and coordination.

Circular supply chains are particularly relevant in the context of plastic, which is now embedded across a vast range of products and industries. Managing material flows through reuse and recycling is critical in reducing the environmental impact. As plastic is continuing to rise, supply chains need to adapt to be able to handle the growing volume of plastic material. Globally, approximately 14% of plastic packaging is collected for recycling purposes, of which only about 5% is retained to be reintroduced to the production cycle (Ellen MacArthur Foundation 2017, King and Locock 2022). Therefore, there has been a growing interest in investigating circular practices for plastics in a diverse range of products and sectors (Johansen et al. 2022). These include, amongst other, agricultural, automotive and construction, as well as more end-consumer facing areas such as municipal waste

management and targeted approaches for packaging waste in electronic equipment (King and Locock 2022).

Whilst plastics research in the context of supply chain management is applied across a wide range of sectors, its implementation often relies on systemic changes that consider the complexity of the various ecosystem players. Early work by Stahel (1982) already highlighted the importance of obtaining new resources from what is often called post-consumer waste via recycling of materials. More recent research from the supply chain discipline has suggested that there is a need to develop strategic long-term commitments between a group of core actors to develop the systems and networks, including the creation of potentially new relationships to enable such a vision (Miemczyk, Howard, and Johnsen 2016). In doing so, research in circularity has started to adopt an ecosystem-view, in which the management of multilateral dependencies and the alignment of partners is of greater focus and importance in circular supply chains and the wider circular economy context (Adner 2017; Pietrulla 2022).

Despite the growing efforts in plastics waste management and recycling, research and industry identified a variety of barriers. One of the issues included organisational and infrastructural barriers, such as a lack in existing infrastructure to collect, and store material suitable for reuse (Hahladakis and Iacovidou 2018; Kahlert and Bening 2020; Stumpf et al. 2023). Further issues have been identified alongside scalability, including collecting sufficient quantities of plastic that are both suitable for the recycling process, e.g. reducing contamination rates, and available in volumes large enough to ensure financial viability (Hopewell, Dvorak, and Kosior 2009).

Another barrier relates to the materials, components and products and their technicalities and characteristics for reuse and recycling processes. Products are often not fit for the purpose of being reused or recycled. This highlights the growing importance of design for circularity (WRAP 2025). Further, a related concern, is the quality of the covered materials, which can be compromised by poor product design, contamination or material degradation through the product lifecycle. Specifically, the quality of plastic packaging may change at different stages of the plastic materials lifecycle, known as downgrading. These changes may not always be associated with alterations in material properties, but in the way materials are collected and handled for reprocessing. Furthermore, ensuring consistent supplies, and risk reduction of demand and price volatility are also challenges (Hahladakis and Iacovidou 2018).

In addition to technical and systemic barriers, circular supply chains need to deal with a range of financial and corporate tensions, as well as social behaviour change. Behavioural and organisational dynamics in organisations can influence the implementation and progression of circular supply chains. When implementing circular initiatives, a very common tension is that companies' informal systems strongly promote circularity whilst their formal systems have a very focus on financial performance. In day-to-day decision making, this can mean conflicting priorities in relation to social, environmental and financial performance (Epstein, Buhova, and Yuthas 2015).

Whilst financial and organisational tensions pose internal challenges, achieving a functioning circular supply chain also relies heavily on the social behaviour change and commitment of the end-consumer. Hence, behaviour change for circularity is identified as an emerging field. Given the difficulties in motivating consumers to return used products (Farooque et al. 2019; van Weelden, Mugge, and Bakker 2016), circular strategies need to consider incentives and interventions fostering positive behaviour change (Farooque et al. 2019). Social influence, education, awareness, information, knowledge, trust and policy approaches have been identified as key motivational factors achieving such positive approach towards circularity (Crome et al. 2023). In addition, the consumer's physical and social environment play a vital role. Supporting circular behaviour change requires both well-designed behavioural nudges and adequate infrastructure to facilitate easy and accessible return processes from the end-consumer perspective (Farooque et al. 2019, Parajuly et al. 2020).

To enable the effective implementation of circular supply chains it is important to also understand the broader policy and economic drivers that support this systemic change. Drivers for circularity have been identified, alongside legislation in the form of legal and regulatory frameworks, to apply light pressure but equally supportive mechanisms such as tax incentives and funding initiatives (Aloini et al. 2020). Economic drivers are often linked to cost efficiency and innovation which can generate tension in the realisation of circularity. Organisational dimensions, such as brand reputation and social responsibility, can be seen as driver and barrier simultaneously (Aloini et al. 2020). Recent research on household collection has highlighted how collaborative initiatives can help overcome systemic barriers and inform scalable models for integrating challenging materials like flexible plastics into circular systems (Flexible Plastic Fund 2025). This interplay of economic and organisational factors shows the need for systemic approaches that go beyond isolated initiatives, ultimately connecting material recovery with broader supply chain strategies.

Given the behavioural, financial and infrastructural challenges in circularity, applying the principles of circular supply chains becomes essential in facilitating effective material flows and return processes.

Principles for uncertainty reduction in 'open-loop' supply chains

It has been argued that many modern supply chain principles may be traced back to the classic production distribution systems simulations by Jay Forrester (Towill 1997). Furthermore, by integrating the methodologies of industrial dynamics (Forrester 1961), and material flow control (Burbidge 1961), a set of system operation principles have been developed (Towill 1997). The latter looked to provide a foundation for sound supply chain design. The 'FORRIDGE' principles, a phrase derived from combining the key intellectual influences of Forrester and Burbidge, were originally defined as control system principle, time compression principle, information transparency principle and echelon

elimination principle, and a previously implied fifth 'synchronisation' principle was later made explicit by Geary, Disney, and Towill (2006). Since publication in 1997, the principles have been shown to offer a powerful guide for engineering effective supply chains. The principles can be summarised briefly as:

- Control system principle - integrated control of production volumes to avoid bullwhip and stock outs.
- Time compression principle - stabilise processes, automate, optimise and compress to achieve minimum reasonable time.
- Information transparency principle - Ensure order information (i.e. volumes) are shared throughout chain and not distorted.
- Echelon elimination principle - Reduce the number of material or information stages and/or interfaces to minimum reasonable level.
- Synchronisation principle - Enable coordinated process flows to reduce potential for 'batch and queue' to create phasing issues and unsynchronised activity.

In addition to the five principles documented in the existing literature, a sixth 'Design for X' (DfX) principle was later developed by Gosling et al. (2014), based on empirical work in the construction industry. DfX has become an umbrella term used to imply effective design principles, including, for example, approaches such as design for assembly, design for manufacturing, design for buildability, and design for life cycle are all included in this umbrella. Two enablers of training and learning, as well as supply chain integration have been added (Gosling et al. 2014). More recently, empirical work has confirmed the reliability of the six overarching principles as effective for governing uncertainty mitigation in the shipbuilding sector (Alfnes et al. 2023) but also noted tactical differences in deployment of the principles, particularly in highly innovative environments.

Uncertainties in 'closed-loop' supply chains

It is claimed that without an understanding of uncertainty then strategists and managers are doomed to make wrong decisions when attempting to develop circular economy models, especially regarding the flow of waste streams that are the source of supply (Esbensen and Velis 2016). Goltso et al. (2019) outline the various uncertainties faced in a remanufacturing context, summarised as uncertainties found in traditional forward, or open-loop, supplies chain (internal process, demand side, supply side, and production control uncertainties) which are then exacerbated by the reverse flows rather than them instigating new forms of uncertainty types. Of particular interest to this current paper is that the supply side is aggravated by uncertainties in the quality, volume and timing of return flows from the customer.

de Lima, Seuring, and Sauer (2022, de Lima, Seuring, and Genovese 2024), in presenting the integration of circular economy considerations with general supply chain management, highlight the more general circular economy

uncertainties, that include remanufacturing but also other forms such as reuse and recycling, which they categorised as internal organisation, internal supply chain and external. Of the four internal supply chain uncertainties identified they name one of them as 'customer as a supplier' uncertainty but without any further elaboration.

Unlike the previous two contributions, that are literature review based, Marcos et al. (2021) take the uncertainty framework of Goltsos et al. (2019) and provide empirical evidence from existing published data for the existence of the different types of uncertainty, with the addition of an environmental uncertainties category, in an electric vehicle batteries industry context. They indicate that in the battery industry the forward supply chain is still the biggest instigator of uncertainties with the reverse flow account for somewhere between 0%-17% of uncertainties depending on the specific category. For the supply side uncertainty of interest in this paper, the reverse flow of quality, quantity and timing of returns goods account for 13% of the uncertainty experienced.

Alfnes et al. (2023) explicitly connect uncertainty in supply chains with established supply chain design principles. Their analysis focuses on engineer-to-order (ETO) production systems and builds on the work of Gosling et al. (2014). In contrast, the original principles developed by Towill (1997) were grounded in high-volume production environments, the context that is more closely aligned with the setting examined in this paper. A systems perspective underpins the original suite of supply chain design and operation principles (Towill 1997), emerging from control theory, industrial dynamics, and material flow analysis. In traditional linear supply chains, these principles have proven effective for uncertainty reduction and performance improvement. However, as explained above, circular supply chains introduce different types of uncertainties, particularly as consumers have the possibility to become both downstream recipients and upstream suppliers (Goltsos et al., 2018). This dual role expands system boundaries, increases behavioural and quality-related uncertainty, and disrupts the controlled flow assumptions embedded in the original principles. Hence, driving our inquiry into the application and extension of the principles.

While there is no explicit reference to the principles, and the role of uncertainty, in the circular context we do have examples where there are implicit considerations. For example, Suzanne, Absi, and Borodin (2020) highlight the challenges of coping with uncertainties (e.g. volume of return and quality of returned products) in production planning and control (control system principle).

Recent research on closed loop supply chain identified lead times as important component, with closed loop supply chains facing similar challenges to traditional supply chains (Ponte et al. 2025) (time compression principle). Do and Stevenson (2026) consider the implications of electronic platforms in supporting organisations and supply chains in developing circular economy approaches. They found that digitalisation enables coordination among partners (synchronisation principle), information visibility (information

transparency principle) and forms of semi-disintermediation (echelon elimination principle).

Kazancoglu et al. (2023) argue that Industry 4.0 technologies can be used to mitigate many of the risks of the transition to circular supply chains, for instance supporting capable real time information management of returns, standardising processes, and adopting DfX to support product design for minimising waste and improved recyclability (information transparency, synchronisation and DfX principles). Bhatia et al. (2022) consider the need for 'green' innovation to ensure product design enable recovery after use (DfX principle).

Method

Research design

The research design follows intervention-based research approaches, which have recently gained significant attention in operations management (Chandrasekaran, Treville, and Browning 2020; Oliva 2019), as well as in studies focused on supply chain interventions (Hasle and Vang 2021). These approaches suggest that learning can be captured through interventions by considering the methodology used to apply a set of theories, in our case supply chain principles, to transform a problem situation into an improved state (Chandrasekaran, Treville, and Browning 2020; Oliva 2019).

In this study, the problem situation involves overcoming the uncertainties to achieving a closed-loop supply chain model for plastic products in the construction sector. To address this, we draw on existing knowledge related to open-loop and closed-loop supply chains, including previously identified principles and uncertainties. These theoretical insights are refined as we engage with the problem situation.

The method consists of conducting trial projects aimed at introducing new products with higher recycled content and implementing return processes that support the closed-loop model. These trials not only reaffirm certain aspects of the existing theory but also challenges the sufficiency of the existing principles, prompting further theoretical development.

Since two project trials are considered, we explore two distinct pathways from the initial problem situation to the improved state. This dual intervention-trial approach also provides an opportunity to capture learning between the trials. Consequently, insights gained from the first trial can inform adjustments to the theoretical framework or the methodology applied in the second trial. Our approach was analogous to the Population-Intervention-Comparison-Outcome (PICO) method adopted by healthcare researchers and clinicians to better determine and refine clinical questions. Huang et al. (2006) undertook a review of PICO healthcare applications and found that, despite limitations, the PICO method was sufficient for helping clinicians undertaking evidence-based medicine. More recently, Nishikawa-Pacher (2022) argues that PICO has universal applicability although there is no explicit mention of how it may be exploited for production or supply chain management purposes.

Given the increasing emphasis on intervention-based research in operations management (Gupta et al. 2024; Oliva 2019), PICO offers a valuable and underutilised mechanism for systematically comparing real-world trials, clarifying causal mechanisms, and ensuring transparency in how interventions influence outcomes. We therefore apply the PICO framework here to provide a structured approach for describing, comparing, and contrasting the two trials across each element of the mnemonic.

For Intervention Trial 1 (IT1), the core project team included members from a manufacturer, consultants specialising in sustainable solutions, researchers specialising in supply chain and engineering testing, and a waste collector. For Intervention Trial 2 (IT2), the core project team consisted of a large brand owner of aggregates, a large retailer, consultants specialising in sustainable solutions, researchers specialising in supply chain management and materials testing, and a waste collector. In addition, both trials involved a range of supply chain actors as highlighted in Table 1. Hence, in both interventions, there was an interdisciplinary team working collaboratively to problem solve. The two main areas of focus for each intervention were, firstly, increasing recycled content in the plastic manufactured product, secondly, developing a new collection and returns process for each trial. In addition to regular and frequent 'core team' meetings, a wide range of data collection methods were used, which are summarised in Table 1 that indicates the mechanisms used for data collection as well as the key performance indices used to assess the outcomes of the trials. Big picture mapping (Hines and Rich 1997) was a key technique to bring together understanding from the different data collection activities.

Intervention trial 1 – plastic mortar tubs

The primary industrial partner on the project was a Welsh plastic rotational moulding manufacturer, who sells approximately 26,000 products annually in a mortar tub range manufactured in a variety of colours. The manufacturer adopts a rotational moulding process using pulverised polyethylene (PE) or low-density polyethylene (LDPE) powder, ground to a diameter of <600microns. Powder is poured into metal moulds and rotated in a gas fired oven to layer the inside of

the mould resulting in a shaped product. After production, tubs are dispatched to several categories of customer including mortar companies that use the tubs to provide mortar, wholesalers that can supply either builders or smaller retailers, house building companies, and finally general builders including self-employed bricklayers. Once a contractor has finished using a mortar tub on a project many likely go to landfill, while a very small percentage are re-used for other projects. A small proportion of these would be unrecyclable due to damage or contamination. However, other quantities could re-enter the supply chain but do not do so due to lack of a viable pathway. In addition, there is a lack of visibility/traceability of tubs post-delivery to customer.

At the start of the project there was no commercially viable option for recycling mortar tubs due to levels of contamination. Hence, the aim was to have recycled content of 75–100% and trial the new tubs in-situ and gather feedback on use. At the start of the trial, it was clear that there were well established partnerships between production, material suppliers and some customers. However, the reverse logistics supply chain was largely fragmented. Recycled content with varying proportions of recycled content, 25%/50%/75%/100%, was sourced to manufacture mortar tubs and demonstrate through tests the robustness of the recycled products in use.

There were several key barriers to production of mortar tubs; firstly, the limited material quality parameters set by the manufacturer, and secondly, a reluctance by the manufacturer to trial more than 50% recycled content. To overcome barriers around provenance of material, we established a circular model working with an industrial plastic recycler to reprocess mortar tubs into a useable material for the project. This included, washing and granulating tubs using a multi-stage industrial wash process, extruding back into pellet and finally grinding to a powder for use in the rotational moulding process. The project intervention gave the manufacture confidence to trial manufacture approaching 100% recycled content that had known provenance and material quality parameters, and the 100% recycled content tub was demonstrated to be the most robust in material tests.

Figure 1 shows the process map indicating the tracking pathway through forward and reverse logistics processes. The dotted line illustrates the pathway of the in-situ trials, where a sample of 80 mortar tubs was produced from the recycled materials, and a QR code and tracking system was

Table 1. Summary of data collection activities.

	Intervention Trial 1	Intervention Trial 2
Interviews to support problem formulation and solution development	Customer groups, including builders merchants, housebuilders and general contractors (x10).	Manufacturers (x2), Retailers (x2), IT solutions for waste (x1), waste processor/collectors (x3), organisations to support reverse logistics (x1)
Site Visits	Manufacturer, recycling centres, waste processors.	Bagging facility, retailer, supplier, waste processors.
Feedback / Evaluation Mechanisms	Material testing Tracking data of tubs in use (qualitative and quantitative) Qualitative stakeholder feedback.	Material testing Bagging observation Finished goods monitoring Stakeholder feedback on collection process
Key performance indices	Mechanical performance / durability % recycled content achieved Product functionality Tracking engagement rate Closed-loop feasibility Reprocessing success Customer perception	Tear / puncture / slippage / seal performance % recycled content achieved % carbon emissions reduction Customer return participation Contamination level of returns Collection scheme feasibility

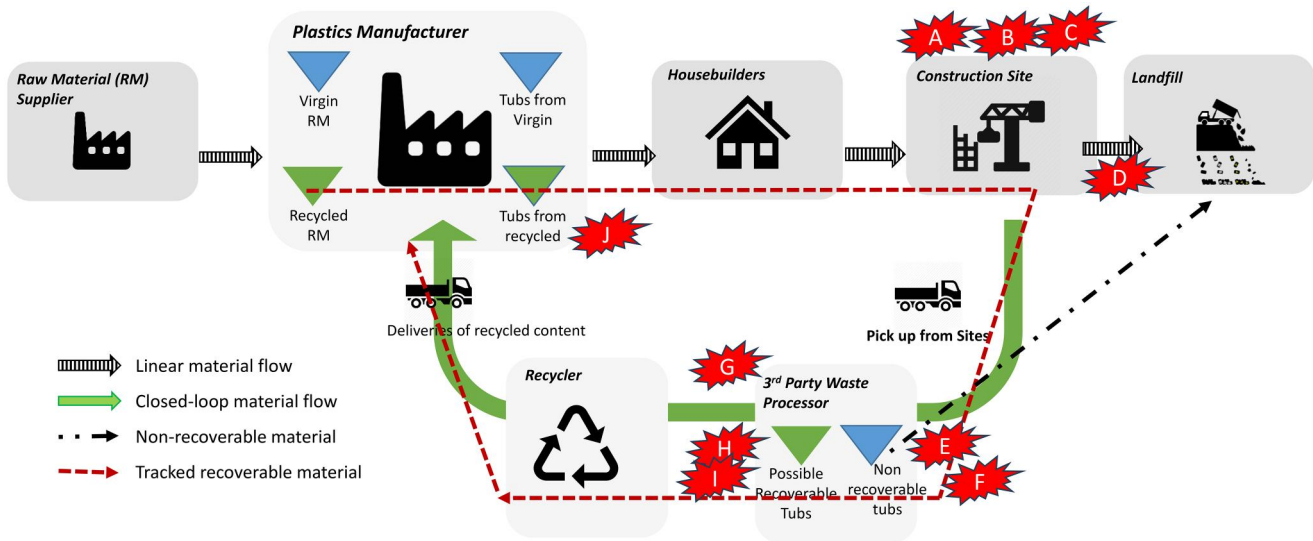


Figure 1. Intervention and tracking pathway for Intervention Trial 1.

deployed to monitor the new recycled plastic tubs in use. An asset tracking app was employed to track and return the used tubs.

Figure 1 also indicates the substantive ‘pain points’ that were identified during discussions with trial participants and that needed addressing. These are

- A. Tubs get bashed around a lot and damaged on site.
- B. Forklift truck drivers are the main cause of damage.
- C. Cleaning difficult to enforce as they used by subcontracted brick layers and often no mains water on site at start of project.
- D. Broken tubs enter the general waste stream for landfill.
- E. Currently used tubs are chopped-up and put into the skips for landfill.
- F. Larger builders will have segregated skips, but some may just use inert general waste.
- G. Mortar tubs are often filled with rubbish before being thrown in a skip.
- H. Most contractors will not return used tubs to a central depot.
- I. Most house builders will not transfer to other working sites at end of life.
- J. Perception that recycled tubs are not as strong as original tubs using raw material.

Pains A – I are directly related to the CaaS principle.

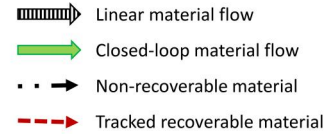
Intervention trial 2 – plastic bags for aggregate products

Trial 2 is focused on LDPE film plastic packaging products for aggregate materials sand, gravel and decorative materials. The primary project partners were a large brand owner and producer of aggregate products and a large retailer of building products. At the start of the project, the producer incorporated up to 50% recycled material comprising a post-consumer clear pellet with approximately 20 million plastic packaging products per annum for aggregate materials. Many bag manufacturers do not use

post-consumer recycled material in their aggregate bags due to concerns over product quality. Raw materials, or pellets, are supplied to a plastic sheet supplier, who then produces plastic single wound sheets. These are purchased by the aggregate producer who loads a reel of printed plastic film onto the bagging machine, forms and seals the bag at the back and bottom, fills the bags with materials and seals the top at their quarry or manufacturing sites where aggregate, sand or cement is produced. Packed bags are then transported to retail outlets, where large retail chains then sell to either individual consumers or trade customers. In terms of reverse logistics, most packaging will enter mainstream waste management streams, either as household or commercial waste. Few retailers systematically recover or collect aggregate bags. Hence, the aim of the intervention was to source and manufacture packaging for plastic aggregate range using >60% post-consumer recycled content, and establish a trial collection and recovery process with three large retail stores and gather feedback.

Project partners manufactured plastic packaging made from ‘jazz’ recycled pellets. This results in a ‘non-clear’ opaque product, which moves away from industry standards for clear bags. Jazz pellets, made from post-consumer waste, were used to manufacture packaging with 60%/80%/90% recycled content. Figure 2 shows the big picture map, where the arrows indicate the intervention pathway through forward and reverse logistics processes. These new products were tested at the bagging facility in October 2023. As well as observation of the bagging procedure, tear, strength, puncture, and slippage tests were performed. The different products were then stored and labelled so that the team could monitor performance over a time.

The final phase of the trial was to establish a collection scheme for the packaging with a large retailer. The team designed a cover for collection bins to be placed in stores which instruct users to deposit only plastic bags. A 3rd party was used for collections and returns. Figure 2 also displays the ‘pain points’ that were established prior to trial implementation. These were;



- A. It is unclear exactly how willing the customer would be to return the packaging, and how they would segregate.
- B. Many returns are simply mixed in with other items.
- C. Major issues with sorting, cleaning, and detection of contamination.
- D. Generally work on basis of spot purchasing.
- E. A lot of collaborative work is needed to establish the right mix to meet specifications for a particular producer.
- F. Difficult to know or test how many times recycled materials have been recycled.
- G. Very little regulation related to quality.
- H. Prices of virgin and recycled inputs are very variable.
- I. Lack of partnership structure between sheet supplier and recycler leading to lack of effective working.
- J. Our customers are very price sensitive.
- K. Customers are very sensitive to colour as they want to see what is in the bags.

Pain points A – C are particularly pertinent to the CaaS principle, but they also have a ripple effect on the other pain points.

The methodological approach followed a five-step process integrating human interpretation with AI-assisted analysis to support thematic development and pattern recognition.

Each trial concluded with a comprehensive report for the funder, documenting outcomes and lessons learned. These reports served as the foundation for constructing a narrative of the intervention trial, collaboratively developed by the co-author team.

The team engaged in iterative cycles of reflection, drawing on insights from the trial data, theoretical frameworks, and

Microsoft Co-pilot (Version 4), a generative AI tool based on large language models, was used to produce structured reports aligned with established supply chain management principles (Gosling et al. 2014). In addition, reports were created for each trial focusing on emergent principles identified during the analysis. Each report was structured using the PICO framework, followed by lessons learned for each principle. In this context, PICO provided a consistent scaffold for framing each report, enabling comparative synthesis across trials (Nishikawa-Pacher 2022).

The co-author team reviewed the AI-generated reports in collaborative sessions, manually interpreting the findings and coding emergent themes. This step ensured that the AI outputs were critically evaluated and contextualised within the broader research framework. The approach aligns with recent scholarship advocating for human-AI collaboration in thematic analysis, where AI supports but does not replace human interpretive judgement (Naeem, Smith, and Thomas 2025).

Comparative synthesis was conducted using AI-generated summary tables, which were then refined through manual cross-checking and interpretation by the research team. This dual approach enabled both breadth and depth in the thematic comparison across trials.

To ensure transparency and replicability, the role of AI was deliberately restricted to structured analytical support tasks, that is, summarisation, comparative tabulation and principle-based framing. Co-pilot did not access raw empirical data, make coding decisions or generate theoretical claims. All AI-

Table 2. Governance, transparency, and validation of the human–AI collaborative analysis.

Human–AI governance area	How it is addressed in this study	Procedural evidence in the five-step approach
AI inputs	Only researcher-authored, trial-level reports and synthesised analytical narratives were provided as inputs. No interview transcripts, raw observations, or identifiable stakeholder data were input.	Step 1 establishes curated trial reports. Step 3 explicitly limits AI inputs to these documents.
Transparency of AI prompts and task scope	Co-pilot was used for bounded analytical tasks only (structured thematic summarisation, principle-based comparison, tabular synthesis), following consistent prompt templates aligned with supply-chain principles and PICO. A typical prompt would be “summarise this trial using the PICO approach with a focus on ‘supply chain synchronisation’”.	Step 3 specifies principle-aligned and PICO-structured reports used consistently across trials.
Risk of AI replacing human interpretation	AI outputs were treated as provisional analytical artefacts. All thematic interpretation, coding and theoretical articulation were conducted exclusively by the research team.	Step 4 documents collaborative human coding sessions independent of AI output acceptance.
Reliability and validity of AI-assisted analysis	AI-generated outputs were systematically interrogated. Themes were only retained where they were independently corroborated across data sources and author consensus.	Step 2 establishes iterative human reflection. Step 4 documents critical evaluation and rejection/refinement of outputs.
Replicability of the analytical process	A standardised, five-step workflow, consistent reporting scaffold (PICO) and clearly delineated AI role enable procedural replication without requiring identical data.	Steps 1–5 define a repeatable analytic architecture rather than a black-box AI process.
Confidentiality and data governance	All AI-assisted analysis was conducted using permission-compliant documents under institutional data governance arrangements. No personally identifiable or commercially sensitive data were exposed and Co-pilot was only used where enterprise data protection applied.	Steps 1 and 3 confine AI inputs to curated, pre-approved documents.
Potential bias or over-generalisation by AI	Comparative synthesis outputs were treated as hypothesis-generating only and were manually cross-checked against empirical trial evidence.	Step 5 documents manual refinement and rejection of unsupported generalisations
Decision Rights	All analytical judgments, theme acceptance, and theoretical contributions remained human decisions, with AI having no decision-making authority.	Steps 4–5 explicitly assign interpretive authority to the co-author team.

generated outputs were treated as provisional and were subjected to collective review, challenge and refinement by the research team. Analytical authority, interpretation and theoretical contribution therefore remained entirely human-led. Table 2 offers a summary of how the collaboration between human-AI analysis was governed following the adoption of a robust five-step thematic development approach, along the lines of Abramson et al. (2025) to support qualitative data analysis (de Paoli 2026) and ‘enhance reproducibility and ethical transparency’ (Mendoza and Quilantang 2026).

Replication approach

Replication studies are often associated with the physical and life sciences although there are widespread calls for its inclusion in management studies (Kozuch, von Deimling, and Eßig 2022) and in particular operations management (Pagell 2021). Replication studies, common in physical and life sciences, are less valued in social sciences, including operations management, despite their potential for generalising theories and improving research validity. Hendrick (1990) identified three types of replication: strict, partial, and conceptual. Strict replication validates a study but adds no new insights. Partial replication modifies elements while keeping the same population. Conceptual replication changes both approach and population, aiming to refine or expand theories. While strict replication ensures credibility, partial and conceptual replications foster innovation but pose risks if they fail to confirm or generalise findings.

In our case, we build on the theory developed by Towill (1997), which was a conceptual paper building on existing literature and secondary data. In revisiting that original 1997

paper, Towill and Gosling (2014) note the need to test the generalisability of the principles which were originally applied to high volume context. Although Gosling et al. (2014) explored the principles in a broad ETO context, their empirical research was conducted exclusively within the UK construction sector. Then Alfnes et al. (2023) undertook a conceptual replication study to test the principles in a ship-building setting. We also undertake here a conceptual replication study. Table 3 shows how our study compares in terms of approach with the Gosling et al. (2014) and Alfnes et al. (2023) research.

Outcomes and evaluation using PICO

CaaS as a new principle

Intervention trial 1

Population (P). The focal organisation of the trial was a Welsh plastic rotational moulding manufacturer producing mortar tubs, with an annual sales volume of approximately 26,000 units. The supply chain included material suppliers, granulators, mortar companies, wholesalers, housebuilders, and general builders, with customers such as self-employed bricklayers. The core team of the trial included two environmental consultants, the managing director of the plastics manufacturer, a recycling and supplier of plastic pellets, and the commercial manager of plastic recycling firm, as well as academics from across business and engineering disciplines. Data was collected from housebuilders and wholesalers via a survey to collect information and perceptions of plastic recycled products, leading to 10 responses.

Table 3. Characteristics of current and previous studies.

Attributes of the research methods adopted (based on Hendrick 1990)	Original replication in Gosling et al. (2014)	Conceptual replication in Alfnes et al. (2023)	Conceptual replication in this paper	Comments on conceptual replication approach
Population	UK construction sector	Norwegian shipbuilding	UK plastics recycling supply chains	The original Towill (1997) principles were based in non-ETO production environments that this current research returns to.
Assumption about the supply chain	'Open-loop'	'Open-loop'	'Closed-loop'	Advances the 'one-size-fits-all' approach of the original study.
Research approach	Deductive and inductive	Deductive and inductive	Intervention based	The overall research strategy is distinctly different, utilising an intervention based method, that yielded a 'surprise' that needed to be addressed.
Deductive element	Builds on the manufacturing FORRIDGE principles (Towill 1997)	Exploits the construction ETO principles (Gosling et al. 2014)	Post-implementation literature review on 'customer as a supplier' in closed-loop supply chains	Indicates the progression and advancement of the original 1997, 2015 and 2023 studies.
Empirical inductive element	Interrogating interviewees' approaches to mitigating problems in a homogeneous ETO process	Interrogating interviewees' approaches to mitigating uncertainty in heterogeneous ETO system	Intervention based approach that was initially aimed at ensuring successful implementation of closed-loop supply chains for plastics recycling	Various data-collection sources allowing for data triangulation, more considered and refined principles to be determined.
Analysis	Align theoretical principles and underlying tactics to the real-world problems in predominantly ETO open-loop supply chains	Align theoretical principles and underlying tactics to the real-world uncertainties in more nuanced ETO open-loop supply chains	Align theoretical principles to the real-world uncertainties in closed-loop MTS plastic products in construction supply chains	A systematic consideration is given to different forms of uncertainty explicitly for closed-loop supply chains with a focus on the uncertainty of supply from customer returns.
Unit of analysis	Two different networks for two different construction projects	A sample of first-tier suppliers	Two distinctive closed-loop supply chains	Builds on comprehensive intervention trials aimed at achieving closed-loop supply chains involving various actors including customers, retailers, builders merchants, manufacturers, collectors, processors among others.
Data collection method	Interviews	Workshops	Various methods including materials testing, interviews, surveys, observations.	Rather than predominantly opinion based individual responses and workshop debate, discourse and consensus, exploits field-based sources.
Number of companies	Nine in Network 1 and three in Network 2 with no cross-over	10 first-tier equipment manufacturers supplying to different markets	10 house builders and wholesalers	9
Size of companies	20–44000 employees	50–3500 employees	50–350	1–27000
Researchers	Four academic researchers with expertise in 1. manufacturing systems and who was the sole author of the FORRIDGE principles paper 2. construction management, especially in the UK sector 3. engineer-to-order supply chains with a focus on construction business systems engineering with cross-sector applications	Four academic researchers with expertise in 1. manufacturing planning and control, especially in the Norwegian shipbuilding sector 2. supply chain management across different industry sectors 3. engineer-to-order supply chains with a focus on construction as per Gosling et al. (2014) 4. business systems engineering with cross-sector applications as per Gosling et al. (2014)	Three academic researchers with expertise in 1. circular economy supply chain management 2. engineer-to-order supply chains with a focus on construction as per Gosling et al. (2014) and Alfnes et al. (2023) 3. business systems engineering with cross-sector applications as per Gosling et al. (2014) and Alfnes et al. (2023) plus two industry practitioners with expertise in delivering sustainability solutions in the public, private and third sectors regulatory compliance in waste and environmental management	The team has continuity and know-how from previous studies but brings new academic and industry skills and knowledge to remove bias by original researchers.

Intervention (I). Total project time, which includes planning and mobilisation, product manufacture, trial of new products 'in-situ' and incentivization of the new circular economy model, was a total of 26 months including planning and mobilisation, product manufacturing and testing, and eight months for the in-situ trial. Prior to the intervention, most used mortar tubs were sent to landfill due to contamination, lack of recycling pathways, and negative perceptions about the quality of recycled plastic. The project sought to increase the recycled content in mortar tubs to between 75% and 100% while implementing a closed-loop supply chain model.

To achieve this, recycled plastic feedstock was sourced and tested at four levels, at 25%, 50%, 75%, and 100%, for integration into the rotational moulding process. The intervention also addressed concerns raised by manufacturers regarding the provenance and quality of recycled materials by partnering with plastic recyclers who undertook washing, granulating, and reprocessing of used tubs. Product performance was validated through pull-to-failure and cyclic load testing. Additionally, a collection and tracking system was introduced, utilising QR codes alongside third-party logistics to monitor the recovery of mortar tubs at the end of their lifecycle.

Comparison (C). Before the intervention, the production of mortar tubs relied exclusively on virgin plastic, with no incorporation of recycled content. There was no established system for returning used tubs, which resulted in substantial waste and landfill disposal. Additionally, negative perceptions about the quality of recycled plastic, alongside concerns about contamination, acted as significant barriers to both adoption and recyclability within the supply chain.

Outcome (O). Technical testing confirmed that mortar tubs produced with higher levels of recycled content exhibited no significant differences in mechanical performance or durability compared to those made with virgin plastic. During customer trials involving 80 tubs, users reported no noticeable impact on functionality, although some feedback highlighted areas for design improvement, such as new colour variants and/or performance for different weather conditions. Engagement with the tracking system was moderate, with 37 tubs actively monitored throughout the trial. The newly established closed-loop process proved successful, demonstrating that post-consumer mortar tubs could be effectively recycled into new products. Nonetheless, several challenges were identified, including persistent negative perceptions surrounding recycled plastics, logistical complications in managing closed loop supply chains, and the limitations faced by small and medium-sized enterprises in resourcing and administering product returns.

Intervention trial 2

Population (P). The project involved multiple stakeholders across the supply chain, including a large aggregate producer (top five in the UK), one of the largest building products retailers in the UK (working with three of their ~300 outlets),

a plastic packaging manufacturer (a Fortune 100 company), and a waste processing firm. End users, including retail customers and trade buyers, were also considered as part of the trial. The core team involved two environmental consultants, a Category Manager for packaging of aggregates, Managing Director of waste processor, and Head of Sustainability for a major retailer of building products.

Intervention (I). The project was set up in three phases, with the first phase including the design and testing of the aggregated plastic bags with an increase of recycled content of up to 90% recycled content. This was followed by a phase of front store collection of three months, with the last phase included an extension of the front store collection over two months with improved signages and collection receptacle. The trial aimed to increase the use of post-consumer recycled content in LDPE plastic aggregate bags, moving from 50% to 90% recycled content. Additionally, a collection and reverse logistics system was tested across three retail stores in Wales to assess feasibility, consumer behaviour, and contamination levels in returned plastic packaging.

Comparison (C). Before the intervention, aggregate packaging contained no more than 50% recycled content, with no structured return or recycling system in place. The industry predominantly used virgin plastic due to concerns about quality, regulatory uncertainties, and logistical challenges in collection.

Outcome (O). The trial successfully demonstrated that plastic packaging with up to 90% recycled content could be produced while maintaining functionality. Testing identified minor technical challenges (e.g., sealing accuracy and slippage) that were resolved through process adjustments. The reverse logistics trial showed consumer willingness to return used packaging but highlighted contamination issues. Life Cycle Analysis (LCA) indicated a 36% reduction in carbon emissions when increasing recycled content from 50% to 90%. The project identified key behavioural, regulatory, and logistical challenges for future scale-up.

CaaS uncertainties

Table 4 highlights the key challenges faced in both trials when considering the return of products from the CaaS. The uncertainties in quality of materials coming from customers was a substantive impediment to the successful technical implementation of the circular supply chain. In IT1, tubs contained hardened concrete and required considerable cleaning before making them fit for preprocessing before recycling, while in IT2 the addition of non-plastic waste, including organic materials, was a major problem.

Two major attitudinal factors were faced by the trials. In both cases customers were uncertain about the value of recycling from a cost perspective and the value to themselves let alone the environment. Also, it was found that customers lacked awareness of various aspects of returns, such as the existence of such a facility and the use of QR codes.

Table 4. Challenges in recycling used plastics from customers.

Theme	IT1	IT2
Material quality	Customers often disposed of tubs without proper handling, leading to contamination that made recycling more challenging. There were also lingering perceptions that recycled plastic was inferior in quality, although test results proved otherwise.	Many returned plastic bags were mixed with general waste, including non-recyclable materials. Customer understanding of correct recycling practices was inconsistent, leading to high contamination rates.
Lack of incentives	Customers had no financial or operational benefits for returning used tubs. Without clear advantages, such as cost savings, deposits, or discounts, there was limited motivation to engage with the system.	Customers had limited motivation to return used packaging. The absence of financial or convenience-based incentives (e.g., deposit schemes, discounts, or retailer rewards) reduced participation.
Behaviours	Many customers were unaware of the option to return used mortar tubs for recycling. Engagement with the QR tracking system was moderate (only 37 out of 80 tubs were actively tracked), indicating a need for better communication and incentives.	Some customers viewed plastic waste as disposable rather than a valuable resource. Many lacked awareness of the environmental impact or the role they could play in circular supply chains.
Logistical barriers	The reverse supply chain was fragmented, with no established process for collecting used tubs. Customers had no convenient or standardised method for returning tubs, making participation in the circular model inconsistent. Return volumes were insufficient to incentivise logistics companies to participate.	Customers had to actively bring plastic bags back to designated collection points, which may not have been convenient. Variability in store engagement also affected the effectiveness of collection schemes.
Operational capabilities	Small and medium-sized enterprises (SMEs) lacked the resources and infrastructure to store and return used tubs efficiently. Many relied on third-party waste processors, adding complexity to the recycling process.	–
Regulatory environment	–	The classification of returned materials under EPR regulations remains unclear. Retailers and consumers may face additional costs or compliance burdens if plastic returns are not properly managed.

Table 5. Summary of the other primary principles for IT1.

Principle	Relevant aspect of the trial	Description
Time Compression Principle	Efficient Testing and Feedback	Rapid testing (pull-to-failure and cyclic tests) and feedback collection allowed for timely adjustments and improvements. Although this was part of the research itself rather than the trial it showcased the opportunity for future quality control monitoring should there be any non-conformance issues raised.
	Integrated Control System	The implementation of a QR based system allows for rapid tracking and tracing ensuring that information is timely.
Control System Principle	Integrated Control System	Implemented QR codes and asset tracking software to monitor the tubs' lifecycle, ensuring transparency and accountability.
Synchronisation Principle	Supply Chain Mapping	Identified and addressed fragmentation in the reverse logistics supply chain, ensuring seamless coordination between forward and reverse logistics.
Information Transparency Principle	QR Code System	Provided visibility into the tubs' lifecycle, from production to end-of-life, ensuring transparency in the recycling process.
Echelon Elimination Principle	Collaboration and Partnerships	Collaborated with an industrial plastic recycler and a third-party waste company to streamline the recycling process and eliminate unnecessary steps. While this suggests additional echelons the collaborations ensured that partners 'acted as one', avoiding siloed thinking.
Design for X Principle	Robustness and Recyclability	Designed tubs to be robust and recyclable, using high-quality recycled content and conducting rigorous testing to ensure performance.

The potential for incentives was high to motivate customers to comply with returns processes.

Both trials also suffered due to uncertainties in the process of returns. In IT1 there was a lack of standard operating procedures while in IT2 the lack of accessibility was a major hurdle to customers placing products in collection points.

While the above were common uncertainties found in the trials two issues were specific to each trial. In IT1 the uncertainty in operational capability of SMEs meant that there was a need to include third-parties in the returns process with the potential for adding complexity. In IT2, regulatory uncertainties were observed meaning that often customers feared failure in adhering to them and hence failed penalty fines.

While this paper is focussed on the substantive output of identifying a new CaaS supply chain principle for reducing

uncertainties in the circular supply chain it also identified the application of the other primary principles. These are summarised for each trial in [Tables 5 and 6](#). We note here that the underpinning principles of Training and Learning, and Supply Chain Integration are satisfied by the trials themselves which are to showcase the potential of closed-loop supply chain integration. The learning from the trails is expanded on in the next section.

Learning about the CaaS principle from the interventions

[Table 7](#) highlights the main learnings from the two trials.

Table 6. Summary of the other primary principles for IT2.

Principle	Relevant aspect of the trial	Description
Time Compression Principle	Real-time Monitoring	Continuous feedback loop and ongoing monitoring of product performance facilitated timely adjustments and optimisation.
Control System Principle	Centralised Coordination	Mobilising critical supply chain stakeholders early ensured alignment and streamlined planning and implementation phases.
	Collection point design and location	Collection points need to be visible and self-explanatory for the end consumers, while also being easily accessible to them and waste collectors.
Synchronisation Principle	Supply Chain Mapping	Identified and addressed fragmentation in the reverse logistics supply chain, ensuring seamless coordination between forward and reverse logistics.
Information Transparency Principle	Process Documentation	Detailed mapping of the entire circular supply chain provided visibility and helped identify potential bottlenecks and areas for improvement.
Echelon Elimination Principle	Integrated Reverse Logistics	Designing and implementing a waste collection scheme demonstrated the importance of coordinated reverse logistics and collaboration with waste processing and logistics firms.
Design for X Principle	Design for Recycling	Focused on using >60% post-consumer recycled content in packaging, addressing issues like product quality, sealing, density, and strength.
	Design for Sustainability	LCA indicated a significant reduction in carbon emissions when transitioning from 50% to 90% recycled content.
	Design for Usability	Addressed challenges with slippage and eye-mark definition through technical adjustments, ensuring product performance and user satisfaction.

Table 7. Summary of the main learnings from the intervention trials.

Learning topic	IT1	IT2
Communication & Education	Customers lacked awareness of return procedures, leading to low tracking engagement.	Limited understanding of recycling resulted in high contamination; signage and education were needed. Making information more readily available will allow participants to make more informed decisions.
Incentives	Lack of motivation to return tubs; suggested financial or operational rewards to boost engagement.	Participation was low without incentives; discounts or loyalty schemes encouraged returns.
Logistics & Convenience	No structured return process created barriers; simplified collection proposed.	Complex or distant drop-off points reduced engagement; integrated or at-home options preferred.
Retailer & SME Engagement	SMEs faced resource constraints managing returns; third-party logistics or shared schemes proposed.	Retail staff involvement was vital; active engagement improved return rates and reduced contamination. Getting bigger firms involved helps with longevity.
Contamination Management	Improper handling at sites led to low material quality; education and pre-sorting recommended. The involvement of a third-party recycling company helped mitigate the impact of low quality material.	Even engaged customers caused contamination; better bin design and clearer guidance were needed.
Customer Perceptions	Despite strong test results, scepticism persisted about recycled quality; real-world proof required. While the trial evidenced the viability of recycling, financial constraints and lack of government incentives acted as barriers to longevity.	–
Policy & Compliance	–	Future schemes must comply with EPR regulations and ensure traceable, compliant returns.

The interventions undertaken in IT1 and IT2 revealed a consistent set of practical insights essential to the design of effective closed-loop supply chains. Across both contexts, communication emerged as a critical factor. In IT1, many customers were unfamiliar with the process for returning mortar tubs, contributing to low participation in the tracking system. Similarly, IT2 highlighted that poor understanding of recycling practices led to high contamination rates. These findings underscore the importance of targeted education efforts and clear, accessible guidance to support user engagement.

Motivation to participate was also lacking, particularly in the absence of incentives. Both trials demonstrated that financial or operational rewards, such as discounts, deposits, or loyalty schemes, are likely to stimulate customer involvement. Additionally, logistical challenges hindered return processes. IT1 lacked structured collection mechanisms, while IT2

showed that requiring customers to travel or follow complex procedures reduced the likelihood of participation. Streamlining logistics through convenient drop-off points, retailer-supported returns, or home collection options was identified as an enabler of more efficient material recovery.

Retailer involvement proved especially influential in IT2. Sites where staff were engaged and committed to the scheme achieved better results in terms of return volumes and material quality. The issue of contamination recurred in both trials, frequently caused by improper disposal or handling at construction sites. Solutions identified included clearer signage, educational interventions, bin redesigns, and pre-sorting infrastructure.

IT1 further highlighted the challenges faced by small and medium-sized enterprises (SMEs), which often lack the resources to manage reverse supply chains independently.

The support of third-party logistics or collaborative collection frameworks was proposed as a solution. In both trials, customer scepticism around the quality of recycled materials persisted, despite empirical evidence confirming comparable performance to virgin alternatives. Addressing these perceptions through certification, demonstrations, and transparent data is essential to building trust.

Finally, IT2 emphasised the need to align future initiatives with evolving policy frameworks, notably EPR. Ensuring compliance and material traceability will be vital for the scalability and sustainability of customer-driven supply chain models.

Discussion

The research explores two emerging areas within circular supply chains. Firstly, it addresses the increasing uncertainty element which emerges in the transition from linear to circular supply chains. Therefore, the focus is on the original supply chain principles and the required adaptation for circular supply chains (RQ1). Secondly, the research addresses the role of the customers in circular supply chain management, with a specific focus on their role and impact on return processes (RQ2).

Our research findings have highlighted that the supply chain principles identified by Towill (1997) and latterly enhanced by Gosling et al. (2014) and Alfnes et al. (2023) are necessary but not sufficient principles for establishing a closed-loop supply chain. The original supply chain principles, time compression, transformation transparency, synchronisation, echelon elimination, control systems and design for X principles, are widely applicable in circular supply chains. However, our research shows that, in a circular supply chain the returns environment in which the linear supply chain is operating has a high degree of uncertainty. In circular supply chains, customers become an integral part of the supply chain, actively contributing to the supply of material, and engaging with other players of the circular supply chain. This highlights the additional principle, namely CaaS, now added to the existing suite of principles as shown in purple text in Figure 3.

Figure 3 illustrates the CaaS principle, accompanied by suggested tactics derived from the outcomes of two trials. In this context, 'principles are regarded as guiding rules and tactics relate[d] to practices and techniques' (Gosling et al. 2014). The CaaS principle emphasises the importance of:

- Clear communication, education and incentives (behaviourally engaged participant)
- Convenient return logistics (logistics-aware collaborator)
- Contamination control (quality gatekeeper of returns)
- Engagement to ensure high-quality material recovery (active material contributor)

This principle extends the existing framework and highlights the active role of end-users in resource recovery, thereby supporting sustainability. While both open and closed-loop supply chains incorporate circular elements and processes that rely on the CaaS principle, this discussion

focuses on closed-loop systems, as these were the subject of the trials.

Customer inclusion in supply chain processes is particularly critical in closed-loop systems. Our research shows that customers play a vital role in the circular supply chain, yet they also introduce a significant element of uncertainty. Alfnes et al. (2023) argue that understanding and categorising the causes of uncertainty enables the development of tactics to mitigate it. The trials, along with other research on circularity, confirm that behaviour change is essential, though most circular behaviour literature focuses predominantly on customer behaviour. This underscores the need to further investigate the CaaS principle, where the end-consumer becomes an active participant in a functioning supply network (Vidal-Ayuso et al. 2023).

The trials reveal the complexity of embedding circular principles into supply chains, especially as end-consumers shift from passive users to active contributors. Our findings confirm that consumer behaviour significantly affects material quality, contamination rates, and the consistency of return streams, core aspects of the CaaS concept. However, this reliance on consumers introduces persistent uncertainty.

Several key themes emerged from the interventions that yielded our suggested tactics:

Communication and education

Effective communication and education are foundational to enabling circular supply chains. Both trials revealed that limited consumer awareness of return procedures and recycling practices led to low engagement and high contamination. In IT1, only 37 out of 80 tubs were tracked, while IT2 showed that many customers were unaware of proper recycling protocols, resulting in mixed waste and contamination.

This aligns with Crome et al. (2023), who emphasise that social influence, information, and trust are key motivational factors in fostering circular behaviour. Farooque et al. (2019) and Parajuly et al. (2020) further argue that behavioural nudges must be supported by clear infrastructure and communication to be effective. The trials confirmed that signage, digital platforms, and on-site guidance are essential to inform customers of their role and the impact of their actions on supply chain performance.

The challenge lies in shifting consumer perception from passive disposal to active contribution. As Goltsos et al. (2019) note, uncertainty in the quality and timing of returns is exacerbated by inconsistent consumer behaviour. Educating customers about their influence on contamination rates, material quality, and return consistency, as seen below, is critical to reducing this uncertainty and enabling a functioning circular supply network.

Incentivising returns

Motivating consumers to return used products remains a persistent challenge. Both trials demonstrated that without financial or operational incentives, participation in return schemes was limited. In IT1, customers had no clear

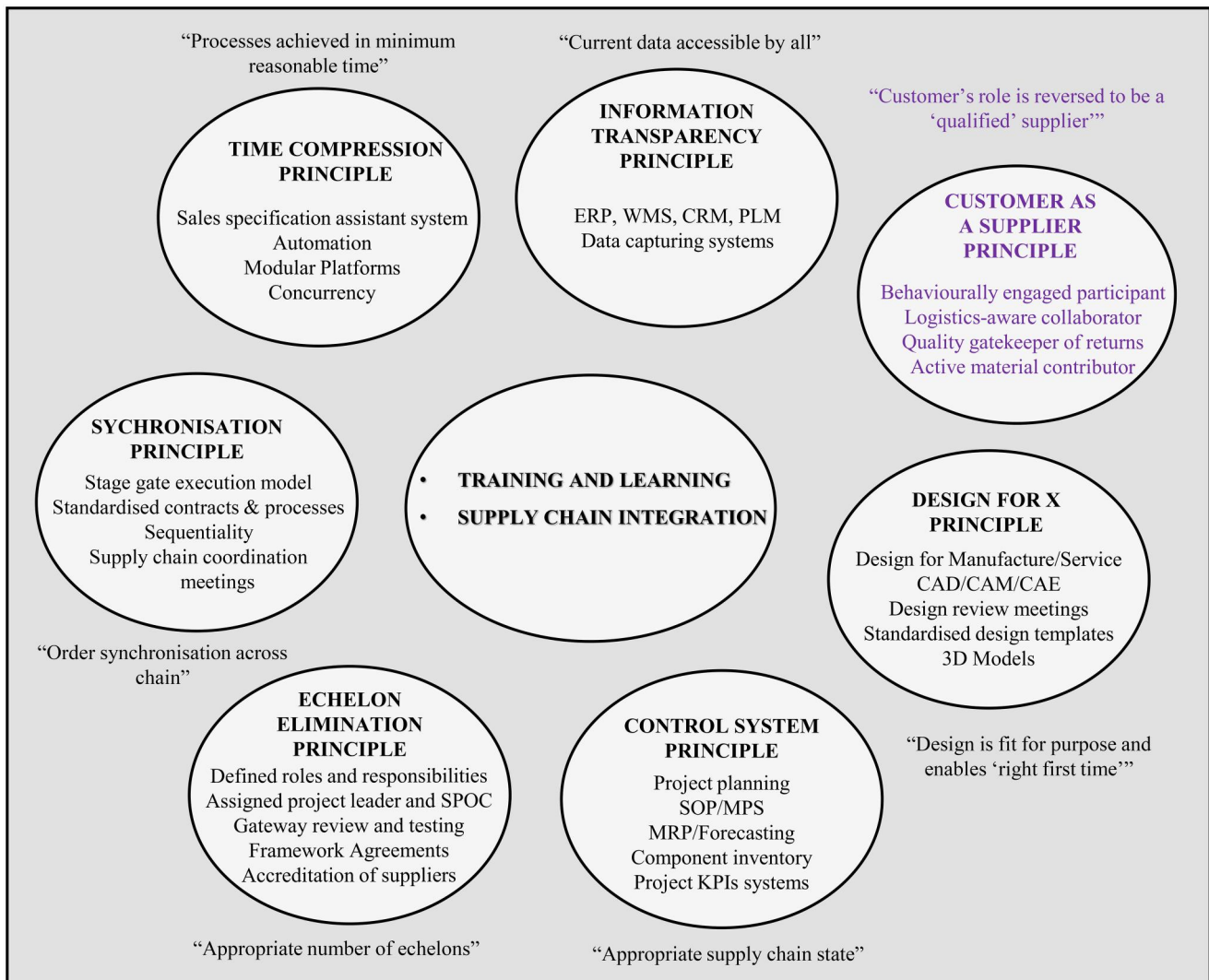


Figure 3. The new suite of supply chain principles including CaaS (latest updated iteration from Towill 1993, Gosling et al. 2014 and Alfnes et al. 2023).

advantage for returning tubs, while IT2 showed that the absence of deposit schemes or loyalty rewards reduced engagement.

The literature strongly supports the use of incentives to drive circular behaviour. Farooque et al. (2019) and Parajuly et al. (2020) highlight the effectiveness of nudge theory in circular contexts, where financial rewards, loyalty schemes, and deposit systems can encourage timely and uncontaminated returns. These mechanisms not only improve participation but also help reduce uncertainty in reverse flows.

Alfnes et al. (2023) emphasise that the operating environment is key to selecting appropriate tactics. Whether through positive reinforcement (e.g., vouchers, discounts, cash-back) or negative reinforcement (e.g., fees, deposits), the choice of incentive must be tailored to the industry and consumer base.

Convenient returns and reverse logistics

Convenience in return logistics emerged as a critical enabler of circular supply chain participation. Both trials revealed that fragmented or inaccessible return systems discouraged customer engagement. In IT1, the absence of a structured return process created barriers for mortar tub recovery, while

IT2 showed that requiring customers to travel to designated drop-off points reduced participation.

This aligns with Farooque et al. (2019), who emphasise that circular behaviour change is contingent on infrastructure that supports easy and accessible return processes. The physical and social environment must be designed to facilitate consumer action. Parajuly et al. (2020) similarly highlights that logistical simplicity is essential to support behavioural nudges and encourage circular practices.

Contamination management

Contamination was a recurring challenge in both trials, directly impacting the quality and recyclability of returned materials. In IT1, hardened concrete in mortar tubs required extensive cleaning, while IT2 faced contamination from organic and non-plastic waste in returned packaging. These issues reflect the supply-side uncertainty described by Goltos et al. (2019), where the quality, volume, and timing of customer returns introduce significant variability.

The literature highlights that contamination is often exacerbated by poor product design and inadequate handling infrastructure (Hahladakis and Iacovidou 2018; WRAP 2025).

Inconsistent material quality due to lifecycle degradation or improper disposal practices undermines the viability of recycling processes.

Educational interventions and clear guidance were identified as necessary tactics to mitigate contamination. Crome et al. (2023) stress the role of consumer awareness, trust, and information in shaping recycling behaviour. The trials confirmed that signage, bin design, and pre-sorting infrastructure are practical strategies to reduce contamination and improve material recovery.

Stakeholder commitment

Retailers and SMEs play a pivotal role in operationalising circular supply chains, yet both trials revealed significant resource constraints and coordination challenges. IT1 highlighted that SMEs often lack the infrastructure to manage returns independently, necessitating third-party logistics support. This complexity reflects the ecosystem-view of circular supply chains, where multilateral dependencies must be aligned (Adner 2017; Pietrulla 2022).

Retailer engagement was especially influential in IT2. Stores with active staff involvement achieved higher return rates and lower contamination, underscoring the importance of internal organisational dynamics. Epstein, Buhova, and Yuthas (2015) note that informal systems promoting sustainability can conflict with formal systems focused on financial performance, creating tension in day-to-day decision-making.

To overcome these barriers, collaborative logistics schemes and staff training were proposed, overlapping with the need for education. These strategies align with the Training and Learning enabler (Gosling et al. 2014), which supports capacity building and operational readiness. Supply Chain Integration, another enabler, was demonstrated through partnerships with recyclers and waste processors, streamlining reverse flows and reducing siloed operations.

The trials confirm that circular supply chains require systemic interventions beyond consumer behaviour. Coordinated action among retailers, SMEs, logistics providers, and consumers is essential to mitigate uncertainty and scale circular practices effectively.

Across the two intervention trials, the study demonstrates tangible progress from fragmented, predominantly linear plastics use towards functioning closed-loop arrangements, while simultaneously revealing important constraints on scalability and durability. In IT1 mortar tubs were successfully manufactured using between 75% and 100% post-consumer recycled plastic, with material testing and in-situ trials confirming performance equivalence relative to virgin products. The introduction of a QR-enabled tracking and return system showed that a waste stream previously destined for landfill could be recovered, reprocessed, and reintegrated into production. However, despite technical feasibility, longer-term viability was constrained by weak and inconsistent customer engagement, price sensitivity, limited reverse-logistics capability among SMEs, and the absence of strong economic incentives to stabilise return volumes and quality. In IT2, aggregate packaging incorporating 60–90% post-consumer

recycled content proved technically feasible within existing bagging and retail systems, and consumer returns via front-of-store collection points were demonstrably achievable. Nonetheless, the trial exposed persistent operational challenges, including contamination of returned materials, variable retailer commitment, logistical complexity, and the need for clearer behavioural incentives and governance alignment.

Conclusion

This paper addressed two key research questions:

- How does an original suite of linear supply chain principles need to be augmented to cope with uncertainties in circular supply chain management?
- What is the role of the customer in circular supply chain management, given that they become an integral part of the returns process and hence a source of material supply uncertainty?

Through two intervention-based trials on plastic products in the construction sector, i.e. our course of action (Lange and Pfarrer 2017), the study demonstrated the practical feasibility of closed-loop supply chains for mortar tubs and aggregate bags. These trials applied Towill's (1997) foundational linear supply chain principles, later extended by Gosling et al. (2014) and Alfnes et al. (2023), and revealed the need for a seventh principle: Customer-as-a-Supplier (CaaS), which is our contribution (Lange and Pfarrer 2017). This principle acknowledges and overcomes the substantive complication (Lange and Pfarrer 2017), namely, the customer's evolving role from passive recipient to active contributor, introducing new uncertainties in material quality, volume, and timing of returns i.e. the concern (Lange and Pfarrer 2017).

While the study offers valuable insights, its scope is limited by product specificity and sectoral focus. To strengthen generalisability of the findings, as well as the use of the PICO method for structuring the intervention and findings, future research should explore other industries, such as grocery, automotive, and electronics, and alternative materials like glass, cardboard, and textiles. Further investigation into sector-specific incentive models, contamination reduction strategies, and digital tracking systems will help refine the CaaS principle and test the broader applicability of circular supply chain design. In particular, there is a need to consider not just the principles themselves but also the suite of underpinning tactics. Moreover, while our findings suggest that the CaaS principle may extend beyond recycling to other circular economy strategies, such as reuse, remanufacturing, and refurbishment, this broader applicability remains speculative and requires systematic empirical investigation. Building on the trials, we propose a managed scale up towards a system wide application of all the supply chain principles, including CaaS. This could include increasing the scope of the trial, and the extent of stakeholders, including for example, policy-makers and other relevant regional authorities.

Ultimately, this research contributes to the evolving understanding of circular supply chains by integrating

behavioural, logistical, and design considerations into a cohesive framework. The CaaS principle offers a foundation for future work, emphasising that successful circularity depends not only on systems and infrastructure, but on the active participation of the customers.

Acknowledgements

The authors gratefully acknowledge the support of WRAP Cymru and the Welsh Government for funding and supporting the trials. We also wish to thank the wider project team, and participating organisations whose expertise, commitment, and contributions were invaluable throughout the intervention trials and the development of this study.

Author contributions

CRediT: **Jonathan Gosling**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Nadine Leder**: Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing; **Mohamed Naim**: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Lucy Hoggins**: Data curation, Investigation, Project administration, Resources, Validation; **Jane Hall**: Data curation, Investigation, Project administration, Resources, Validation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was supported by WRAP Cymru and Llywodraeth Cymru.

Notes on contributors



Jonathan Gosling is a Professor of Supply Chain Management at Cardiff Business School, where he is also Impact, Innovation and Enterprise Lead. He is a Fellow of the Institution of Civil Engineers and works closely with Constructing Excellence to promote industry improvements and best practice. His research and teaching revolve around the themes within innovation, projects, circular economy, and supply chain management. In particular, he focuses on “engineer-to-order” supply chain environments and complex engineering projects, taking a system’s approach to facilitate improvements and challenge current practice. He has led a wide range of funded research projects, more recently in the areas of Digital Product Passports and scalable circular supply chains in the built environment.



Nadine Leder is a Lecturer in Logistics and Operations Management at Cardiff Business School, Cardiff University. Her research focuses on circular operations, circular business models, reuse and repair systems, and circular supply chains. Her work links academia with industry and policy, and she actively collaborates with policymakers, industry bodies, SMEs, and NGOs to support the transition towards circular

ecosystems. She has led international research projects funded by the European Regional Development Fund and the British Academy, applying her expertise in sustainable operations and circularity to the Waste and Resource Management, and Tourism & Hospitality sector. She has also authored and reviewed papers for leading operations management journals.



Mohamed Naim is a Professor in Logistics and Operations Management at Cardiff Business School, Cardiff University. His underlying ethos is best described as taking a whole systems multidisciplinary approach to problem solving, with due consideration of people, processes and technologies, to make supply chains more resilient and sustainable, exploiting existing, and developing new, quantitative and qualitative models. He undertakes cocreated and co-delivered research, development, innovation and impact projects with practitioners, from industry and government, and collaborates with a wide range of academic partners. He is a Fellow of the Institution of Engineering and Technology, and a Fellow of the Chartered Institute of Logistics and Transport. He has published in many internationally leading operations, engineering and logistics journals.



Lucy Hoggins is a dynamic sustainability leader with 25 years’ experience driving climate response, circular economy innovation, and sustainability strategies. Founder of a successful sustainability consultancy Resilience Sustainable Solutions since 2014, she has also worked with the Carbon Trust, Bluestone Wales during business start-up to operation, and the UN Industrial Development Organisation. Lucy has led public sector climate strategies and supported corporate clients with GRI-aligned ESG programmes, SBTi standards, and supply chain sustainability. Over the past five years, she’s secured innovation funding and led multiple circular economy innovation projects with private sector and academic partners. She’s also worked on climate risk and resilience planning, and mitigation strategies for businesses and public organisations. Lucy is a qualified project manager and management systems expert, known for her collaborative approach in managing complex programmes and multi-stakeholder projects. She excels at mobilising stakeholders, embedding governance frameworks, and delivering measurable sustainability outcomes across private, public, and third sectors. Lucy is skilled at leading diverse teams and influencing senior leaders to achieve ambitious goals.



Jane Hall BSc(hons) is a Chartered Environmental Consultant and a Fellow of the Chartered Institution of Wastes Management with over 20 years’ industrial, environmental and waste management experience and is the Director of Green Edge Applications Limited. She has worked with both commercial organisations and regulators in a senior capacity, and she employs this specialist skill base to help companies manage resources efficiently and comply with environmental regulations. Jane delivers waste and environmental regulatory training to waste and industrial operators operatives through her own company and in collaboration with CIWM.

ORCID

Jonathan Gosling  <http://orcid.org/0000-0002-9027-9011>

References

- Abramson, C. M., T. Prendergast, Z. Li, and D. Dohan. 2025. "Qualitative Research in an Era of AI: A Pragmatic Approach to Data Analysis, Workflow, and Computation." arXiv preprint, arXiv:2509.12503.
- Adner, R. 2017. "Ecosystem as Structure." *Journal of Management* 43 (1): 39–58. <https://doi.org/10.1177/0149206316678451>.
- Alfnes, E., J. Gosling, M. Naim, and H. C. Dreyer. 2023. "Rearticulating Supply Chain Design and Operation Principles to Mitigate Uncertainty in the Norwegian Engineer-to-Order Shipbuilding Sector." *International Journal of Production Economics* 262: 108903. <https://doi.org/10.1016/j.ijpe.2023.108903>.
- Aloini, D., R. Dulmin, V. Mininno, A. Stefanini, and P. Zerbino. 2020. "Driving the Transition to a Circular Economic Model: A Systematic Review on Drivers and Critical Success Factors in Circular Economy." *Sustainability* 12 (24): 10672. <https://doi.org/10.3390/su122410672>.
- Alves, B. 2024. "Plastics Waste Worldwide – Statistics & Facts." *Statista*. Accessed April 12, 2024. <https://www.statista.com/topics/5401/global-plastic-waste/#topicOverview>.
- Batista, L., M. Bourlakis, P. Smart, and R. Maull. 2018. "In Search of a Circular Supply Chain Archetype – a Content-Analysis-Based Literature Review." *Production Planning & Control* 29 (6): 438–451. <https://doi.org/10.1080/09537287.2017.1343502>.
- Bhatia, M. S., R. K. Srivastava, S. K. Jakhar, and S. Kumar. 2022. "What's Critical for Closed-Loop Supply Chain Operations? Findings from the Indian Small and Medium Manufacturing Enterprises." *Journal of Cleaner Production* 372: 133791. <https://doi.org/10.1016/j.jclepro.2022.133791>.
- Bocken, N. M. P., S. W. Short, P. Rana, and S. Evans. 2014. "A Literature and Practice Review to Develop Sustainable Business Model Archetypes." *Journal of Cleaner Production* 65: 42–56. <https://doi.org/10.1016/j.jclepro.2013.11.039>.
- Bouzon, M., K. Govindan, and C. M. Taboada Rodriguez. 2018. "Evaluating Barriers for Reverse Logistics Implementation under a Multiple Stakeholders' Perspective Analysis Using Grey Decision Making Approach." *Resources, Conservation and Recycling* 128: 315–335. <https://doi.org/10.1016/j.resconrec.2016.11.022>.
- Bressanelli, G., M. Perona, and N. Sacconi. 2019. "Challenges in Supply Chain Redesign for the Circular Economy: A Literature Review and a Multiple Case Study." *International Journal of Production Research* 57 (23): 7395–7422. <https://doi.org/10.1080/00207543.2018.1542176>.
- Burbidge, J. L. 1961. "The 'New Approach' to Production." *Production Engineer* 40 (12): 769–784. <https://doi.org/10.1049/tpe.1961.0104>.
- Chandrasekaran, A., S. Treville, and T. Browning. 2020. "Intervention-Based Research (IBR)—What, Where, and How to Use It in Operations Management." *Journal of Operations Management* 66 (4): 370–378. <https://doi.org/10.1002/joom.1093>.
- Crome, C., V. Graf-Drasch, F. Hawlitschek, and D. Zinsbacher. 2023. "Circular Economy is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting." *Journal of Cleaner Production* 423: 138613. <https://doi.org/10.1016/j.jclepro.2023.138613>.
- de Lima, F. A., S. Seuring, and A. Genovese. 2024. "How to Enhance Circular Supply Chains? Aligning R-Imperatives, Uncertainty Management and Sustainability." *International Journal of Operations & Production Management* 44 (4): 836–858. <https://doi.org/10.1108/IJOPM-11-2022-0708>.
- de Lima, F. A., S. Seuring, and P. C. Sauer. 2022. "A Systematic Literature Review Exploring Uncertainty Management and Sustainability Outcomes in Circular Supply Chains." *International Journal of Production Research* 60 (19): 6013–6046. <https://doi.org/10.1080/00207543.2021.1976859>.
- de Paoli, S. 2026. "Can Machines Perform a Qualitative Data Analysis? Reading the Debate with Alan Turing." *Social Science Computer Review*. Advance online publication. <https://doi.org/10.1177/08944393261451707>.
- den Hollander, M. C., C. A. Bakker, and E. J. Hultink. 2017. "Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms." *Journal of Industrial Ecology* 21 (3): 517–525. <https://doi.org/10.1111/jiec.12610>.
- Ding, Z., X. Wang, and P. X. Zou. 2023. "Barriers and Countermeasures of Construction and Demolition Waste Recycling Enterprises under Circular Economy." *Journal of Cleaner Production* 420: 138235. <https://doi.org/10.1016/j.jclepro.2023.138235>.
- Do, Q., and M. Stevenson. 2026. "The Dual Brokerage Role of Digital Platforms in the Transition to a Circular Economy." *Journal of Operations Management* 72 (1): 108–130. <https://doi.org/10.1002/joom.70025>.
- Ellen MacArthur Foundation. 2017. *The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action*. Cowes: Ellen MacArthur Foundation.
- Epstein, M. J., A. R. Buhova, and K. Yuthas. 2015. "Managing Social, Environmental and Financial Performance Simultaneously." *Long Range Planning* 48 (1): 35–45. <https://doi.org/10.1016/j.lrp.2012.11.001>.
- Esbensen, K. H., and C. Velis. 2016. "Transition to Circular Economy Requires Reliable Statistical Quantification and Control of Uncertainty and Variability in Waste." *Waste Management & Research: The Journal of the International Solid Wastes and Public Cleansing Association, ISWA* 34 (12): 1197–1200. <https://doi.org/10.1177/0734242X16680911>.
- Farooque, Muhammad, Abraham Zhang, Matthias Thürrer, Ting Qu, and Donald Huisingsh., 2019. "Circular Supply Chain Management: A Definition and Structure Literature Review." *Journal of Cleaner Production* 228: 882–900. <https://doi.org/10.1016/j.jclepro.2019.04.303>.
- Flexible Plastic Fund. 2025. "FPF FlexCollect Report: The Future of Recycling Flexible Plastic Packaging in the UK." SUEZ Recycling and Recovery UK, WRAP, RECOUP, Ecosurety.
- Geary, S., S. M. Disney, and D. R. Towill. 2006. "On Bullwhip in Supply Chains—Historical Review, Present Practice and Expected Future Impact." *International Journal of Production Economics* 101 (1): 2–18. <https://doi.org/10.1016/j.ijpe.2005.05.009>.
- Goltsos, T. E., B. Ponte, S. Wang, Y. Liu, M. M. Naim, and A. A. Syntetos. 2019. "The Boomerang Returns? Accounting for the Impact of Uncertainties on the Dynamics of Remanufacturing Systems." *International Journal of Production Research* 57 (23): 7361–7394. <https://doi.org/10.1080/00207543.2018.1510191>.
- Gosling, J., D. R. Towill, M. M. Naim, and A. R. Dainty. 2014. "Principles for the Design and Operation of Engineer-to-Order Supply Chains in the Construction Sector." *Production Planning & Control* 26 (3): 1–16. <https://doi.org/10.1080/09537287.2014.880816>.
- Govindan, K., and H. Soleimani. 2017. "A Review of Reverse Logistics and Closed-Loop Supply Chains: A Journal of Cleaner Production Focus." *Journal of Cleaner Production* 142: 371–384. <https://doi.org/10.1016/j.jclepro.2016.03.126>.
- Guo, Y., D. A. Yen, R. Geng, and G. Azar. 2021. "Drivers of Green Cooperation between Chinese Manufacturers and Their Customers: An Empirical Analysis." *Industrial Marketing Management* 93: 137–146. <https://doi.org/10.1016/j.indmarman.2021.01.004>.
- Gupta, M., H. Lowalekar, C. V. Chaudhari, and J. Groop. 2024. "A Design Science Approach to Manage Spare Parts Distribution: combining Design Logic and Goldratt's Thinking Processes." *International Journal of Physical Distribution & Logistics Management* 54 (7/8): 775–801. <https://doi.org/10.1108/IJPDLM-08-2023-0288>.
- Hahladakis, J. N., and E. Iacovidou. 2018. "Closing the Loop on Plastic Packaging Materials: What is Quality and How Does It Affect Their Circularity?" *The Science of the Total Environment* 630: 1394–1400. <https://doi.org/10.1016/j.scitotenv.2018.02.330>.
- Hasle, P., and J. Vang. 2021. "Designing Better Interventions: Insights from Research on Decent Work." *Journal of Supply Chain Management* 57 (2): 58–70. <https://doi.org/10.1111/jscm.12261>.
- Hendrick, C. 1990. "Replications, Strict Replications, and Conceptual Replications: Are They Important?" *Journal of Social Behavior and Personality* 5 (4): 41.
- Hines, P., and N. Rich. 1997. "The Seven Value Stream Mapping Tools." *International Journal of Operations & Production Management* 17 (1): 46–64. <https://doi.org/10.1108/01443579710157989>.
- Hopewell, J., R. Dvorak, and E. Kosior. 2009. "Plastics Recycling: Challenges and Opportunities." *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 364 (1526): 2115–2126. <https://doi.org/10.1098/rstb.2008.0311>.

- Huang, X., J. Lin, and D. Demner-Fushman. 2006. "Evaluation of PICO as a Knowledge Representation for Clinical Questions." *AMIA. Annual Symposium Proceedings. AMIA Symposium 2006*: 359–363.
- Johansen, M. R., T. B. Christensen, T. M. Ramos, and K. Syberg. 2022. "A Review of the Plastic Value Chain from a Circular Economy Perspective." *Journal of Environmental Management* 302 (Pt A): 113975. <https://doi.org/10.1016/j.jenvman.2021.113975>.
- Kahlert, S., and C. R. Bening. 2020. "Plastics Recycling after the Global Pandemic: Resurgence or Regression?" *Resources, Conservation, and Recycling* 160: 104948. <https://doi.org/10.1016/j.resconrec.2020.104948>.
- Kazancoglu, Y., Y. D. Ozkan-Ozen, M. Sagnak, I. Kazancoglu, and M. Dora. 2023. "Framework for a Sustainable Supply Chain to Overcome Risks in Transition to a Circular Economy through Industry 4.0." *Production Planning & Control* 34 (10): 902–917. <https://doi.org/10.1080/09537287.2021.1980910>.
- King, S., and K. E. S. Locock. 2022. "A Circular Economy Framework for Plastics: A Semi-Systematic Review." *Journal of Cleaner Production* 364: 132503. <https://doi.org/10.1016/j.jclepro.2022.132503>.
- Kirchherr, J., L. Piscicelli, R. Bour, E. Kostense-Smit, J. Muller, A. Huibrechtse-Truijens, and M. Hekkert. 2018. "Barriers to the Circular Economy: Evidence from the European Union (EU)." *Ecological Economics* 150: 264–272. <https://doi.org/10.1016/j.ecolecon.2018.04.028>.
- Kozuch, A. C., C. von Deimling, and M. Eßig. 2022. "Implementing Green Public Procurement: A Replication Study." *Journal of Cleaner Production* 377: 134424. <https://doi.org/10.1016/j.jclepro.2022.134424>.
- Lange, D., and M. D. Pfarrer. 2017. "Sense and structure - The Core Building Blocks of an AMR Article." *Academy of Management Review* 42 (3): 407–416.
- Marcos, J. T., C. Scheller, R. Godina, T. S. Spengler, and H. Carvalho. 2021. "Sources of Uncertainty in the Closed-Loop Supply Chain of Lithium-Ion Batteries for Electric Vehicles." *Cleaner Logistics and Supply Chain* 1: 100006. <https://doi.org/10.1016/j.clscn.2021.100006>.
- Mendoza, K. P. R., and R. F. Quilantang. 2026. "In Relation, Not Replacement: A Reflexive Case for Generative AI in Qualitative Research." *Qualitative Research Journal*. Advance online publication. <https://doi.org/10.1108/QRJ-11-2025-0428>.
- Miemiczyk, J., M. Howard, and T. E. Johnsen. 2016. "Dynamic Development and Execution of Closed-Loop Supply Chains: A Natural Resource-Based View." *Supply Chain Management: An International Journal* 21 (4): 453–469. <https://doi.org/10.1108/SCM-12-2014-0405>.
- Naeem, M., T. Smith, and L. Thomas. 2025. "Thematic Analysis and Artificial Intelligence: A Step-by-Step Process for Using ChatGPT in Thematic Analysis." *International Journal of Qualitative Methods* 24: 16094069251333886. <https://doi.org/10.1177/16094069251333886>.
- Nishikawa-Pacher, A. 2022. "Research Questions with PICO: A Universal Mnemonic." *Publications* 10 (3): 21. <https://doi.org/10.3390/publications10030021>.
- Oliva, R. 2019. "Intervention as a Research Strategy." *Journal of Operations Management* 65 (7): 710–724. <https://doi.org/10.1002/joom.1065>.
- Pagell, M. 2021. "Replication without Repeating Ourselves: Addressing the Replication Crisis in Operations and Supply Chain Management Research." *Journal of Operations Management* 67 (1): 105–115. <https://doi.org/10.1002/joom.1120>.
- Parajuly, Keshav, Colin Fitzpatrick, Orla Muldoon, and Ruediger Kuehr., 2020. "Behavioural Change for the Circular Economy: A Review with Focus on Electric Waste Management in the EU." *Resources, Conservation and Recycling: X* 6: 100035. <https://doi.org/10.1016/j.rcrx.2020.100035>.
- Pietrulla, F. 2022. "Circular Ecosystems: A Review." *Cleaner and Circular Bioeconomy* 3: 100031. <https://doi.org/10.1016/j.clcb.2022.100031>.
- Ponte, B., M. de Arquer, S. Cannella, and R. Dominguez. 2025. "The Dynamics of Closed Loop Supply Chains, Definitions, Trends, and Challenges." In *Encyclopedia in Operations Management*, edited by T. M. J. Choi. Amsterdam: Elsevier. <https://doi.org/10.1016/B978-0-443-28993-4.00197-9>.
- Sampson, S. E. 2000. "Customer-Supplier Duality and Bidirectional Supply Chains in Service Organizations." *International Journal of Service Industry Management* 11 (4): 348–364. <https://doi.org/10.1108/09564230010355377>.
- Sampson, S. E., and M. Spring. 2012. "Customer Roles in Service Supply Chains and Opportunities for Innovation." *Journal of Supply Chain Management* 48 (4): 30–50. <https://doi.org/10.1111/j.1745-493X.2012.03282.x>.
- Stahel, W. R. 1982. "The Product Life Factor." In *An Inquiry into the Nature of Sustainable Societies. The Role of the Private Sector*, 72–105. Houston: Houston Area Research Centre.
- Stumpf, L., T. Wenzel, S. Hirth, and S. Roth. 2023. "Circular Plastics Packaging – Prioritizing Resources and Capabilities along the Supply Chain." *Technological Forecasting and Social Change* 188: 122261. <https://doi.org/10.1016/j.techfore.2022.122261>.
- Suzanne, E., N. Absi, and V. Borodin. 2020. "Towards Circular Economy in Production Planning: Challenges and Opportunities." *European Journal of Operational Research* 287 (1): 168–190. <https://doi.org/10.1016/j.ejor.2020.04.043>.
- Towill, D. R. 1997. "Forridge – Principles of Good Practice in Material Flow." *Production Planning & Control* 8 (7): 622–632. <https://doi.org/10.1080/095372897234722>.
- Towill, D. R., and J. Gosling. 2014. "Celebrating 50 Years of FORRIDGE." *Production Planning & Control* 25 (9): 731–736.
- Tukker, A. 2015. "Product Services for a Resource-Efficient and Circular Economy – a Review." *Journal of Cleaner Production* 97: 76–91. <https://doi.org/10.1016/j.jclepro.2013.11.049>.
- UK Environment Act. 2021. "Environment Act 2021 (Bill 2593)." Accessed October 19, 2025. <https://bills.parliament.uk/bills/2593#timeline>.
- UK Government. 2021. "Next Steps to Tackle Plastics Waste." *Press Release*. Accessed August 7, 2025. <https://www.gov.uk/government/news/next-steps-to-tackle-plastic-waste>.
- Urbanati, A., S. Franzò, and D. Chiaroni. 2021. "Enablers and Barriers for Circular Business Models: An Empirical Analysis in the Italian Automotive Industry." *Sustainable Production and Consumption* 27: 551–566. <https://doi.org/10.1016/j.spc.2021.01.022>.
- van Nunen, J. A., and R. A. Zuidwijk. 2004. "E-Enabled Closed-Loop Supply Chains." *California Management Review* 46 (2): 40–54. <https://doi.org/10.2307/41166209>.
- van Weelden, E., R. Mugge, and C. Bakker. 2016. "Paving the Way towards Circular Consumption: Exploring Consumer Acceptance of Refurbished Mobile Phones in the Dutch Market." *Journal of Cleaner Production* 113: 743–754. <https://doi.org/10.1016/j.jclepro.2015.11.065>.
- Vidal-Ayuso, F., A. Akhmedova, and C. Jaca. 2023. "The Circular Economy and Consumer Behaviour: Literature Review and Research Directions." *Journal of Cleaner Production* 418: 137824. <https://doi.org/10.1016/j.jclepro.2023.137824>.
- World Economic Forum. 2023. "Circularity in the Built Environment: Maximizing CO2 Abatement and Business Opportunities." White paper. Geneva: World Economic Forum, in collaboration with McKinsey & Company.
- WRAP (Waste and Resources Action Programme). 2006a. "Resource Action Fund." <https://www.wrap.ngo/what-we-do/our-services/grants-and-investments/resource-action-fund>.
- WRAP (Waste and Resources Action Programme). 2006b. "The UK Plastics Pact." <https://www.wrap.ngo/take-action/the-uk-plastics-pact>.
- WRAP. 2021. "Recycling Your Customers' Plastic Bags and Wrapping." Accessed August 7, 2025. <https://wrap.org.uk/resources/guide/recycling-your-customers-plastic-bags-and-wrapping>.
- WRAP. 2025. "Designing for Recyclability." Accessed October 19, 2025. <https://www.wrap.ngo/what-we-do/prevent-problem-plastics/designing-for-recyclability>.