# Exploring Dynamics in Construction Circular Supply Chains Using a Systematic Literature Review: New Supply-push and Demand-pull Perspectives

# EXPLORING DYNAMICS IN CONSTRUCTION CIRCULAR SUPPLY CHAINS USING A SYSTEMATIC LITERATURE REVIEW: NEW SUPPLY-PUSH AND DEMAND-PULL PERSPECTIVES

**Jieling Huang[1], Mohamed Abadi and Jillian Yeow**

*Department of Mechanical, Aerospace and Civil Engineering (MACE), Engineering Building A, The University of Manchester, Oxford Road, M13 9PL*

A full transition to Circular Economy (CE) in construction requires a rethinking of its operations from a supply chain viewpoint. The transition to Circular Construction Supply Chains (CCSC) can be discussed from supply-push (SP) and demand-pull (DP) perspectives; however, this understanding is underdeveloped in the literature. The study aims to explore barriers to the transition to CCSC and associated SD/DP countermeasures and investigates whether the current configuration of CCSC is SP- or DP-driven. A systematic review of 81 peer-reviewed articles was conducted. Thirty-seven barriers were identified, combined into nine factors, and further classified into three groups: technical, managerial, and contextual. Countermeasures to these barriers were linked to SP/DP and their level of control (macro, meso, and micro). Findings revealed countermeasures are mainly SP-related and used to create a DP environment. This new "push-to-pull" attribute shows the dynamic nature of CCSC transition that requires greater collaboration of actors at different levels.

Keywords: circular economy; circular construction; supply chain; barriers

## INTRODUCTION

### Circular Supply Chains (CSCs) in the Construction Industry

The concept of Circular Economy (CE) has gained increasing momentum among academia, industry, and policy agendas (Jones and Comfort, 2018). It seeks to sustain the circulation of resources within a quasi-closed system and keep them in usage for the longest duration possible to maintain their value (Nasir *et al.,* 2017). It provokes a rethink of construction Supply Chains (SCs) to reduce construction waste and improve resource efficiency by adopting CE concepts (Chen *et al.,* 2022). As opposed to process-based industries (e.g., manufacturing), construction SCs are typified by instability because of fragmented and project-based characteristics (Loosemore, 2000). A typical construction SC comprises clients and designers in the upstream preparing for the on-site production, and main contractor, subcontractors, and suppliers in the downstream performing project delivery tasks (Akintoye *et al.,* 2000). Unlike manufacturing sectors where standardised and repetitive processes are

[1] jieling.huang@postgrad.manchester.ac.uk

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undertaken in a controlled environment, construction deals with unique and bulky units, and the associated production processes are conducted on-site that suffer from variability (Solomon *et al.,* 2006). Challenges in construction SCs, such as a lack of information transparency, and incompatible business purposes (Behera *et al.,* 2015), often lead to a significant amount of rework and waste generation (Chen *et al.,* 2022). Rethinking construction SCs is in line with the widely spreading idea of Build Back Wiser that seeks new solutions to the issues of industrial concern.

The linear SC follows a cradle-to-grave process starting from raw materials and ending up with final products (Beldek *et al.,* 2016). The incorporation of CE replaces the end-of-life concept (or 'grave') with new input (or 'cradle') and features a 'cradle-to-cradle' process by enabling products at the end of lifecycle to re-enter the supply chain through reuse, recycling, or remanufacturing (Nasir *et al.,* 2017). Various research endeavours were paid to explore the potential of circular construction supply chains (CCSC). For instance, Leising *et al.,* (2018) developed a conceptual framework to assist the collaboration of CCSC. Moreover, Nasir *et al.,* (2017) made comparison between the linear SC and CSC focusing on building insulation products regarding their environmental impact. Through a wide review of literature, Chen *et al.,* (2022) identified an array of CE strategies relevant to different SC stages ranging from design, manufacturing, construction, operation, and maintenance, to end of life. This aligns with calls by Abadi *et al.,* (2021), to adopt a project life-cycle assessment (PLA) approach to facilitate the transition of construction SCs to CCSC.

**Supply Push (SP) and Demand Pull (DP) in the Circular Transition**

As part of SC management strategies, SP and DP describe different patterns of production and control. SP features a produce-to-stock model that is seen as forecast-driven production based on historical data and projections, whilst DP is typified as a produce-to-order model based on actual customers' orders (e.g., Pyke and Cohen, 1990). Delivery of construction projects is characterised by Engineer-to-Order (i.e., a ‘pull’ system), but production activities might be pushed towards the contracted due date (Kalsaas *et al.,* 2015). Besides physical products, the literature also addresses SP and DP in relation to knowledge promotion. In innovation research, SP (also known as 'technology-push') and DP are used to explain technical changes, where SP connotes knowledge development drives the direction and rate of innovation and DP considers innovation derived from unmet needs in the market (e.g., Nemet, 2009). Besides, push and pull are also used to study switching behaviour, where push factors are negative perceptions that motivate people to leave an origin and pull factors are appealing attributes that drive people to initiate changes (e.g., Hazen *et al.,* 2017).

Discussions were retrieved in the literature about SP and DP relevant to promoting CE. For instance, Kiefer *et al.,* (2019) investigated how different types of eco-innovations contributed to the circular transition in firms and considered collaboration with universities, research centres and consultants as SP and with clients as DP. Besides, Moon and Lee (2021) summarised that CE in digital TV industry can be shaped through technology-oriented strategy by adjusting its tangible and intangible resources to seize opportunities (SP), market-oriented strategy by sensing market changes and consumer needs (DP), and adaptive follower strategy that integrates the features of both two strategies. In addition, CE transition is often discussed from a policy perspective, where policies are conducive to boosting both the supply of circular projects through SP measures (e.g., imposing eco-design standards, strengthened producer responsibility schemes and R&D funding) and increasing the demand for them via DP measures (e.g. differentiated VAT rates, recycled content mandates, green procurement) (OECD, 2019). By comparison, Hazen *et al.,* (2017) examined consumer behaviours in terms of switching from traditional SCs to CSCs through the lens of theory of migration, where 'push' factors (e.g., high price, low quality and poor service) are assumed to be negative in nature that drive individuals to abandon current consuming patterns and 'pull' refers to positive factors (e.g. superior product performance, government incentives and tax breaks) that encourage behaviour changes in desired directions.

SP and DP measures are weighed differently depending on varying contexts and there seems to be a trade-off between these two approaches. For instance, Nemet (2009) claimed that current policies about promoting innovations were overwhelmingly dominated by DP measures whose effectiveness of inducing non-incremental innovation was largely doubted due to the technological incapability resulted from SP negligence. A rational allocation of resources between SP and DP instruments should exist based on the need for non-incremental technical improvements (Nemet, 2009). Conversely, Motoyama and Malizia (2017) posited that current practices of promoting entrepreneurship relied heavily on SP factors, although they proved that some SP factors had with no correlation with start-up rates in high-tech industries.

**Using the 'Innovation Chain' Model to Describe Dynamics in CCSC**

The challenges in CE implementation nowadays are not only involved with institutions pushing the development of new ideas or technologies, but also the market and society players creating the demand for them (Bezama, 2018). The overwhelming implementation of either SP or DP measures can result in a growth plateau (Nemet, 2009). For example, 'waste-to-value' CE approaches, e.g., production of bioplastic from sewage sludge (Bluemink *et al.,* 2016), is technically feasible but not yet economically competitive in the market, thus not commonly seen in practice. Considering SP and DP are open to various interpretation, this study stands on the perspective of innovation promotion and specifically built on the understanding of innovation chain (shown in Figure 1) proposed by Grubb *et al.,* (2021). The rationale is twofold: firstly, CE is relatively new to the construction industry, and it is fair to be considered from innovation wise; secondly, the presented innovation chain provides ideas of trade-off between SP and DP measures in different stages of development. It indicates different weighting between SP and DP as a new concept matures. This would provide a new thinking about the status quo of current CE implementation in the construction industry. Considering the above discussions, in this study, SP measures are defined as initiatives to promote CCSC by actors who mainly provide and communicate new solutions, whilst and DP measures refer to CE initiatives arising from actors who apply CE in their business practices.

Although the literature shows some discussions about SP and DP in CE context, it lacks an explicit definition of DP and SP resulting in ambiguous understanding of their application. The transition to CE in construction has initiated extensive discussions about associated barriers/enablers in the academia. However, the literature has not investigated the application of DP and SP measures in the CCSC context. The 'wiser' aspect of this study lies in that it provides a new understanding of the transition to CCSC by considering a dynamic balance between SP and DP measures. However, it is unclear about whether SP or DP predominates the driving forces to CCSC. Thus, this study aims to explore barriers to the transition to CSC in construction and associated SP/DP measures used to overcome these barriers and investigate the current configuration of CCSC in terms of whether being SP- or DP-driven. This can be achieved by the following four objectives: 1) to identify the focus of CCSC literature; 2) to identify barriers to the transition to CSC in construction; 3) to identify measures used for their mitigation and classify these measures according to their nature whether SP or DP; 4) To explore the interplay between SP and DP measures.

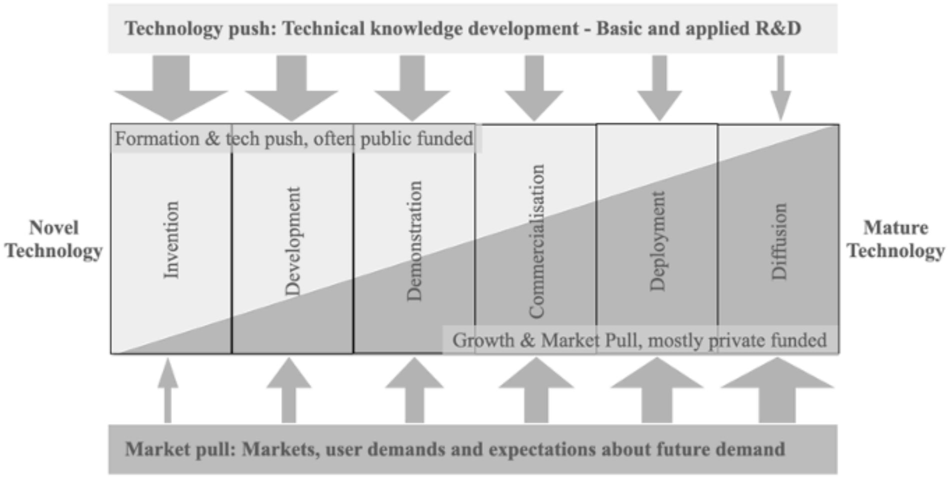


*Figure 1: Innovation chain from novel to mature technology (Grubb et al., 2021)*

## METHOD

A systematic review of 81 peer-reviewed journal articles was conducted. Figure 2 depicts the review process including data collection and analysis: search engines, keywords used, number of articles, screening procedure followed, and analytical strategies. 'Google Scholar', 'Scopus' and 'Web of Science' were adopted to retrieve relevant articles. Keywords used comprise 'circular', 'green' and 'sustainable' due to the conceptual overlap of these terms in CCSC literature. The development of sustainable and green SC is also considered to be in parallel with CSC discourse (Nasir *et al.,* 2017). This enabled a comprehensive capture of relevant articles.

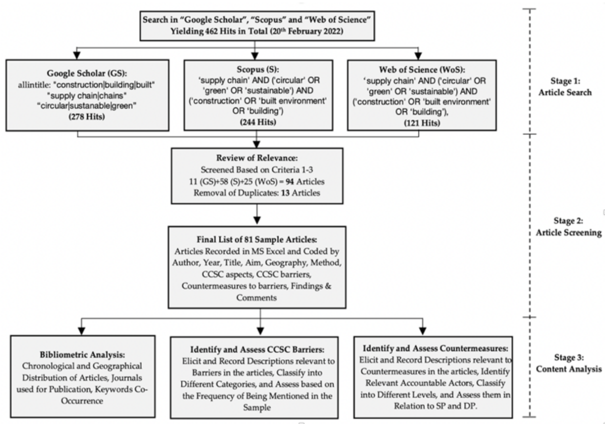


*Figure 2: Schematic design of the systematic review*

The actual search was conducted in February 2022, and the 462 "hits" returned from the initial search were screened using three main selection criteria: 1) peer-reviewed journal articles to improve research rigour, 2) published after 2013 when CE gained ground thanks to a series of seminal reports by the Ellen MacArthur Foundation, 3) research scope in close proximity to CE principles applied in construction SCs in light of CE strategies in construction SCs identified by Chen *et al.,* (2022). The selection resulted in a final sample of 81 articles recorded in MS Excel for further analysis (the full list of articles is available upon request). In general, an upward trend of research is witnessed in the sample focusing on CCSC with most articles (35/81) published in 2021, indicating a growing awareness of this topic in the academia.

# FINDINGS

A relational diagram (Figure 3) aided by VOSviewer was used to show co-occurrences in a network of 39 keywords generated by setting 'the minimum number of occurrences' of a keyword in the research sample at '5'. The size of each node reflects its occurrence in the sample, whilst the thickness of a line between two nodes infers the frequency of their co-occurrence. The top eight keywords whose occurrences and link strength are above 19 and 100 respectively are 'supply chains', 'construction industry', 'sustainable development', 'sustainability', 'circular economy', 'recycling', 'supply chain management' and 'waste management'.

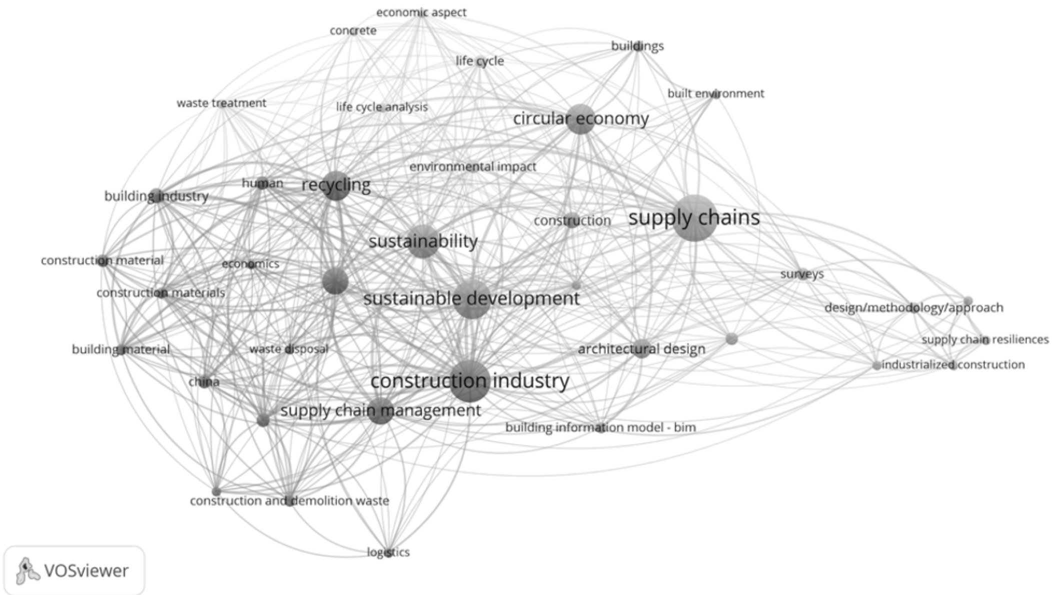


*Figure 3: Keyword co-occurrence network*

Two points are worthy of note here. Firstly, a high linkage between 'sustainability' and 'circular economy', which echoes the perceptions of Geissdoerfer *et al.,* (2017) who summarised three types of relations between "sustainability" and "circular economy", i.e., pre-condition, a beneficial relation, and a trade-off. However, the impact of keywords used should be admitted on the resulted high relation. Secondly, "recycling" and "waste management" are of high relevance to "circular economy", which is also reflected in the sample where 62.97% (51/81) of articles mentioned R-related principles in the waste hierarchy (i.e. refuse (2/81), rethink (2/81), reduce (26/81), reuse (46/81), repair (6/81), refurbish (5/81), remanufacture (9/81), repurpose (2/81), recycle (50/81), and recover (6/81)), among which 3Rs (reduce, reuse and recycle) were found to be the most common combination mentioned in 24.69% (20/81) of the sample.

This is consistent with Kirchherr *et al.,* (2017) who reviewed 114 definitions of CE and found that "recycle" was the most common element mentioned in 78.95% (90/114) of definitions and 3Rs were the most commonly elements of CE definitions.

This finding aligns with claims by Adam *et al.,* (2017) that construction CE has been largely limited to waste management and recycling and has a little relevance to other compelling requirements of CE highlighted by Abadi and Sammuneh (2020) concerning 'design for circularity' and 'new SC business models'. In addition, the four clusters in different colours in the network show different focus with "building materials" (red) (e.g., fit-out waste, bioplastics…), "industrialised construction" (green) with 30.86% (25/81) of relevant articles, "building information modelling" (blue) with 37.04% (30/81), and "environmental impact" (yellow) echoing Geissdoerfer *et al.,* (2017) who revealed that most CE studies focused on environmental aspects of CE.

**Barriers and Countermeasures Associated with CCSC**

A Sankey diagram was used for the visualisation of barriers to the transition to CSC in construction identified from the research sample (Figure 4). Thirty-seven barriers were identified in total from the research sample; these were combined into nine factors and further classified into three groups according to their nature (technical, managerial, and contextual). The width of flows in Figure 4 represents occurrences of different barriers in research sample, which indicates the level of attention they received in the CCSC literature, given that each article in the research sample may address several barriers/factors at the same time.

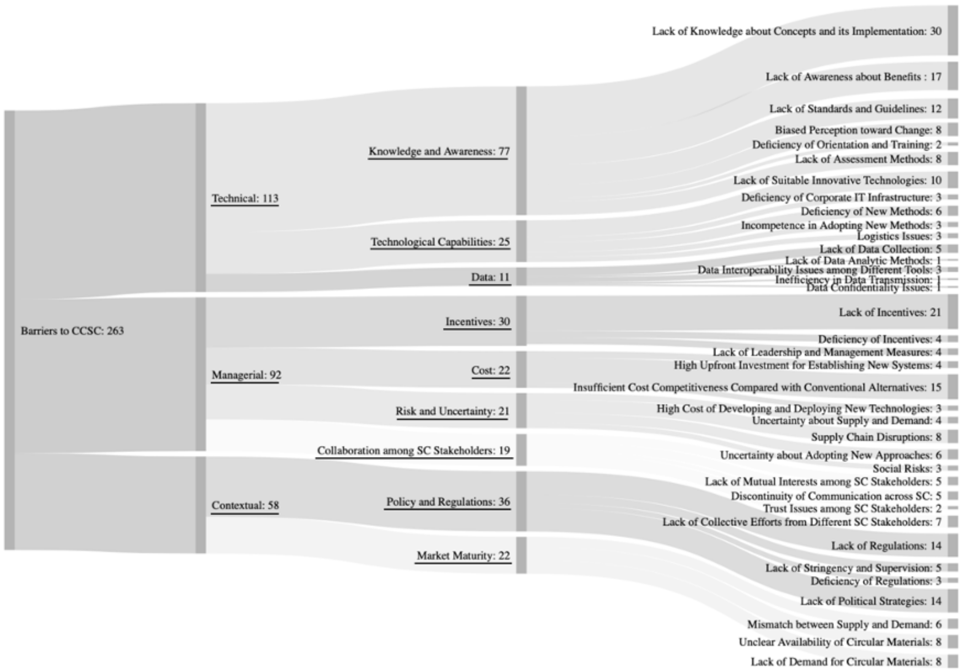


*Figure 4: Barriers to CCSC identified from the research sample*

Figure 4 shows that 'Knowledge and Awareness' is the most important factor identified in 29.28% (77/263) of the articles, with 'Lack of Knowledge Concept and its Implementation' being the predominant barrier mentioned under this factor (11.41% (30/263)). This is also evidenced by a compelling argument by Adam *et al.,* (2017) who discerned a lack of awareness of CE adoption in the construction industry where SC actors (i.e., clients, designers and subcontractors) were the least informed. As Wijewickrama *et al.,* (2021) revealed that designers were aware of the importance of designing out waste, but they did not have sufficient knowledge to take actions. A few articles also show that some practitioners were conducting CE practices, but they were unaware of the concept perhaps due to some similarities between sustainability and CE. This fact is also seen in the sample where 59.26% (48/81) of articles studied CE-related topics in construction SCs, but they did not literally specify CE.

A relational Sankey diagram was used to depict CCSC dynamics; these include barriers to transition to CCSC, associated countermeasures, and responsible actors and their level of control (Figure 5). Twenty-nine countermeasures were elicited from the research sample and their links to different barriers listed under the nine factors discussed earlier were established. Moreover, the accountable actors responsible for individual countermeasures were identified and classified into three groups according to their level of control in CCSC as suggested by Wijewickrama *et al.,* (2021). The three levels include: firstly, the micro, i.e. project supply network, level including actors contracted by the need of a project (e.g. developers, architects, contractors, suppliers… etc.); secondly, the meso level including non-governmental organisations (e.g. Association of Project Management APM, and the Ellen MacArthur Foundation), research institutions providing knowledge and guidance for project delivery (e.g. universities, and research centres); thirdly, the macro level including governmental bodies and policy makers. In Figure 5, the three levels of control were colour-coded, and flows were configured with the same width since the purpose is to identify dynamics in CCSC and associated frequencies are insignificant in this context.

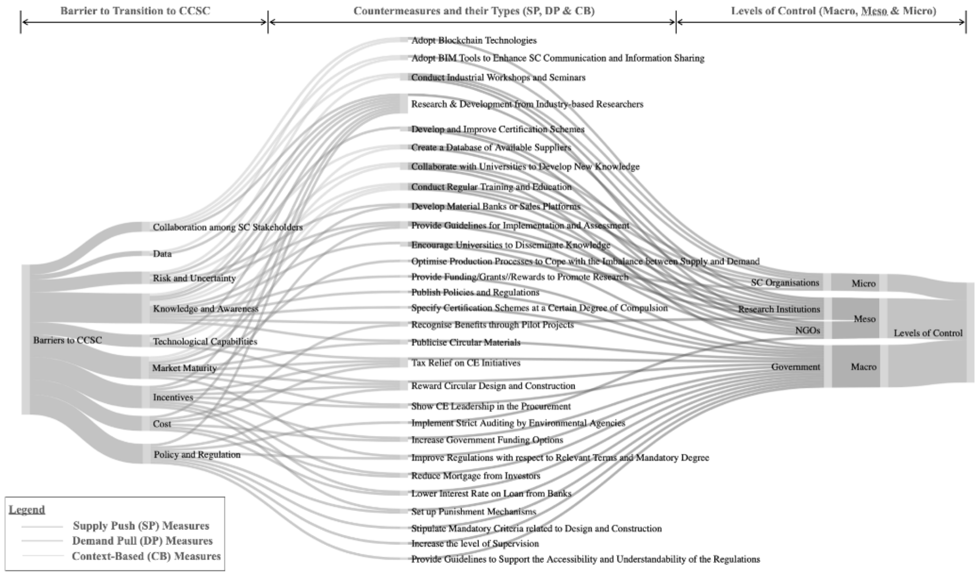


*Figure 5: A relational diagram of CCSC dynamics*

Two points are worthy of note in terms of dynamics of the transition to CSC in construction. Firstly, the 'macro', i.e., government and policy makers, level is of high expectation to develop strategies and policy to support the transition to CSC in construction. Secondly, Figure 5 reveals that the transition to CSC in construction has a complex nature and requires greater collaboration of all actors at different levels of control (micro, meso and macro). Each of the identified countermeasures can be used to tackle different barriers; for example, 'Tax Relief on CE Initiatives' can be used to mitigate barriers listed under 'Technological Capabilities', 'Maturity of Market', 'Cost' and 'Incentives'. Similarly, each barrier can be tackled using different countermeasures, and consequently, actors responsible for these countermeasures that may exist at different levels would be involved in its mitigation.

*The Interplay Between SP and DP Configuration in CCSC*

Reflecting on SP and DP configurations in CCSC, countermeasures identified from the research sample were classified into three groups: 'SP-related', 'DP-related', and 'Context-Based'; these three groups were colour-coded in Figure 5. Findings reveal that the identified countermeasures are mainly SP-driven focusing on providing appropriate contexts to support the transition to CCSC from a level of control higher than the micro level, i.e. project supply network, instead of being initiated from the demand side. However, no clear evidence has shown any DP measures initiated by the micro-level actor to tackle the barriers. Moreover, some countermeasures can either be SP or DP depending on the context within which they are applied, and thereby classified as 'Context-based'. For example, 'Conduct Regular Training and Education' can be classed as 'SP-related' if it is devised by actors at the 'macro' or 'meso' levels to promote new strategies at the micro level and classed as 'DP-related' if devised by actors at the micro level reacting in response to their own needs.

Despite the SP-driven nature of CCSC, findings interestingly reveal that SP measures, e.g., 'Tax Reliefs on CE Initiatives' and 'Provide Funding/Grants/Rewards to Promote Research', are devised to reduce the environmental impact of construction activities as well as gradually create a DP environment in CCSC by mitigating barriers to adoption, raising awareness of actors at the micro level about benefits of CE, creating opportunities and establishing demand for circular materials. This indicates that barriers to CE implementation are not static, but instead they change over time with the SP effects. Although this systematic review cannot reflect the changing process of SP and DP due to the different contexts in the sample articles, the dynamics in CCSC can be explained considering the 'Innovation Chain' model. Based on this model, measures of promoting CCSC would gradually move from SP- to DP-driven with increased CCSC maturity (i.e., a transitional process), and more initiatives would come from actors at the micro level (i.e., project supply network) and a DP environment eventually develop once benefits have been widely acknowledged. Given CCSC is currently primarily SP-driven, it is fair to assume that CCSC is still in its early stage of development, which is also supported by views of Hossain *et al.,* (2020). On the other hand, as CE is perceived as a combination of relevant strategies and concepts, its adoption in CCSC would need to undergo continuous iterations from SP to DP to support/embrace emerging CE strategies and concepts (i.e., 'transformational' process).

## CONCLUSIONS

This paper explores dynamics of construction circular supply chains (CCSC) from new supply-push (SP) and demand-pull (DP) perspectives by systematically reviewing 81 peer-reviewed articles. First, data analysis revealed that the CCSC literature is still engaging with concepts related to waste management, e.g., waste hierarchy and Rs concepts, overlooking more compelling concepts of SC management, e.g., 'design for circularity' and 'sharing economy'. Second, the transition to CCSC is still associated with barriers; with 'Knowledge and Awareness' being the most common barrier revealing a nascent stage of CCSC development. Third, analysis of dynamics of this transition (barriers, countermeasures, and actors) revealed a complex system, as overcoming individual barriers requires the use of multiple countermeasures and greater collaboration of various SC actors at different levels (micro, meso and macro). Fourth, governance in CCSC showed a supply-push dominance with more influence of actors at levels higher than the micro level, i.e., project supply network, to facilitate the transition. Fifth, findings revealed that "push" measures are usually devised to gradually create a "pull" environment in CCSC (e.g., by easing barriers to adoption, raising awareness, creating opportunities, establishing demand for circular materials), and "push" measures can be revoked when a "pull" environment has been created. Sixth, this new "push-to-pull" environment justifies the use of the 'innovation chain' model to describe dynamics in CCSC, and the fact that CCSC are currently more SP-driven provides extra evidence that CCSC is still at an early stage of development. Finally, the circular economy (CE) paradigm includes a long list of strategies/ concepts, and their adoption in construction SCs requires continuous iterations between SP to DP measures to embrace emerging CE strategies/concepts reflecting a complex 'transformational' rather than 'transitional' nature of CCSC. This complex understanding of CCSC dynamics provides directions for future research. It brings the concept of resilience in CCSC into view and suggests potentials of system dynamics modelling for informing decision-making and policy design. This will, eventually, shift the attitude of SC actors toward the transition to CE from 'passive' (i.e., externally stimulated by policies and arrangements devised on an ad hoc basis), to 'active' (i.e., actor-inclusive initiatives well-informed by deep understanding of CCSC dynamics).

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