Business Strategy and the Environment

WILEY | Business Strategy and the Environment

RESEARCH ARTICLE OPEN ACCESS

A Proposed Circular Economy Readiness Framework for the Rail Sector, A Literature Review and Conceptual Framework

Carl Waring | Kapila Liyanage

College of Science and Engineering, University of Derby, Derby, UK

Correspondence: Carl Waring (c.waring@derby.ac.uk)

Received: 22 October 2024 | **Revised:** 22 August 2025 | **Accepted:** 30 August 2025

Keywords: Asset management | Circular economy | Railways | Readiness | Strategy | Systems thinking

ABSTRACT

The circular economy (CE) offers a transformative approach to addressing global sustainability challenges, yet few frameworks integrate it with business strategy, systems thinking (ST) and asset management (AM), especially within critical infrastructure sectors like rail. This paper conducts a comprehensive literature review to assess existing CE frameworks and their application in the rail sector, exploring how these frameworks intersect with ST and AM practices. The analysis reveals significant gaps, particularly in the application of ST at a complex level necessary to drive meaningful shifts in business models and stakeholder behaviour. To address this, the paper proposes a novel Circular Economy Readiness Framework tailored to the rail industry, offering a systematic approach to transitioning from traditional, linear business models to sustainable, networked or circular practices. The framework underscores the role of AM in driving circular outcomes, aligning business strategy with long-term economic, environmental and societal goals. This research contributes to the broader discourse on CE readiness by offering actionable insights for industries aiming to enhance resilience and sustainable growth.

1 | Introduction

In Western civilised and democratic societies, if companies are the engine of value creation and technical progress (Lockhart 2023), then they should show what value they create. That value should be enshrined as the product of corporate purpose and identity, where purpose is brought to life through the continuous development of business strategies and implementation of plans. Business strategy sets the agenda for organisational transformation (Younger et al. 2020), which is when strategy enacts the organisation's purpose. Organisations should not set a strategy in isolation from the outcome or impact of what the organisation does. Just as much as political structures, a national economy or an immune system cannot be regarded as simply a property of that system taken in isolation (Schlindwein and Ison 2004).

But since the 1970s, our economies and businesses have seen a shift away from a make-do-and-mend mentality to one that operates on a take–make–waste basis. Our economies work on a relentless drive for directors to raise stock price over the short term (Stout 2012). In contrast, the premise that organisations hold a responsibility that goes beyond their shareholders is not new. Early Quaker families were a remarkable phenomenon of British business history such as the original Barclays or Lloyds in banking, or Sainsburys in food retail. The Quaker business philosophy was to take the long view and would not be blown off course by short-term commitments (Quaker faith and practice Fifth Edition 1911).

To challenge the way our economies work in addressing climate change, organisations face a plethora of external themes or regulations such as corporate social responsibility (CSR)

(Economist 2009), carbon accounting (Gov.UK 2020) or Environment, Social Governance (ESG) (World Bank Group 2004–08), (Economist 2022), (Eccles 2023). In addition, Sustainable Development Goals (UN DESA 2023) or 'Six Capitals', developed by the International Integrated Reporting Council (IFRS 2024) should also be considered.

The Circular Economy (CE) is one such emerging theme that looks to tackle climate change and supports sustainability by leveraging the value and utility of assets and asset lifecycles. The CE is a shift away from our current economic dependency on seeking short-term profits reliant upon increasing consumption and resulting waste. Value is leveraged through the exploitation of systems thinking (ST) and circular business models.

Our current business strategies rely upon operating models with the singular alignment of producing technology on an exploitative take-make-waste basis. An economy and the value it creates should not just be based upon price. New conditions are needed that support and commit to longer-term investment horizons (Mazzucato and Penna 2015). Businesses need to change their mindset to break out of their short-term zero-sum games. The opportunity to create synergies through ST in business strategy is missed and represents a major challenge for industry and the economy in general. Importantly, if an organisation sets the right strategy, most of these external themes already get addressed.

The reasoning behind the literature analysis is to determine if any CE frameworks connect the application of ST to influence the development of organisational strategy to influence 'value beyond price' outcomes within a CE context. For example, moving beyond short-term 'take make waste' operating models. This is in relation to exploiting the utility of assets and therefore should consider the exploitation of asset management (AM).

The CE relies upon ST to reframe the boundary of the firm to the boundary of opportunity. This includes reframing regulation not just as a barrier, but also as an enabler to promote positive behaviours for longer-term and reframed cooperative goals. Yet CE has yet to grasp how ST can be exploited to achieve these aims.

The spectrum of unresolved issues around the CE from previous studies is far reaching. From a lack of integrating ST into AM (El-Akruti et al. 2013; Hanski and Valkokari 2020; Acerbi et al. 2020; Waring and Liyanage 2022), and existing AM standards, e.g., ISO 55000:2024 (ISO 2024a) assumes a cradle to grave model not cradle to cradle and a lack of circular economic decision support tools. There are disconnects between Design and Operations (Bocken et al. 2019; Braungart et al. 2007; Amaitik et al. 2022) There are stakeholder misalignments and scenario planning gaps where Strategic Options Development and Analysis (SODA) (Ackerman and Eden 2020) could be better utilised to explore circular options (Kayikci et al. 2022). Policy short termism in public investment prioritises CAPEX over lifecycle value and complexity theory insights are not operationalised in circular asset strategies (Green Book Review 2020; Mazzucato and Penna 2015; Stahel 2007).

This paper proposes a CE Readiness Framework specifically designed for the rail sector, addressing the critical need for strategic integration of ST and AM in circular transition efforts. Whilst existing frameworks often emphasise material flows and recycling processes, they largely overlook the complex interdependencies, long-term planning and operational dynamics that are essential in infrastructure-intensive sectors like rail. This research has highlighted a range of limitations in existing research that links business strategy, the exploitation of AM, ST and the CE. Whilst individual studies provide insights into a few of these areas, the joining up of these themes remains largely fragmented and opens up opportunities for further research. Through a systematic literature review, the study identifies significant gaps in current CE frameworks, particularly their limited application of ST and AM to inform strategic business planning and value creation beyond price.

Building on this analysis, the paper introduces a systems thinking-based novel framework that aligns circular principles with strategic, operational and stakeholder dimensions. In doing so, it contributes to both academic discourse and practical implementation by offering actionable guidance to organisations aiming to enhance resilience and sustainability in critical infrastructure systems.

This study addresses a gap in CE literature by proposing a novel readiness framework for the rail sector that integrates ST and AM. By conducting a systematic literature review across interdisciplinary sources, we identify the limitations of existing CE frameworks in addressing complex interdependencies and strategic planning in infrastructure-heavy sectors. The proposed CE Readiness Framework aims to support organisations in aligning their strategic goals with sustainable, long-term value creation. This framework contributes to both the academic field of CE and the practical implementation of CE practices in critical infrastructure sectors like rail.

2 | The Factors Considered for the Theoretical Framework

The proposed theoretical framework draws upon ST, the features of the CE and AM, as well as a selected system of interest in this case, the rail sector to inform business strategy. The paper explains the five interrelated subjects separately and then converges them across a proposed theoretical framework. The specific issues this study seeks to address are shown in Figure 1.

2.1 | The CE—Another Theme

The CE is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, pollution and regeneration and relies upon the application of ST. CE principles and concepts are becoming popular with policy makers, industry and academics (Geissdoerfer et al. 2017). CE can be seen as a strategy within the scope of sustainability (Ruggieri et al. 2016). Although its effective deployment has been limited, possibly because of its perceived value over time (Webster 2013).

Kirchher (2017) identifies 114 definitions and 17 characterisations of the CE. Few definitions or models target a move towards a systemic shift in the economy or sustainability. This implies

1. ***Purpose beyond profit***: *If an organisation wants to be seen as part of a circular economy, it should focus on creating value that goes beyond just making money. This mindset should be built into its overall strategy.*
2. ***Asset management is exploited strategically***: *The strategy should make smart use of asset management to support this shift toward circular practices.*
3. ***Applying systems thinking***: *Systems thinking can help the organisation imagine what a circular strategy looks like, assess if it's workable, and work out out how to move away from the traditional "take-make-waste" model.*
4. ***Looking beyond the organisation***: *More value can be unlocked if the strategy considers partnerships, networks, and impacts beyond the organisation's own boundaries.*
5. ***Interpreting measures of this behaviour***: *To understand and track this complex change, we need ways to visualise how all the parts interact and tools to measure progress toward circular goals.*

FIGURE 1 | The specific issues this study seeks to address.

the majority of these definitions ignore the need for our economy to adapt. The concept that the CE is 'an economic system that replaces the end of life' is a useful aspiration although maybe not one that is technically or scientifically achievable.

Skene (Skene 2018) is critical of the concept of the CE, particularly within the context where CE ideas have been over simplified or implied as a panacea. CE concepts cannot ignore the need for a mindset shift and changes in behaviour of all participants. We need to change the way in which we understand and interpret value. For example, some CE concepts ignore the basic idea of sovereignty and the way in which national and global economics work.

Some organisations promote overly simplistic CE ideas that fail after closer inspection. Creating the recent phenomena of 'circular economy rebound' (Zink and Geyer 2017). This occurs when CE activities, which have lower per-unit-production impacts, also cause increased levels of production, reducing their benefit. In other words the business model is ignorant of Jevons paradox.

CE behaviour contributes towards sustainability but even the concept of 'sustainability' has its challenges (King 2013). Sustainability remains an ambiguous concept open for interpretation (Hopwood et al. 2005) and whilst CE is still an emerging practice it can be argued there is no commonly agreed concept of it. It is suggested that a single lens needs to be seen through so different actors have distinct interpretations of what CE could or should depict (Moraga et al. 2019), (Blomsma and Brennan 2017).

CE cannot be seen as an 'ad-on process' to an existing 'take-make-waste' organisation or economy. Perhaps the search for what 'a single lens to see through' means is a distraction. Because it ignores the complexity that needs to exist across our economies to thrive, and at the same time it needs to be countered from whose and what perspective? CE is a nebulous term.

There are no shortages of frameworks which attempt to bound the dimensions of what the CE is and what it means. Garza-Reyes (Garza-Reyes et al. 2018) provides an analysis using 12 dimensions to make comparisons. The research points to a pattern that existing frameworks mainly cover only four out of 12 proposed dimensions. A key observation here is that if this is what the mainstream is saying what the CE is, then what are the others missing out on and why? Outputs and outcomes are different. Outputs are measures of quantity; outcomes are measures of impact. CE interventions should all lead to future desirable outcomes.

Lord Rutherford, the discoverer of the atomic nucleus, divided science into physics and stamp collecting. Other sciences, such as astronomy, chemistry, geology and, most notably, biology, rely a lot on collecting things (not literally, in the case of astronomy) and classifying them in various ways until a pattern emerges (*Economist*. 2023). These patterns should then be known as theories. The point being, there are as many patterns as there are contexts.

To address this complexity, the CE relies upon the application of systems theory or ST, which are the application of multimethodological approaches.

2.2 | Systems Theory and ST in Context

The field of cybernetics is wide ranging and associated with feedback. It is described in a number of ways. For example, 'control and communication in the animal and the machine' (Wiener 1948). Mead describes it as "a form of cross-disciplinary thought which made it possible for members of many disciplines to communicate with each other easily in a language which all could understand" (Mead 1968). Ashby describes it as 'the art of steermanship' (Ashby 1956), Beer describes it as 'the science of effective organisation' (Beer 1995).

The history of cybernetics is not straightforward and overlaps with other themes. Other disciplines have emerged that have extended or reinforced the concepts originally developed or inferred from cybernetics. For example, 'complexity science' (Johnson 2009), which is an understanding of the behavioural aspects of systems. Zayed et al. (2010) discusses many dimensions around complexity, and whilst there may be no single definition for complexity science, the general way in which complexity is expressed is through behavioural models or examples.

It is helpful to think of systems as a series of interacting parts within a boundary definition, knowing full well that boundary

definitions constrain or enable the value of what the outcome of the system can facilitate. This must be true because of the concept of 'emergence'. Whereby emergence is something that is created from the outcome of complexity, with the combination of the output or relationship between several systems relying upon the interdependent feedback loops that communicate between them.

From a grand perspective, biology is the emergence of chemistry; from an environmental perspective, global warming is an emergent property of the outcome of mankind's behaviour, predominantly from industry and agriculture due to the increasing demands of mankind's consumption.

The term systems theory in this research encompasses all subject matter in relation to the study of systems of any form. The term ST is the understanding of systems theory and the application of it in any form, part or whole within an applied space.

Within a ST context, CE can be described by using the outcomes from two ends of a spectrum. Circular economic value is only understood when it is compared with an alternative in context. At one end of the spectrum is the linear economy that is influenced by short-term profit gain, minimal compliance to the detriment of externalities. The CE is at the other end of the spectrum, which is complex and influenced by taking an ecological view by creating medium- and longer-term profit and creating wider value. That value is the product of what could not have otherwise been created if those values did not exist, or those constraints were enabled by actors and stakeholders who were not dependent on a sole arbiter to influence or shape or do what they do.

CE value should be outcomes based and must be aligned with having a positive impact on externalities. How value is created comes from innovation, changes in behaviours and changes in the prioritisation and the understanding and meaning of value. At the complex and CE end of the spectrum, the focus should be the ability to make a judgement as to which CE interventions are more effective when compared with others as part of a decision-making process. The link of the CE to ST pivots around the concept of a system boundary, which reveals a useful definition for circularity. One that is necessary, expanding, de-toxifying and regenerating the boundary of 'the system' or the positive outcome on the system/s and the system/s externalities. And when we think of systems, we need to understand systems from whose and what perspectives. And when we do that, we need to realise that changes in one system have positive and negative consequences with others.

We should be comfortable with the principle that we are not able to fully understand the scope and boundaries of systems and the impact that they have on externalities. This distinction is comparable with the differences between mankind's understanding of physics and understanding of biology. Whilst mankind has discovered laws of science, this only represents a small window into mimicking or altering nature. This certainly does not represent understanding nature, only a small part of it. Rosen (2011) makes the point when Elsasser argues insofar as physics must deal entirely with such averages at the macroscopic level, biology is *in principle* irreducible to physics. It further follows that the laws governing the behaviour of biological systems are not inferable or exclusive from physical laws although they are compatible with them. This is a common misconception and often exploited for the wrong reasons. Just because you have mimicked a small behavioural characteristic of a system does not mean you understand how the system works.

It is important then to understand how emergence occurs. Emergence occurs in nature from systems we struggle to understand, but we can describe the conditions and the products of systems that enable emergence to happen (Ladyman et al. 2013).

2.3 | AM in Context

Assets are invested in and built and managed to serve a purpose to enable an outcome. The practice of AM covers the management of the built environment. This paper considers the investment in and exploitation of railways.

The history of AM has emerged from two boundary definitions. A bottom-up perspective, which mainly focuses on the cost of the asset, its condition, reliability and maintenance effort, has lesser regard for corporate purpose. It is possible to have an effective and efficient AM system that is essentially carrying out unethical aspirations of the business. Investment in assets is needed to maintain asset life. Requirements are escalated up the management hierarchy.

Management system design, negligence in human decision making and bottom-up AM systems often lead to catastrophic events; for example, the Hatfield train derailment (ORR 2006). This can include poorly defined contracts set by the government or poor governance or management that are too distant from understanding the technicalities needed to manage assets, or the consequences of underinvestment. Recently, UK water companies have been heavily criticised for pumping raw sewage into rivers whilst at the same time underinvesting in upgrading water infrastructure, but also being able to share billions of pounds of profit back to shareholders (Hall 2021). Governance and management system failures occur when there is an ethical or moral disconnect between corporate purpose and the effectiveness of a management board to enact that purpose through strategy, planning and into operations.

Without a corporate purpose linked to non-financial outcomes, bottom-up AM will always be influenced by whole life cost (WLC). WLC is an investment appraisal that assesses the total cost of an asset over its whole life. It takes into account the initial capital cost, operational, maintenance, repair, upgrade and eventual disposal costs. Bottom-up AM is baked into a take-make-waste way of working.

The other AM boundary definition takes a strategic (holistic) or 'top–down' and 'bottom–up perspective' at the same time. Corporate purpose is defined. The impact that the outcome of the organisation has on its external environment across the social, economic and environmental spectrum is made clear. This wider view enables visibility of the resilience, viability and robustness of the business by regularly adapting the AM system to be more effective as the organisation's external horizon changes.

The explanation of how the business transforms that value is reflected in the organisation's AM Strategy (AMS) and enacted through the AM Plan (AMP).

The ISO 55000:2024 (ISO 2024a) series of standards "enables an organisation to realise value from assets in the achievement of its organizational objectives". If the business strategy did not value a particular outcome then the AM system would not be obliged to consider them (El-Akruti et al. 2013). Ness and Xing (2017) recognise the focus on CE adoption for the built environment, incorporating AM and wider stakeholder/actor engagement. For example, organisations that manufacture railway systems should have a vested interest in what railways are enabling in the societies they sell their rail technology into.

It is relevant then that both top–down and bottom–up perspectives have the potential to be combined through international collaboration with the IAM working with the 'Global Forum on Maintenance and Asset Management' (GFMAM 2014a, 2014b). The publication of ISO 55000:2024 (ISO 2024a), ISO 55001:2024 (ISO 2024b) and ISO 55002:2018 (ISO 2018) represents an impressive collaborative effort among a variety of organisations and interests in 25 countries (Moodley 2014). It is only recently that the discipline of AM is considering the CE (Ness and Xing 2017), (Waring and Liyanage 2021).

2.4 | Readiness in Context

Within a strategic context, readiness is the organisational capacity and novelty to create or respond to new challenges, and to carry out planned business activities to fulfil business strategy and planned objectives. Business strategy and planning are bounded in the future and should be continuously adapted in the short, medium and longer term. If the future is important enough, then sufficient time and effort should be placed in the understanding of it and/or shaping it so as not to be caught unaware.

If organisations develop and adopt strategies that are related to the future economy becoming more circular, then the more robust and resilient and sustainable the business and the economy will become. For example, working in more complex ways by engaging in synergistic relationships with other organisations who have a similar outlook. Future 'circular economic competition' in context can be formed. This would present new risks and opportunities for organisations to adapt business models. Organisations do not need to wait for an alternative competitive horizon to exist before they react to it. The industrial revolution did not wait for an industrial strategy or a regulatory framework for our economies to grow. Organisations can continually work on their 'niche', the organisation's perspective of their position in the market horizon they choose to work in.

2.5 | The Rail Sector in Context

The rationale for selecting the rail sector as part of this research is that each actor and stakeholder that engages with the railway has the potential to contribute to the positive outcomes that the railway enables. Where the value of rail should not just be based on price but a series of wider value metrics that business strategy could identify with or leverage. This is the difference between a 'value extracting' or 'value creating' business operating model. These values need to be developed and identified at multiple levels of impact. Each actor or stakeholder is in a position to change its perception of value and can choose to incentivise and change rail sector behaviours. The following observations on the value of rail are limited to the UK.

Rail is a low-carbon transport mode. Just in the UK, rail accounts for only 1.4% of overall transport emissions when compared to alternatives (ORR 2020). Freight moved by rail results in 76% less carbon when transferred by road, although only 9% of freight is moved by rail (DfT 2016). The UK now has a legally binding net zero target by 2050, and new interim targets to reduce emissions by 78% (UK Gov 2021). Revising transport policies, industry strategies and incentives to maximise the switch of transport to rail is one of the most effective measures the UK government and industry could take.

It is recognised that railways join up communities and can represent distributive platforms for mobility and economic growth at national, meso and micro scales. Some transport plans incorporate active travel, reducing the burden on our health systems (PHE 2016). In the UK, the Government has recognised the differences in societal and economic conditions between the North and South of the country and the need to improve social and economic investment distribution with the findings from the Green Book Review (2020).

Unfortunately, inconsistencies exist in benchmarking the value of rail across wider social, economic and environmental dimensions (Azzouz and Jack 2020). Research points to a range of potential viable indicators that require further investigation. There is also emerging practice and understanding around rail sustainability (UIC 2016).

Gaps and opportunities also exist across government departments, with one government department's decisions having a positive or negative impact on another. It is not within the terms of reference of the DfT to favour one form of transport mode over another. Recently, however, its position around policy may have changed, given the Secretary of State for Transport setting a target of 75% growth in rail freight by 2050 (GBRTT 2023). To put this into context, in 2022, in the UK, 175 billion tonne-kilometres were moved by roads, 25 by water and 16 by rail (DfT 2022).

The negative impact to the environment of any form of transport is everyone's burden. Future desirable conditions should be set over successive government cycles so decisions become shared political outcomes. We are starting to see laws that protect individuals from the negative impact pollution has on living conditions wherever it comes from (National Archives 1993).

An example where there are inconsistencies in decision-making for investment is the UK's High Speed 2 Railway (HS2) currently being built between London and Birmingham. The northern Birmingham to Manchester extension has been

cancelled because it will not meet the business case criteria. It has overlooked the value of releasing capacity on the existing railway lines that the existing high-speed services took up. This could allow for more trains for local services and expand the utility of the old rail system by enabling more and different types of rail traffic, such as the integration of shuttles, light rail, and trams and smaller rail freight transport systems perhaps in 5 to 10 years time. The business case did not include wider economic benefits such as foreign direct investment, as is the case previously where there have been major upgrades to access regional locations through rail in the past. It has not included clustering from induced development. The emergent properties that the railway enables and the value of these properties are not envisaged. The result being that the economy in the North of the UK will be smaller with what it is compared to today (BBC 2023a).

Railway investors procure from 'take–make–waste' markets that assume that railway assets have a finite lifecycle. For example, railway carriages are designed to last for 25 years. The reality is railway carriages that were designed and built over 50 years ago are still running on the UK network (Railway Gazette 2012). High-speed trains that were designed and built between 1975 and 1982 have been recently shipped to Nigeria and Central America to be used for their metro system (BBC 2023b). It is not as if assets could not be purposefully designed to last significantly longer than their 25-year design lifecycle because they already do. This asset lifecycle extension approach is already systematically adopted in the nuclear and aerospace sectors long after asset depreciation.

If this is the horizon that governments and its supply chain make railway investment decisions on, then it can be argued that a current or future 'non-take–make–waste' decision making horizon does not exist. Or rather, market conditions do not exist that would incentivise government or the railway supply chain to work in a different way.

ST should be used more effectively for rail investment to target and achieve longer term desirable conditions. It is not what the railway is; it is the plurality of the desirable outcomes the railway continues to enable that is of significance. In ST terms, it is the value from the benefits of the emergence from the railway that matters.

3 | The Potential Research Gap

A potential research gap has been identified to assess whether existing CE readiness frameworks inform business strategy and consider the exploitation of ST and AM that would enable 'value beyond price' across the rail sector. Links should be made that recognise the relationship that business has with the emerging properties that assets enable (outcomes) and how the lifecycle of the asset is envisaged, evolves, exploited and managed. It is useful that the IAM recently updated its guidance to include consideration of the AM system's 'purpose and context' and the system's 'value and outcomes'.

Also, an understanding of organisational readiness is needed that considers the application of these themes in context. A readiness framework is not a tick-box exercise. It has to consider the organisation's niche in the market and the wider economy. Creating value will rely upon ST to create visibility of options, bringing in fresh ideas about how the organisation can create alternative forms of value. The CE challenge landscape is represented in Figure 2.

The application of ST and AM to enable CE outcomes is underutilised as strategic levers. This area remains largely unexplored, particularly in the context of business strategy within critical infrastructure sectors such as rail. The literature review highlights gaps in how existing CE readiness frameworks incorporate ST principles and AM strategies to develop sustainable, long-term business models.

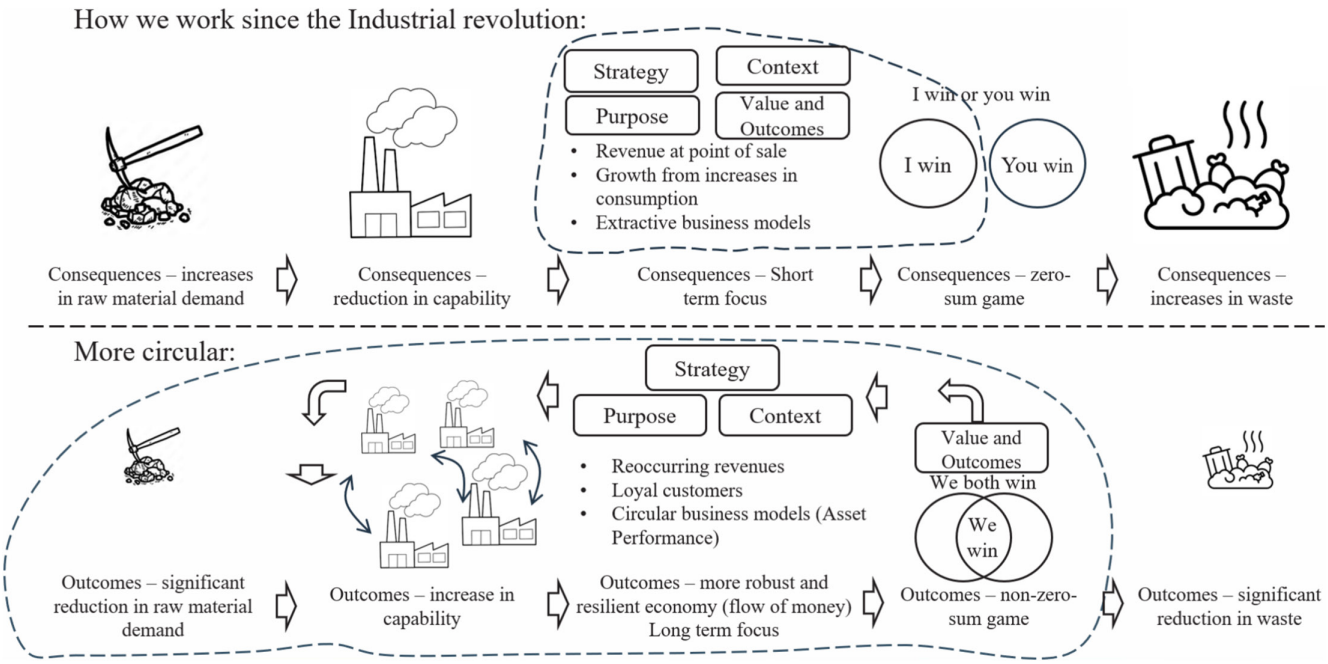

FIGURE 2 | The CE challenge landscape.

Existing CE frameworks predominantly suffer from conceptual narrowness in CE discourse focusing on material flows, recycling and waste reduction but lack an integrated approach that considers business strategy development within a ST and AM context. This absence suggests that current CE readiness frameworks may not be sufficiently robust for industries like rail, where complex interdependencies among stakeholders, assets and long-term sustainability goals must be considered. There is limited research in rail ecosystem-level value creation.

There is also a lack of meaningful metrics and visualisation tools that help us understand this level of complexity. This study addresses these gaps by focussing on the premise that the organisation's personality is a legal concept. The organisation should be aware of emerging challenges in regulation and global and economic dynamics when it develops its future strategic goals in relation to 'value beyond price' that those goals create or enable. In this context, the study looks at the development of organisation strategy to create circular outcomes. In so doing, the study looks to research the exploitation of ST to develop future strategic options. With prior knowledge and insight of the application of ST tools and techniques from the author, Critical Systems Heuristics (CSH) (Ulrich and Reynolds 2010) could be used to explore critically, assumptions, boundaries and an understanding of value. Strategic options development and analysis (SODA) (Ackerman and Eden 2020) could be used to identify potential new value streams. The Viable Systems Model (VSM) (Beer 1979, 1981, 1985) could be used to frame how business models could be adapted or developed. Soft Systems Methodology (SSM) (Checkland 1999) could be used to understand how value gets transformed. AM could be deployed more effectively to develop and extend the life of assets in relation to the value or outcome the assets enable. An understanding of complex market conditions could be interpreted through an understanding of complex systems (Ladyman et al. 2013) and in order for organisations to thrive and to create resilience in complex conditions, cooperation is required across multiple organisations. In this case, Cooperation Theory (Axelrod 1990) could be considered within the context of creating non-zero sum games between different actors and stakeholders. A line of sight can be created that enables transparency and how value gets transformed.

This study redefines organisational circularity by introducing a strategic, systems-based framework that addresses key gaps in the literature, presenting a more holistic approach to defining, measuring and implementing circular practices.

4 | Research Methodology

This research looks to analyse the published literature using a systematic literature review (SLR) adapted from (Garza-Reyes 2015). This will contribute to filling this gap and the development of a CE readiness framework. The outline of the methodology is shown in Figure 3 and described briefly in this section.

An SLR is a specific methodology that locates existing studies, selects and evaluates contributions, analysis and synthesises

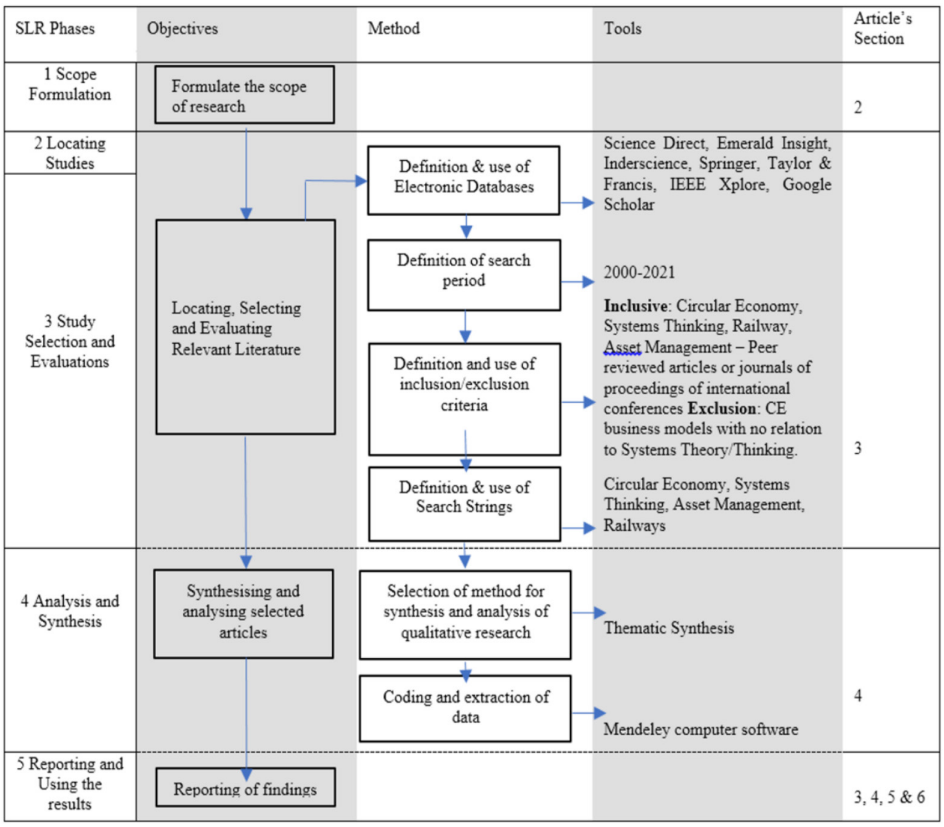

FIGURE 3 | SLR phases, objectives, methods, tools and location within the article.

data and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and is not known (Bryman and Buchanan 2009).

An SLR differs from a literature review in the traditional sense, as a systematic review is a self-contained research project that studies a clearly defined question. In contrast, an expert review (Gough 2007) is enabled by the skill, knowledge and experience of the reviewer and does not adopt a clear method; therefore, it is subject to hidden bias. The systematic review research activity sets boundaries around subject scope and explains rationale implying subject relevance and quality criteria to aid transparency of interpretation and replication.

Systematic reviews exploit evidence-based practice and whilst this practice has never sought to provide answers, the outcome of systematic reviews informs decision-making and action (Sackett et al. 1996). In particular, where there is little evidence or knowledge gaps, this signifies a research need and raises questions for future research.

The focus of this SLR is to research across three dimensions. The following framing has been used to bound the research:

- The application of ST tools and techniques to inform business strategies to have CE enabling characteristics. This would help understand interrelationships, perspectives and boundaries.
- The status of CE-related business strategies that exploit the practice of AM.
- The status of research that combines the previous dimensions and relates this to the rail sector, with rail having emergent properties with society, the environment and the economy.

In this context, the value relates to business strategy to fundamentally change the meaning and value of the transformation process. From a take–make–waste operating model that extracts value in the form of short-term profit, towards a *value creation operating model* that interprets transformation as an improvement of *asset performance*. Where profit generation is dependent upon complex and viable economic flows across multiple actors and stakeholders across the supply chain.

Economic flows is where profit is generated from the flow of money, multiple business models and complexity that is dependent upon the increase in asset performance, as opposed to profit extraction from single points of sale. The latter sells the function and burden of ownership, including responsibilities of operating and maintaining the asset, which can imply a 'zero-sum game'. Whereas the former relies upon the supply chain developing complex operating models and interdependent relationships with suppliers, enabling multiple and complex 'non-zero-sum' games (Axelrod 1990).

4.1 | Scope Formulation and Research Questions

The initial step is to start to formulate the scope of research. This has been provided in Sections 1 and 2 and refined further in this section. As part of the SLR process, it is important to structure the line of enquiry around specific research questions:

RQ1: *Do circular economy frameworks inform the development of business strategies to project the value that the organisation creates beyond price (outcomes), especially within a circular economy context?*

RQ2: *Is AM relied upon to support those outcomes?*

RQ3: *Is systems thinking applied to develop how value is transformed across multiple actors and stakeholders to influence those business strategies, business operating models and resulting outcomes?*

The intention is to investigate the application and evidence of specific subject matter in general, catalogue the evidence of occurrence, then assimilate this across into the rail sector if it does not already exist.

4.2 | Locating the Studies and Research Base

This research carried out a comprehensive literature review of CE frameworks, development of business strategy, exploitation of ST, AM and rail. The product of that research is synthesised and characterised to understand strengths and weaknesses and contribute to the proposed framework outlined later.

The database selection relied upon a database aggregator Scopus (www.scopus.com), Web of Science (www.webofscience.com) EBSCO (www.ebso.com), IEEE Xplore (ieeexplore.iee.org/Xplore/home.jsp), ScienceDirect (www.sciencedirect.com) and Taylor & Francis (www.tandfonline.com). Google Scholar (scholar.google.co.uk) and websites of organisations working/promoting CE (e.g., www.ellenmacarthurfoundation.org; www.theiam.org; www.bsonline.org) These organisations are considered prominent sources of CE and AM guidance.

The research search criteria is summarised in Table 1. Additional refinement criteria included "Circular Economy" + "Strategic Options Development and Analysis", "Circular Economy" + "Soft Systems Methodology", "Circular Economy" + "Critical Systems Intervention", "Circular Economy" + "Complexity Science". Where these techniques are applied to more advanced problem structuring/solving around ST. The thought process being is that if ST plays such an important part in the CE, then the application of it would already be researched and discussed at great length.

The research period is initiated from the occurrence of the term 'circular economy' and is chosen to start from 2000 which includes earlier terms used for similar circular activities such as 'Cradle to Cradle' (Braungart and McDonough 2008). The screening process yielded 333 studies. Further screening of the title and abstract reduced the number of studies to 142. A further full text screening returned 38 studies.

This study distinguishes the difference between the term 'framework' and 'model'. Frameworks are structures that support concepts and ideas and can be used in two ways for example

TABLE 1 | SLR phases applied in the paper.

Phase 1	Research questions
Question formulation	RQ1: Do circular economy frameworks inform the development of business strategies to project the value that the organisation creates beyond price (outcomes), especially within a circular economy context? RQ2: Is asset management relied upon to support those outcomes? RQ3: Is systems thinking applied to develop how value is transformed across multiple actors and stakeholders to influence those business strategies, business operating models and resulting outcomes?
Phases 2 & 3 *Locating, Selecting and Evaluating Articles*	**Literature Databases** Key aggregator (e.g., Scopus) and publisher (e.g., Elsevier) databases (peer reviewed only) **Search Period** 2000 to 2024—includes earlier terms used for similar circular activities such as 'Cradle to Cradle' (Braungart and McDonough 2008) **Inclusion criteria** Studies that integrate the circular economy, systems thinking and asset management in business strategy, particularly in the rail sector. **Exclusion criteria** Non-English papers, studies focussing solely on material recycling without strategic implications and articles lacking empirical or theoretical contributions. **Search Strings** "Circular Economy" + "Business Strategy" – 126 "Circular Economy" + "Asset Management" – 51 "Circular Economy" + "Systems Thinking" – 153 not including additional related key words "Circular Economy" + "Readiness Framework" – 3
Phase 4	**Methods for analysis** Descriptive analysis and thematic synthesis
Phase 5	**Reporting of findings**
Reporting	Findings reported in descriptive and analytic (thematic synthesis components)

determinant and evaluative (Nilsen 2015). Frameworks support the defining of principles and inform strategy, policy and governance whereas models, unless explicitly stated assume that strategy, policy and governance is already established. Models are sometimes an oversimplification of complex situations. Both the term frameworks and models can be used interchangeably to influence better outcomes. Hence, models are only useful in context. Frameworks are useful because they validate whether models are effective or not. The term 'framework' or 'model' is included as part of the analysis and filtered using specific ST search criteria.

It is recognised that Systems Dynamics (SD) (Forrester 1968) (Meadows and Wright 2009) is a ST practice. SD was considered in a specific context because SD does not necessarily consider the complexity of the external environment in which systems exist. There are other ST tools and techniques that can help to define what the potential problem landscape is or what the systems boundaries that need to be defined are (Luhmann 1995). In other words, SD on a singular basis is not necessarily considered a problem structuring methodology (PSM). Neither can it be used for reframing an understanding of the purpose of the system or system boundary. SD can be used on the assumption that all relevant issues, constraints and goals that constitute the problem are defined in advance and are uncontroversial. Whereas PSMs assume that there is no single uncontested representation of what constitutes the problem (Rosenhead 1996). Using the wrong ST tools or rather thinking that one size fits all can have unintended consequences (Anastas 2019).

This specific scope is bounded and includes key subject matter and the need to understand evidence of interdependencies or a 'line of sight' between them and within a rail context. A systematic review process is applied to make sure the review is reproducible, focussed and transparent with high levels of reliability and reduces the risk of the introduction of bias (Briner and Denyer 2012).

5 | Comprehensive Literature Review

5.1 | The CE

Quantifying research with organisations setting their strategy and policies to become more circular in the future is bounded by the terms "circular economy" + "strategy" + "business strategy", which returned 126 publications. This is from a top–down perspective. This search criteria should evidence research related to an organisation's 'circular economic line of sight' or its *niche* linked to corporate purpose and market context. Extending the search criteria to include the term 'systems thinking' only returned two publications both of which were authored by the authors of this paper. The same two papers were the only papers to

include the additional search term 'readiness framework'. This suggests a potential research gap where ST does not appear to be deployed in the development of business strategy to create CE outcomes and there does not appear to be research that considers business strategy in relation to CE readiness.

A further analysis of the 126 publications was carried out to include the additional term 'business model', which returned 27 publications. This provided a focus in relation to research to create a model or 'system way of working' but does not necessarily rely upon ST to develop those models. The term 'sustainable development goals' (SDGs), which returned nine publications, was also used to consider the application of business models to relate to external sustainability measures. The following observations were made within the scope of this research.

Korhonen et al. (2018) discuss the concept of the CE and its limitations. It is suggested as a concept that CE is immature but relevant and identifies six themes or boundaries (limits) that need to be researched further to make CE more effective. The paper recognises and is perhaps critical of earlier and current thinking about proposed circular economic solutions being primarily focussed on material flows and adopts a more scientific approach. Similar observations are made by Skene (2018) but Korhonen's paper draws upon and amalgamates several existing research themes to present an enhanced way to think about the value of the CE. These would be important boundaries that business strategies must navigate, which the proposed framework addresses through the application of ST.

Nosratabadi et al. (2019) have carried out an analysis on the use of the term sustainable business models. For example, publications about business operating models towards ways an organisation may work if the business strategy was to work in a more sustainable way. This research catalogued the subject boundary from which the application of the business models was derived. The work may be a useful classification exercise but does not classify to whether the sustainable business model types are effective or not. The proposed framework views the organisation's value proposition and operating model as unique. Its interpretation of value depends not only on the value beyond price (positive impact on outcomes) but also on the value proposition's viability in the medium and long term.

On a more useful and pragmatic level, van Loon (2022) describes the experience that an organisation went through over a seven-year period to develop a business strategy that specifically attempts to develop and incorporate a circular economic business model. Observations are made about the inadequacy of applied academic research in real-world situations to validate hypotheses, as well as the adequacy of business advice from consultants about how to generate revenue and profits from adopting CE practices. The work engages with the Servitisation of white goods, where ultimately a balanced view is required of both the opportunities and challenges (Baines et al. 2017). The idea of an organisation to just move from selling goods to leasing them will not work. A simple search combining the terms "circular economy" + "Servitisation" returned 98 publications. If the search was extended to include 'systems thinking', the return was zero. This, perhaps, suggests that the application of ST in relation to the exploitation of Servitisation business models is underdeveloped. The application of CSH, SODA, VSM and SSM could have been used to simulate what the strategic viable value propositions are prior to making significant investment decisions. Non-zero-sum games (Axelrod 1990) and collaboration theory could be used to develop complex supply networks that provide the opportunity to reduce costs, increase performance to strengthen supply chain resilience.

The stakeholder theory work in part by Kayikci et al. (2022) is useful as the work presents how wider strategic value could be perceived through stakeholder theory. The work attempts to prioritise or normalise SDGs with generic stakeholder values. In contrast, the framework proposed in this paper considers the relationship between the organisation and stakeholder values to be unique, and the value of that relationship is defined and embedded in business strategy. The proposed framework takes the view that business strategy should first generate context-specific impacts and outcomes, which may be interpreted at local, regional or broader levels. These measures can then be linked to the broader emergent properties reflected in *external* frameworks such as SDGs.

Of particular interest, mainly for reasons described previously, is the work carried out to analyse the application of SD (Jonsdottir et al. 2024) in relation to the development of sustainable business models, including CE business models. The work uses a six-stage process PSALSAR (protocol, search, appraisal, synthesis, analysis and reporting) approach. The research returned some 467 papers that referred to SD, which included search terms such as 'causal loop'. The research is a source to understand the application of SD to create business models, some of which are also intended to relate to the CE. Whether the application of SD to create these models is effective or not is another matter. The work goes so far as to describe nine strategies in terms of how SD has been applied. The work shows an increase in the application of SD against the development of sustainable business models.

Whilst SD has its place, if it is continually used out of context and in isolation of relying upon other ST techniques there will be the failure to reframe possibilities when (not if) the horizon changes. Worryingly, this will have a detrimental impact on the viability of business models and the principles of the CE in the future. This observation has already been made when relying upon SD as an approach to product design and business model strategies for the CE, where SD's limitations are discussed in context (Franco 2019). Yet Jonsdottir's work (Jonsdottir et al. 2024) is one of the most cited papers that covers SD and CE and business models.

It is for this reason that the framework presented in this paper purposefully elicits multifaceted end-to-end challenges that organisations need to address if they want to work in a more circular economic way. You would need to rely upon multi-methodological ST techniques to solve those challenges.

5.2 | ST in Business Strategy

ST is a cornerstone of the CE. Yet, a basic search of the term 'systems thinking' appears in less than 0.5% of publications that include the term 'circular economy' suggesting several things.

Firstly, the link between ST and the CE is significantly underdeveloped. Secondly, the other 99.5% of publications that mention CE are discussing other things other than ST.

ST uses models as artefacts to communicate and share concepts and ideas to define system boundaries. A further search including 'circular economy' and 'business model' represents just under 3.5% of the research base, returning 1319 publications.

To understand the application of specific ST tools and techniques a search was carried out, which included "circular economy" + the respective ST technique for example including "strategic options development and analysis" (SODA), "viable systems modelling" (VSM), "soft systems methodology" (SSM), "cooperation theory", which resulted in a total of five publications. The search was broadened to include "circular economy" + "systems thinking" + "business model", which returned 14 publications. The following observations were made within the scope of this research.

Pigosso's CE self-assessment tool (Pigosso and McAloone 2021) implies degrees of readiness related to the number of circular characteristics an organisation adopts. This includes a 30-question set across eight dimensions around behavioural characteristics of CE. As the paper points out, the framework is limited because it is not qualitative. The tool would not be able to determine the value of adopting such practices. The framework proposed in this paper qualifies and measures value from multiple perspectives: from the organisation creating the value, the multiple beneficiaries in receipt of it and the regulatory perspective encouraging CE behaviour.

'Circulytics' launched in 2020 by The Ellen MacArthur Foundation (EMF 2020) similarly measured characteristics of circular economic activity. The framework is now discontinued because the measures are seen to integrate into key non-financial disclosure initiatives. For example, to meet the requirements of the EU's Waste Framework Directive n.d. Corporate Sustainability Reporting Directive (CSRD). Although reporting should be seen as not taking action.

Both frameworks have similar constraints. Circulytics refers to AM but does not make the link that AM could be an enabler for circular economic value. In some respects, both frameworks take a deconstructionist view that if the details of a system are understood, then those components can be replicated. This view is not always relevant, particularly in relation to developing business strategy, as it is differentiators from competition that are sought, not similarities. There is also the risk of the assumption that one size fits all. Viewing the CE through a single lens can marginalises more effective, locally adaptable approaches. This paper proposes a flexible framework for comparing the outcomes of diverse business strategies and the industrial ecosystems they operate within. It does not necessarily follow that the more CE characteristics an organisation has, makes that organisation CE more effective. The scope of CE characteristics should align with business strategy, goals and outcomes.

Organisations cannot become 'CE compliant'. They can instead apply CE concepts more effectively than others and offer or produce greater value in relation to sustainable and regenerative outcomes they are linked to. Organisations can provide degrees of CE activity or become obsolete. Therefore, it is the output or impact of the CE system that matters at a point in time that is an effective measure, and what the planned system's impact is now and in the future. Not so much what that system comprises. The trajectory the organisation chooses to become more circular is unique.

The application of complex and adaptive systems (CAS) is touched on but with limited depth (Roci et al. 2022). The paper applies relevant ST to the CE in relation to actors and stakeholder relationships. This is particularly relevant as it describes the dynamics of complex and different relationships that need to be formed to realise value from CE activity across and between value chains and networks.

Coincidentally, the search for VSM returned papers about the CE that deployed Value Stream Mapping (VSM_2). VSM_2 can be used in conjunction with SSM, for example, to capture and articulate value among actors and stakeholders, organisation identity and so on. The papers that described the use of VSM_2 did not deploy SSM.

5.3 | CE in AM

Asset life extension is already common practice within AM. It is carried out to delay capital costs of asset replacement or the asset is going to have another purpose. Assets are redesigned mid-life or upgraded to extend asset life further or improve performance. This accommodates additional asset capability as functional requirements change. We understand the performance of assets more so as new measurement technologies are invented, helping us to create new types of asset interventions.

These types of practices are not readily considered as contributing to the CE from an AM context but should be. Stahel (2010) has written extensively about the CE or 'performance economy'. This relates to better management of physical assets and life extension. Additional factors that come from this effort include embedded carbon (Stahel 2008). Other types of activities that support CE include a 'product–service–systems' approach, which clearly has a higher burden on understanding and hence the strategic demand on asset performance (Stahel 1997, 2010).

A search on the term "circular economy" + "asset management" returned 51 publications. The following observations have been made from the research base within the context of the scope of this research.

Lejardi et al. (2021) overlook the practice of AM altogether and proposes 10 protocols associated with extending the useful lifetime of obsolete assets. This includes a number of activities, all of which could easily come under the AM umbrella around asset lifecycle management. For example, '*modernisation*' is essentially looking at the possibility of upgrading existing assets in the broadest context. These practices could be seen as tactical changes to the business operating model. For example, '*Remanufacture*' is not a strategy in itself. You would have to develop a business strategy that would develop a business model, part of which would rely upon remanufacturing capability. The

field of AM has clearly been marginalised, where this paper embeds AM as a strategic imperative.

Research on CE and AM is limited, although it is not lost with Ness and Xing (2017) that AM plays a pivotal role with the CE and discusses this relationship with the built environment. The research work carries out a useful horizon scan of the principles and approaches put forward by various proponents of the CE. Categories are proposed with particular emphasis on the benefits and shortcomings of each principle. This is one of the few papers that applies SSM to articulate how value is bounded and transitioned across stakeholders. The research identifies multiple perspectives, each of which can be seen as platforms for further research and the genesis of new types of businesses.

Acerbi et al. (2020) discuss the link between AM and the CE and links the two subjects through circular values of slowing (extending), narrowing (reducing) and closing (recirculating) resource loops (Bocken et al. 2019). As previously covered by Ness and Xing (2017), this is linked to moving towards a service economy (Stahel 2007) and the shift required in 'economic thinking', which focusses on the management of stock (asset) management. Importantly, AM, a service economy and the CE are recognised as areas for further research but need to be joined up. It is also pointed out that there are opportunities to influence growth in industrialisation from the redesign and remanufacture stage of an asset life. This paper builds on these observations where business strategy must articulate value beyond price, changing the customers perception of value from multiple perspectives.

The linking between AM and the CE and the built environment is explored further and a framework is proposed by Ness (2019) that takes a more holistic approach. Although it is not clear if the framework relies upon ST for its application. It is recognised that there is a need for 'integrated systems thinking', which draws upon ST practices such as critical systems intervention (CSI), which looks to bring together divergent views in a problem situation.

There is already a foundation of research work around systems behaviour and the built environment (Grimm et al. 2008). This has been extended further as a UN representation of urban metabolism. Ness (2019) recognises that the principles outlined in this work directly aligns with MIPS (Schmidt-Bleek 1994) and 'Strategic Asset Management', which aims to improve service delivery by more efficient and effective use of assets and resources (ISO 2024a). In this context, there is significant convergence where different research from different sources all strive for the same outcomes. Ness identifies with AM terms such as 'Asset Management Plan' (AMP), 'Total Asset Management' (TAM) and 'Strategic Asset Management' (SAM). Where TAM or SAM may be used to challenge the build mentality culture within which other related approaches may be located.

Rather than simplify and segment definitions, it may be more pragmatic to differentiate between business strategies that have extractive (value-destructing) or non-extractive (value-creating) AM systems and to what extent business strategy does this or does not. It is the application of ST that provides the lines of sight that would enable you to compare one business strategy against another or to identify one or more actors that care more or less than others across a network.

As much as Ness's work includes references to SSM and Critical Systems Thinking (CST) (Jackson 2020), where CST describes a catalogue of ST tools and techniques, the application of a broad range of ST tools in Ness's work in relation to AM is not applied.

Hanski and Valkokari (2020) discuss the impact of the CE on the principles and different perspectives around AM lifecycles in production systems and the exploitation of data. This work is relevant as it discusses several challenges about organisations adopting different types of operating models. For example, principles around 'product as a service', which aims to retain product ownership and incentivise asset utilisation. This can include 'sharing platforms' (Stahel 1997; McMillan 2019) where the asset utilisation may be shared by several parties. There is the view made about the categorisation of operating model types such as 'renewability' categories. The work identifies similar observations to Korhonen et al. (2018) that the emphasis around CE solutions in general is around material flows. Hanski and Valkokari (2020) identify threats to CE around complexity in the supply chain, management of new value elements (that had not been considered before) and the exploitation of data. Observations are made around the conventional linear approach to lifecycle management and asset lifecycles as well as the conventional linear thinking that is being applied to CE solutions.

Amaitik et al. (2022) discuss cost modelling with the optimum selection of life extension strategies that rely upon the RECLAIM n.d. framework, an EU-funded project that intends to demonstrate strategies and technologies that enable the reuse of industrial equipment. This cost modelling may be useful when making decisions about multiple asset lifecycle extension strategies if an organisation choses to change its business model, but this would have to be driven by business strategy.

Korse et al. (2016) suggest the need for a universal CE measuring framework for capital assets. Whilst this may provide some insight as to how to measure ranges of CE characteristics, it is pointed out that a range of core principles needs to be defined upon which measurements can be made. The research does not cover the management of the lifecycle of the asset itself or the business model the organisation adopts. The idea of a universal measure may be impractical to apply and unintentionally encourage undesirable behaviour. This paper introduces a universal framework for assessing and developing contextual differences in CE outcomes within complex environments. It is grounded in core principles linking business strategy and the exploitation of AM and ST. Undesirable behaviour is prevented by upholding a series of market conditions that encourage diverse circular outcomes.

Okorie et al. (2023) take a resource-based view to leverage competitive advantage from digital technologies. The principles are based around *know-what* and *know-how* within the organisation. The work reasserts the importance of skills-based capability to best effect. A VIRO value (V), rarity (R), imitability (I) and organisation (O) approach (Barney 1991, 2001) are used to consider manufacturing, CE, digital transformation and net zero tangible and intangible dimensions. Although the research

does not cover AM, the exploitation of it would fit well with AM, as well as the exploitation of technology to leverage individual organisations and supply chain networks to achieve net zero.

5.4 | CE, AM, Rail and ST

Research that covers combined "circular economy" + "railway" + "asset management" + "systems thinking" did not return any publications. The search criteria were broadened to only include "circular economy" + "railway", which returned 50 publications. These publications fell into a number of categories, including recycling or repurposing waste from railway construction projects and rail being deployed as an alternative transport mode as part of that recycling or repurposing activity. The return included rail as a strategic and integrated transport mode as part of a city's metabolism, the latter being more relevant to research in this paper. The following observations have been made from the research base within the context of the scope of this research.

Lee et al. (2016) discuss the city as having a metabolism and refers to the ebbs and flows of different resources and activities that happen in and around cities. This includes understanding the impact of different transport modes. The work looks at how resources interrelate and flow at local, regional national and international levels via different transport systems and across the three social, economic and environmental dimensions. This is relevant because it aspires to gain an understanding around strategic decision making around integrated transport systems and their impact on cities. This research for example could provide insight into strategic decision making around 'value beyond price'.

The work also points to the iBuild programme (Robertson 2014), which accommodates emerging changes in economic theory around infrastructure investment and to bring in more qualitative and quantitative future dimensions that are not usually priced from conventional means. This aligns with the requirement for defining 'contextualised future desirable outcomes' and value streams that the research work in this paper has already identified the need for. Lee's research (Lee et al. 2016) omits the exploitation of AM and ST as an enabler to achieve this.

Other work includes the repurposing of railway buildings Cardoso de Matos and Lourencetti (2021) in the 'spirit of the CE', which looks to exploit the cultural values and architectural heritage of design. Another 'value beyond price' factor. de Bortoli et al. (2020) discuss the concept of reusable asset lifecycle inventories for CE purposes for high speed rail. There is a clear demand upon asset performance data over the asset lifecycle, the value of which would increase if for example assets were designed to have multiple lifecycles or lifecycle cost analysis incorporated future asset life extensions.

O'Leary et al. (2024) discusses possible implementation strategies and barriers around CE implementation across the rail sector and identifies resistance to change based upon the historic linear approach in how assets are managed now. The work has produced insight and classification of different barriers and enablers around CE adoption within the rail sector. The key to removing these barriers requires a multifaceted approach that can include government intervention, paradigm shifts in operating models and focussing on value optimisation and life extension. This relates to deploying the discipline of AM more effectively. Important observations are made to the meaning of the value of the assets. Whereby buildings get demolished because of changing land value and market forces and not because they have come to the end of their design life (Cheshire 2019; Rose and Stegemann 2018). This suggests that the approach in determining value optimisation (Pomponi and Moncaster2017) finds that The Circular Economy Standard (ISO 2024c) value optimisation principle and product life extension business model within the context of buildings, ignores the principles around 'value beyond price'. Whereas the application of it could more effectively be applied to different types of assets to enable wider and longer term social, economic and environmental outcomes.

As much as O'Leary et al. (2024) work identifies the call to use ST in the built environment, further research on those references do not describe what ST is or how it can be applied, it is just needed and relied upon. From a ST perspective, just because the value has not been observed or quantified, does not mean value does not exist. The question remains 'from who's perspective?'

5.5 | Rationalisation of Existing Readiness Frameworks

The idea of 'readiness' as defined in this research is tied to business strategy. This is in relation to how much the organisation cares about its future. The organisation needs to develop measures to determine if its business strategy is effective within a qualitative and quantitative context. Yet an advanced search on the term "circular economy" + "readiness" returns a result that is just over 0.5% (234 records) of the entire 'circular economy' publication research base. Readiness is as simple as keeping options open.

The return was filtered further by adding the term 'asset management', which resulted in three publications, one of which was produced by the author Waring (2022). The research horizon was reduced further to incorporate "circular economy" + "readiness" + "systems thinking", which returned just one additional paper (Waring 2021). Both of these papers are earlier or foundation research papers around the subject matter covered in this paper. The research horizon was widened and limited to both terms "circular economy" + "readiness" + "framework", which resulted in a return of 68 publications. In the main, the return focussed on a broad range of activities, including frameworks for recycling. These were excluded for reasons already explained. The following observations have been made within the context of the scope of this research.

Thorley et al. (2021) looks at organisational aspects that would encourage or prevent organisations considering the CE or parts of it as a business strategy. This is relevant to the field, although the approach may be more aligned to determine as to whether an organisation is 'receptive to adopting circular economic practices'. As opposed to the research in this paper which attempts to determine if an organisation is aware of or cares about an emerging CE and how ready the organisation it is for it.

Moraga (2019) observes the emergence of the CE and the broad range of measures, meanings and interpretations of different forms of circular economic value. The work proposes a classification framework according to reasoning. The classification identifies measures that incorporate as well as do not incorporate 'lifecycle thinking' (LCT). In this context, we can appreciate LCT being dependent upon the discipline of AM with the deployment of ST. These terms are not discussed, albeit there is an observation around the lack of measures that consider the 'function' of the product within the context of (refuse, rethink, reduce), which would be the product of deploying ST.

The classification framework is useful to interpret some degree of effectiveness of CE scope and impact. One important observation made is that most of the indicators developed by the European Union account for the management of the relationship of material with society and the environment without the consideration of the application of AM LCT. It is important to note that the same application of management should apply also to those assets that already exist as well as those that are to be created in the future.

Okorie et al. (2018) identifies the shortfall in available data around products for the potential to exploit remanufacturing to extend asset life. This is not surprising because original equipment manufacturers discharge their liabilities and knowledge of the product at a point of sale and expiration of the warranty period because they adopt perhaps a take–make–waste operating model. The work draws upon the business model potential for remanufacturing for goods being sold for a lower price and higher profit margin.

The search returned a broad range of measures or characteristics which may contribute in some way to CE activity but only in part. For example, only looking at a particular element or process without consideration of what impact that a change may have on the wider whole. In summary, existing CE frameworks just provide lists of CE characteristics.

One key observation, irrespective that the EMF Circulytics framework is effective or not, is that the framework has been discontinued because its measures have been adapted and are seen to integrate to meet the requirements of the EU's CSRD. In addition to that, the indicators developed by the EU veer towards the accounting for the management of materials without the consideration of the value that can be gained from the application of AM. With the prevalence of the application of SD around the CE and the directives placing an emphasis on the management of materials then there is the risk that all CE will become is a 'systems engineering configuration management system for materials'. Which misses the relationship assets have on society and the environment.

5.6 | Analysis and Synthesis

If the CE and the practice of ST are interdependent, then what do people think ST is? ST comprises many tools and techniques, yet only two appeared in the research, which included Soft Systems Methodology and Systems Dynamics. Similarly, if AM is associated with the lifecycle of assets and their performance, there is a similar, less than 0.2% return of the total publications that include the term "circular economy" + "asset management". This includes Ness' (Ness and Xing, 2017; Ness, 2019) work, which references AM, the built environment, and a limited application of ST practices. The conclusion is the deployment of ST in relation to AM and the future CE is significantly underdeveloped and presents an opportunity for further research.

Due to the lack of literature that connects business strategy, AM and CE principles in sector-specific contexts (e.g., rail) research on CE interventions tends to be downstream (e.g., after manufacture) rather than upstream (e.g., operate non take-make-waste operating models). Upstream interventions, changes in business models and leveraging value beyond price are where the biggest CE and longer-term impacts can be made.

AM is largely overlooked in CE research despite its potential to optimise resource use, extend asset life and support value creation beyond price. A notable blind spot exists within environmental research and consultancy where the strategic value of AM is often unrecognised even though it could contribute meaningfully to the same sustainability goals. Environmental governance appears to work towards compliance where an effective business strategy and the practice of exploiting AM within a strategic context can be seen as a means to exceed it.

The dominance of SD in CE research limits the methodological scope for ST/CE research around viable, context-sensitive solutions. If this continues, it ignores the means to deal with the complexities of political and participatory engagement and systemic change, which are essential for designing inclusive and feasible interventions.

Given the definition of readiness as described in this paper and its value in relation to developing business strategy and management systems that incorporate circular economic value, the findings can be summarised by the following high-level groups:

Group 1: General descriptions of types of circular economic interventions. These describe CE characteristics that an organisation may think about accommodating. With exception to this paper and Ness' (Ness and Xing, 2017; Ness, 2019) work, they are not frameworks that relate to AM and deployment of ST.

Group 2: Operating models. CE activity expressed in model form at various levels of complexity. This includes describing characteristics of hypothetical or existing organisation CE behaviour in isolation of the external environment. Many rely upon SD-like behaviour, being technically and theoretically efficient, for example, from a materiality perspective, but there is no evidence of the model being viable within a business context. For example, placing efficiency (optimisation) over effectiveness (ability to sustain).

Group 3: Specific CE interventions. Relate to 'non-circular economic' organisations and applied as an afterthought or mainly focusing on dealing with waste from the linear lifecycle.

It appears there are plenty of sources and advice on ways to think about how problems could be resolved at multiple scales

in isolation. There appears to be a limited application of ST tools to understand how those solutions connect with others and little evidence of anyone adopting an uptake on anything that would make a difference. The suggestion is that most research is not sufficiently complex or does not have the requisite complexity to address what happens in reality and what is needed to kickstart broader circular economic behaviour.

5.7 | Justification and Requirements for a New CE Readiness Framework

Based upon the outcome of the research, Table 2 describes the identified gaps and proposes requirements to address those gaps for a new CE readiness framework.

6 | The Proposed Readiness Framework

The proposed CE Readiness Framework is structured around four pillars.

1. Strategic Alignment: Ensuring that CE initiatives align with organisational goals and business models. This can be represented as the 'value beyond price' or 'niche' that the organisation's strategy and goals enable.
2. Systems Integration: Leveraging ST methodologies (e.g., CSH, SODA, VSM, SSM) to model interdependencies within and across organisational networks.
3. Asset Lifecycle Value Optimisation: Embedding CE principles into AM to extend asset utility and minimise waste.
4. Stakeholder Collaboration: Encouraging multi-sectoral engagement to create enabling platforms and non-zero-sum business models that promote circular economic value.

The proposition in this paper is that CE behaviour should start at a business strategy level, enabling circular economic competition. The proposed framework reinforces how the organisation is applying ST and AM in order to create visibility of the value that organisations are creating both internally and externally to the business.

The framework proposed in this paper is to help organisations develop or audit and assure their business strategies that are aligned with corporate purpose, exploiting ST, enabling value beyond price through the deployment of AM practices. The framework is intended to stop inhibiting the creative use of ST tools and techniques and therefore specifically calls upon a number of key ST tools that would draw upon others to then be applied.

The framework amalgamates elements of research around AM, cradle-to-cradle (Braungart et al. 2007; Braungart and McDonough 2008). EMAF, the concept of industrial ecology (Jelinski et al. 1992; Frosch and Gallopoulos 1989) and industrial ecosystems (Korhonen 2001), sight of 'High Gain' and 'Low Gain' (Tainter et al. 2003) in relation to the dynamics of business operating models. It also considers strategic, tactical and operational control levers (Roda and Machi 2018) and non-zero sum games (Axelrod 1990). These elements are integrated relying upon multi-methodological ST tools and techniques:

- Critical Systems Heuristics (CSH) (Ulrich and Reynolds 2010) to explore critically, assumptions, boundaries and an understanding of value.
- Strategic options development and analysis (SODA) (Ackerman and Eden 2020) to explore possible strategic routes in creating value at multiple scales.
- The Viable Systems Model (VSM) (Beer 1979, 1981, 1985) to frame the viability of possible ways of working or business operating models.
- Soft Systems Methodology (SSM) (Checkland 1999) to explore and map the transfer and meaning of value across different actors and stakeholders.
- AM (ISO 2024a, 2024b, 2018) to apply at various levels of complexity to support those business models.
- Complexity (Ladyman et al. 2013) in relation to understanding or creating conditions of complex environments, to envision complex market conditions that need creating or working in relation to the corporate 'niche'.
- Cooperation Theory (Axelrod 1990) as a means to develop and validate emergent properties that sit across systems boundaries that show how value gets created 'beyond price'.

The framework creates and exploits conditions for complexity. For example, from a corporate and regulatory perspective to validate the viability of those industrial ecosystems. Whilst at the same time not only being profitable but also tackling

TABLE 2 | Circular economy framework justification and requirements.

Identified gap	How the proposed framework addresses the gaps (requirements)
Conceptual narrowness in circular economy discourse	Emphasis on philosophical and strategic shift for organisations to embrace circularity, '*purpose beyond profit*', combined with ST to expand opportunity horizon.
Lack of ST integration in the CE and limited ecosystem level value creation.	Uses ST methodologies to inform business strategies that would support circular outcomes/CE strategies/value beyond price
Absence of AM in CE models	Embeds ST/AM principles into CE decision-making
No decision-support for CE transition and value transformation or value comparison	Provides a structured model for CE readiness assessment and comparison

boundaries, for example, as described by (Korhonen 2001), Social Value Act, Six Capitals or SDGs or any form of emerging external compliance.

The proposed framework is shown at an outline level in Figure 4, supported by the underpinning rationale.

The framework considers the business and its relationship to an emerging future CE compared to how the business works in the economy now. It uses similar terminology to that used by the IAM and ISO 55000 series standards. The framework is split into three perspectives. The left perspective represents the business environment, directly controlled by the business. The middle perspective is the external environment of the business or 'the market'. The market is a unique interpretation by the organisation and its market 'niche'. The right perspective is the market conditions that enable circular economic activity to thrive.

The business environment is split horizontally into two and adopts the principles of CSH and SODA across the internal and external business environment at scale to bound the organisation's niche, designing strategy and to validate and support decision making to change and adapt the organisation and the external environment. VSM is used to frame the verification of the strategy and decision making.

'Strategy and Planning' of the business (top–down) is separated from the 'Operational' activities of the business (bottom up) by a dotted boundary with necessary feedback loops. VSM is repeatedly applied at scale in two 'modes'. Design mode is used to design a viable system and 'analytical mode' is used to identify failings or opportunities in existing systems. The framework is used to create, discover or monitor evidence of circular economic activity both in the business strategic and operational context.

SODA and VSM are applied within a scalable or nesting context throughout and can be applied to one organisation or several organisations as part of a logical grouping that works within and across sectors or multiple sectors and across geographic regions.

Strategy and planning (top–down) the solid boundary/top part of the framework comprises:

1. (Corporate) Purpose—identifies the purpose of the organisation within a CE context and is directly linked to the value and outcomes that the organisation has with what the assets enable. SSM could be used to develop corporate purpose and meaning of value.
2. (Market) Context—An explanation of the organisation's niche that works across multiple sectors and markets to support resilience. This is the organisation's own awareness of its external boundary it works in. Boundaries of market context can be interpreted through using CSI.
3. (Business) Strategy and Planning is the future CE standpoint the organisation wants to position its niche in. This is outcomes based, 'value beyond price', what the assets enable. Railways enable considerable societal and environmental benefits where new measured need to be formed.
4. (Market) Conditions—is the 'circular economic conditions' the organisation wants to create and respond to in relation to the organisation's niche. These are shown on the right hand side perspective. The organisation may be working towards a service model that generates reoccurring revenues instead of revenue from single points of sale. Conditions for complexity (Ladyman et al. 2013) can be drawn upon as well as the creating of non-zero-sum (win–win) partnerships (Axelrod 1990).
5. Value and Outcomes—is corporate personality, identity that reinforces the value of corporate purpose enabled through business strategy. In simple terms, who and what created the desirable outcomes and the positive impact on society and the environment compared to the alternative.

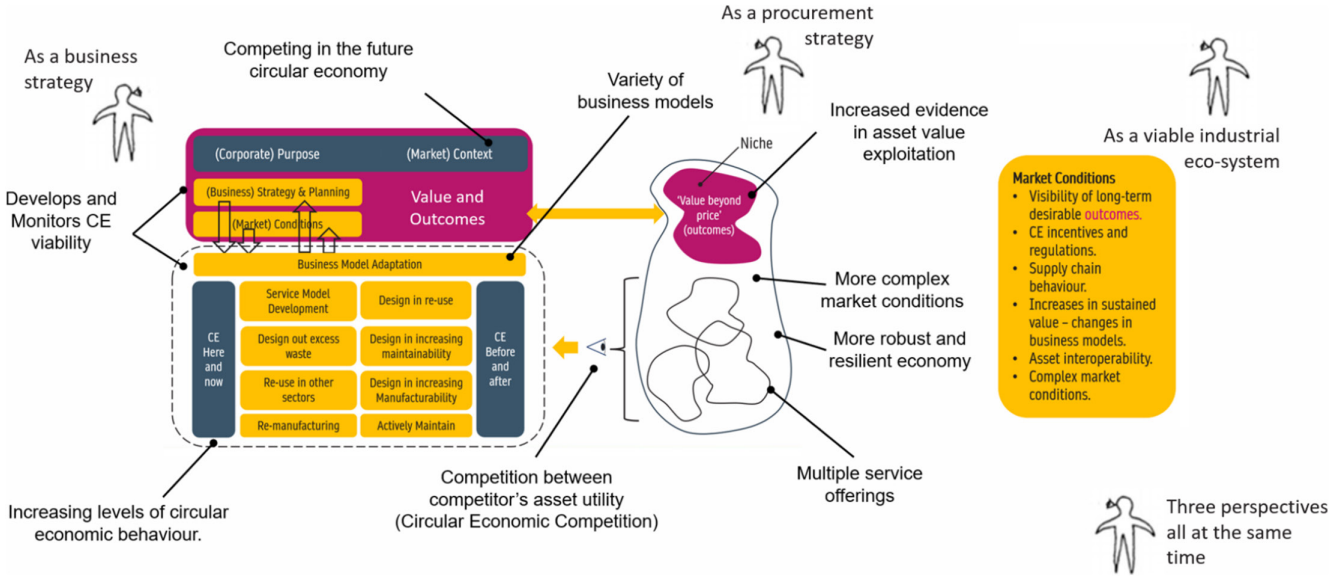

FIGURE 4 | Proposed CE Readiness Framework (top–down and bottom up including CE impact assessment).

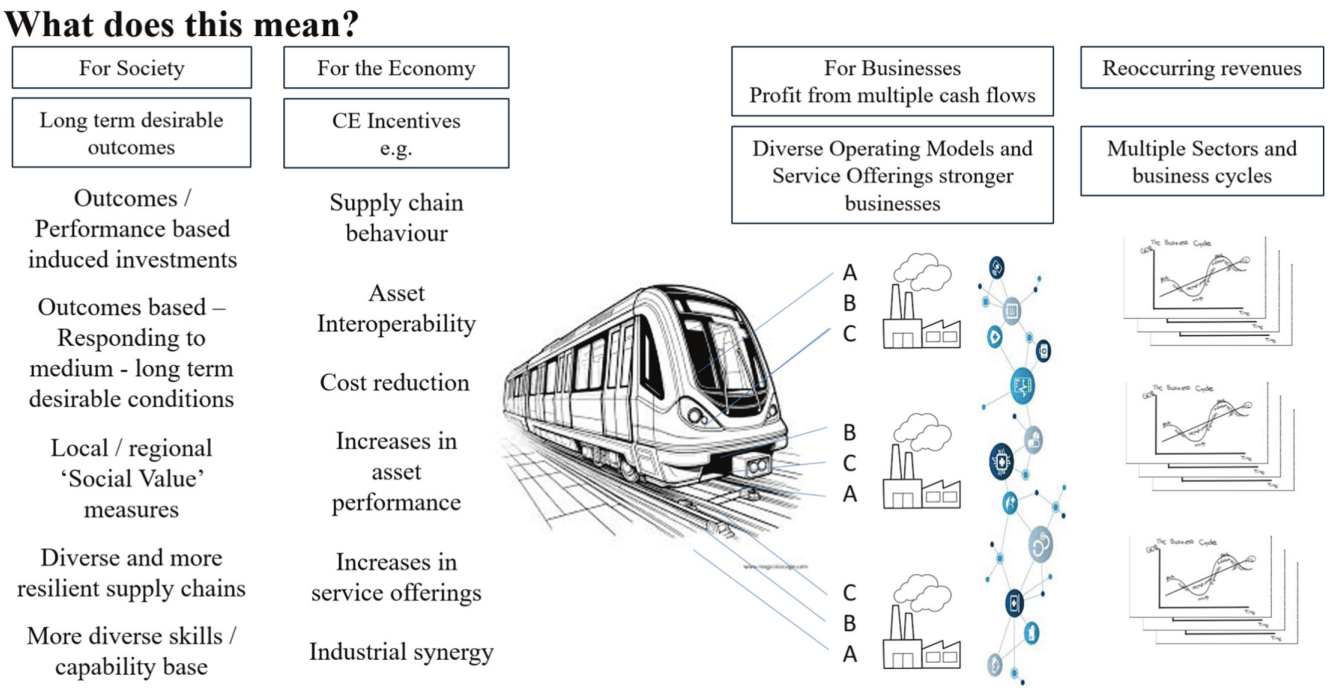

FIGURE 5 | Enabling asset management to achieve circular economic outcomes.

Operational activities (bottom–up) are shown within the dotted area of the framework. This is 'the machine' that creates the CE value:

6. Business Model Adaptation—evidence of business model adaptation that moves away from a take-make-waste operating model through whatever means.
7. CE here and now—refers to the organisation having the intelligence and being cognisant of the condition of the current assets. This is 'asset in-life activity' from any perspective seeking to extend existing asset life and utility.
8. CE Before and After—exploits the output from the 'CE Here and now' as input to future business strategies, asset designs influenced by the tactical activities within the operational boundary. This can also be an 'asset in-life activity' but also apply to future designs of new assets. These are tactical changes.
9. Tactical Changes, these are not comprehensive; the business will define its own:
   a. Service Model Development—seeks evidence of circular economy-oriented business models.
   b. Design out excess waste—evidence of the reduction in unnecessary waste as part of existing and future asset designs.
   c. Re-use in other sectors—evidence of planned multiple asset lifecycles.
   d. Re-manufacturing—evidence that assets are designed for remanufacture.
   e. Design in re-use—evidence that the asset design accommodates features and functions for re-use.
   f. Evidence of long-term maintainability—for example, design where asset obsolescence is minimised and asset interoperability is enabled.
   g. Evidence of reducing the complexity associated with manufacture.
   h. Evidence of increasing levels of asset intelligence to inform business model variations.

The middle part of the framework relates to complexity in the CE marketplace. These relate to the conditions that need to exist in the market for CE activity to thrive (the right hand perspective). For example, with the support of industry-based interoperability standards, procurement strategies could purchase and purposefully select from multiple suppliers knowing that subsystems are interchangeable. The need to have many companies that do different things, work in different ways and work across different markets is a condition of complexity, supporting the resilience of the economy itself and where emergent properties occur.

The application of the framework would in principle provide the resulting industrial and circular economic dynamics shown in Figure 5.

7 | Conclusion

This research was unable to identify frameworks that covered the development of business strategy, AM, the CE and rail specifically. Current research significantly underestimates the complexity of how economies work from a business perspective and how and what needs to happen across economies to change the value of value within a ST and AM context.

The literature reviewed offers a large range of guidance on resolving problems at various scales, but these approaches are often considered in isolation. There is limited use of ST tools to explore how such solutions interrelate and little evidence of

widespread adoption that leads to meaningful change. This suggests that much of the research lacks the necessary complexity to reflect real-world conditions or to stimulate broader circular economic behaviour.

Despite the interconnected nature of manufacturing, industry and the built environment, current research lacks integrated strategic frameworks that support sector-specific transitions. AM, in particular, remains largely absent from the discourse, even though it offers substantial potential to optimise resource use and support long-term value creation, especially in terms of outcomes that go beyond price.

The dominance of systems dynamics (SD) as a proxy for all ST tools narrows the methodological scope of CE research. This limits the ability to design viable, context-sensitive circular solutions. To support future business models capable of navigating complex market horizons, ST must be developed and applied more extensively across both CE and AM domains.

A range of ST methodologies such as CSH, SODA, SSM, VSM and Systems Intervention (SI) offer valuable tools for addressing complex, politically sensitive and multistakeholder problems. These methods enable organisations to visualise interconnected issues, explore perceptions and design feasible operating models. VSM in particular can be used to test and validate changes in business models that aim to deliver circular value, whilst SI provides pluralistic rationale for combining ST approaches to challenges and redefining systems boundaries. SD models can be quantitative or qualitative depending on the objective of their use, *providing there are viable and alternative ways* in which value gets created, which could be visualised using CSH, SODA and SSM.

The theoretical contribution of this research suggests that ST tools and techniques are not currently applied at sufficient levels of complexity in CE studies. Furthermore, it proposes that the discipline and practice of AM could be strategically deployed to support circular transitions using advanced ST methods. This would enable organisations to develop business strategies that demonstrate their contribution to outcomes and values beyond price. Importantly, the CE should be recognised not as a discrete model but as an emergent systemic property, one that arises from the application of ST rather than being a component of it.

The framework proposed in this paper offers a novel decision support tool for complex transitions. It places the enterprise at the centre of value creation, showing how organisations can enable outcomes by applying ST and leveraging AM to move beyond the consumptionist paradigm that dominates current economic models.

The paper outlines a range of desirable outcomes that railways can enable and demonstrates how the framework could help the rail sector visualise the creation and transfer of value within a future CE context. The framework provides a backdrop for regulators to make decisions about incentivising certain types of market behaviour. It enables operators to align asset investment decisions with CE goals, improving long-term performance, reducing waste, reducing cost and extending asset life.

The framework supports actors and stakeholders to better understand and communicate how their decisions contribute to broader societal and environmental outcomes beyond traditional financial metrics. In addition, when ST is applied, it enables actors and stakeholders to anticipate systems-wide impacts and interdependencies, improving their ability to adapt to disruptions and future policy shifts.

The limitations of the study include the constraints of the research methodology and a limited number of publications returned when searching for specific combined search criteria. However, to support this, the search criteria were widened against each subject.

This research and the proposed framework have opened up a number of opportunities for further research. Sector-specific CE research remains underdeveloped, particularly in industries such as rail, where asset lifecycles and the complexity of the infrastructure require tailored approaches. The concept of value within CE is still poorly defined and operationalised. This limits its strategic utility across organisations. There is a lack of readiness assessment tools, which further constrain organisational capacity to plan and monitor circular transitions effectively. CE research has yet to fully engage with participatory and political dimensions of systemic change, which are fundamental when designing context-sensitive interventions. Finally, the role of the enterprise is under-theorised pointing to the need for deeper exploration into how organisations can actively shape CE outcomes through strategic decision making, ST and AM.

A methodology has been developed to present the framework across organisations alongside a scalable measuring framework based upon the Italian flag model. This enables the visualisation and comparison of circular economic impacts presented from both individual and collective business strategies. The next stage of this work will be to carry out a Delphi study. The IAM and the Rail Sector will be used as a platform to validate the framework with the view to create IAM/CE guidance. Preparatory work has already been carried out under the Circular Economy Network+ in Transportation Systems (CENTS) programme (grant number EP/S036237/1).

Conflicts of Interest

The authors declare no conflicts of interest.

References

Acerbi, F., A. Polenghi, I. Roda, M. Macchi, and M. Taisch. 2020. "Exploring synergies between circular economy and asset management. In Advances in Production Management Systems." In *Towards Smart and Digital Manufacturing: IFIP WG 5.7 International Conference, APMS 2020, Novi Sad, Serbia, August 30–September 3, 2020, Proceedings, Part II*, 695–702. Springer International Publishing.

Ackerman, F., and C. Eden. 2020. Strategic Options Development and Analysis. https://doi.org/10.1007/978-1-4471-7472-1_4.

Amaitik, N., M. Zhang, Z. Wang, et al. 2022. "Cost Modelling to Support Optimum Selection of Life Extension Strategy for Industrial Equipment in Smart Manufacturing." *Circular Economy and Sustainability* 2, no. 4: 1425–1444.

Anastas, P. T. 2019. "Beyond Reductionist Thinking in Chemistry for Sustainability." *Trends in Chemistry* 1, no. 2: 145–148.

Ashby, R. 1956. *An Introduction to Cybernetics*. Chapman & Hall Ltd.

Axelrod, R. 1990. *The evolution of cooperation*. Penguin.

Azzouz, L., and A. Jack. 2020. "Benchmarking the Sustainability Reporting of High-Speed Railways (HSRs): Towards a State-of-the-Art Benchmarking and Reporting Framework for HSRs." *Journal of Cleaner Production* 250: 119505.

Baines, T., A. Ziaee Bigdeli, O. F. Bustinza, V. G. Shi, J. Baldwin, and K. Ridgway. 2017. "Servitization: Revisiting the State-of-the-Art and Research Priorities." *International Journal of Operations & Production Management* 37, no. 2: 256–278.

Barney, J. 1991. "Firm Resources and Sustained Competitive Advantage." *Journal of Management* 17, no. 1: 99–120.

Barney, J. B. 2001. "Resource-Based Theories of Competitive Advantage: A Ten-Year Retrospective on the Resource-Based View." *Journal of Management* 27, no. 6: 643–650. https://doi.org/10.1016/S0149-2063(01)00115-5.

BBC (British Broadcasting Company). 2023a. "Retired Trains Set for New Life Abroad." https://www.bbc.co.uk/news/articles/c2x8xj8mz3mo.

BBC. 2023b. "British Broadcasting Company." In *HS2: Decision to axe North high speed rail 'so wrong'*. Andy Burnham says. https://www.bbc.co.uk/news/uk-england-manchester-67006424.

Beer, S. 1979. *Heart of the Enterprise*. John Wiley & Sons.

Beer, S. 1981. *Brain of the Firm*. second ed. John Wiley & Sons.

Beer, S. 1985. *Diagnosing the System for Organizations*. John Wiley and Sons.

Beer, S. 1995. *Designing Freedom (The CBC Massey Lectures)*. House of Anansi Press.

Blomsma, F., and G. Brennan. 2017. "The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity." *Journal of Industrial Ecology* 21, no. 3: 603–614. https://doi.org/10.1111/jiec.12603.

Bocken, N., L. Strupeit, K. Whalen, and J. Nußholz. 2019. "A Review and Evaluation of Circular Business Model Innovation Tools." *Sustainability* 11, no. 8: 2210.

Braungart, M., and W. McDonough. 2008. *Cradle to cradle: remaking the way we make things*. Jonathan Cape.

Braungart, M., W. McDonough, and A. Bollinger. 2007. "Cradle-to-Cradle Design: Creating Healthy Emissions—A Strategy for Eco-Effective Product and System Design." *Journal of Cleaner Production* 15, no. 13: 1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003.

Briner, R. B., and D. Denyer. 2012. "Systematic Review and Evidence Synthesis as a Practice and Scholarship Tool." In *Systematic review and evidence synthesis as a practice and scholarship tool*. Oxford University Press.

Bryman, A., and D. Buchanan. 2009. *The Sage handbook of organizational research methods*. SAGE Publications Ltd.

Cardoso de Matos, A., and F. D. L. Lourencetti. 2021. Reusing railway infrastructures in the spirit of circular theory. A contribution to an operational concept.

Checkland, P. 1999. *Soft systems methodology: a 30-year retrospective; Systems thinking, systems practice*. John Wiley.

Cheshire, D. 2019. *Building revolutions: Applying the circular economy to the built environment*. RIBA publishing.

de Bortoli, A., L. Bouhaya, and A. Feraille. 2020. "A Life Cycle Model for High-Speed Rail Infrastructure: Environmental Inventories and Assessment of the Tours-Bordeaux Railway in France." *International Journal of Life Cycle Assessment* 25: 814–830.

DfT. 2016. Department of Transport. Rail Freight Strategy. Moving Britain Ahead. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/552492/rail-freight-strategy.pdf.

DfT 2022. Department for Transport. Transport Statistics Great Britain: 2022 Freight https://www.gov.uk/government/statistics/transport-statistics-great-britain-2023/transport-statistics-great-britain-2022-freight.

Eccles, R. A. T. 2023. *The Evolving Role of Chief Sustainability Officers*. Harvard Business Review.

Economist. 2009. Corporate Social Responsibility. https://www.economist.com/news/2009/09/09/corporate-social-responsibility.

Economist. 2022. *Growth Cure*. ESG Investing: A Broken System Needs Urgent Repairs. https://www.economist.com/special-report/2022/07/21/a-broken-system-needs-urgent-repairs.

Economist 2023. *Scientists Have Published an Atlas of the Brain*. Economist (London). Economist Intelligence Unit N.A. Incorporated.

El-Akruti, K., R. Dwight, and T. Zhang. 2013. "The Strategic Role of Engineering Asset Management." *International Journal of Production Economics* 146, no. 1: 227–239.

EMF. 2020. *Ellen MacArthur Foundation*. Circulytics. https://ellenmacarthurfoundation.org/resources/circulytics/overview.

Forrester, J. W. 1968. "Industrial Dynamics—After the First Decade." *Management Science* 14, no. 7: 398–415. https://doi.org/10.1287/mnsc.14.7.398.

Franco, M. A. 2019. "A System Dynamics Approach to Product Design and Business Model Strategies for the Circular Economy." *Journal of Cleaner Production* 241: 118327. https://doi.org/10.1016/j.jclepro.2019.118327.

Frosch, R. A., and N. E. Gallopoulos. 1989. "Strategies for Manufacturing." *Scientific American* 261, no. Number 3: 144–153. https://doi.org/10.1038/scientificamerican0989-144.

Garza-Reyes, J. A. 2015. "Lean and Green—A Systematic Review of the State of the Art Literature." *Journal of Cleaner Production* 102: 18–29.

Garza-Reyes, J. A., A. S. Valls, S. P. Nadeem, A. Anosike, and V. Kumar. 2018. "A Circularity Measurement Toolkit for Manufacturing SMEs." *International Journal of Production Research* 57: 7319–7343.

GBRTT. 2023. *Great British Rail Transition Team*. Rail Freight Growth Target. https://gbrtt.co.uk/wp-content/uploads/2023/12/Rail-Freight-Growth-Target-summary-report-v4.7.pdf.

Geissdoerfer, M., P. Savaget, N. M. P. Bocken, and E. J. Hultink. 2017. "The Circular Economy—A New Sustainability Paradigm?" *Journal of Cleaner Production* 143: 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048.

GFMAM. 2014a. "Global Forum on Maintenance and Asset Management." In *The Asset Management Landscape*, 3rd ed. GFMAM.

GFMAM. 2014b. "Competency Specification for an ISO 55001 Asset Management System Auditor/Assessor."

Gough, D. 2007. "Weight of Evidence: A Framework for the Appraisal of the Quality and Relevance of Evidence." *Research Papers in Education* 22, no. 2: 213–228. https://doi.org/10.1080/02671520701296189.

Gov.UK. 2020. "Guidance Carbon Calculator." https://www.gov.uk/guidance/carbon-calculator.

Green Book Review. 2020. *Green Book Review Findings and response*. HM Treasury. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/937700/Green_Book_Review_final_report_241120v2.pdf.

Grimm, N. B., S. H. Faeth, N. E. Golubiewski, et al. 2008. "Global Change and the Ecology of Cities." *Science* 319, no. 5864: 756–760.

Hall D. 2021 Water and sewerage company finances 2021: dividends and investment. [Working Paper] (Unpublished) https://gala.gre.ac.uk/id/eprint/34274/.

Hanski, J., and P. Valkokari. 2020. "Impact of circular economy on asset management–lifecycle management perspective. In Engineering Assets and Public Infrastructures in the Age of Digitalization." In *Proceedings of the 13th World Congress on Engineering Asset Management*, 156–163. Springer International Publishing.

Hopwood, B., M. Mellor, and G. O'Brien. 2005. "Sustainable Development: Mapping Different Approaches." *Sustainable Development* Bradford, West Yorkshire, England 13, no. 1: 38–52. https://doi.org/10.1002/sd.244.

IFRS. 2024. *International Financial Reporting Standards Foundation*. Get to Grips with the Six Capitals. https://integratedreporting.ifrs.org/what-the-tool-for-better-reporting/get-to-grips-with-the-six-capitals/.

ISO. 2018. *55002:2018. Asset Management – Management systems – Guidelines for the application of ISO 55001*. ISO.

ISO (International Organization for Standardization). 2024a. *55000:2024 Asset Management – Vocabulary, overview and principles*. ISO.

ISO. 2024b. *55001:2024. Asset Management – Management systems – requirements*. ISO.

ISO. 2024c. *59004:2024. Circular economy - Vocabulary, principles and guidance for implementation*. ISO.

Jackson, M. C. 2020. "Critical Systems Practice 1: Explore—Starting a Multimethodological Intervention." *Systems Research and Behavioral Science* 37, no. 5: 839–858.

Jelinski, L. W., T. E. Graedel, R. A. Laudise, D. W. McCall, and C. K. N. Patel. 1992. "Industrial Ecology: Concepts and Approaches." *Proceedings of the National Academy of Sciences of the United States of America* 89, no. 3: 793–797. https://doi.org/10.1073/pnas.89.3.793.

Johnson, N. 2009. *Simply Complexity: A Clear Guide to Complexity Theory*. Simon and Schuster.

Jonsdottir, A. T., L. Johannsdottir, and B. Davidsdottir. 2024. "Systematic Literature Review on System Dynamic Modeling of Sustainable Business Model Strategies." *Cleaner Environmental Systems* 13: 100200.

Kayikci, Y., Y. Kazancoglu, N. Gozacan-Chase, and C. Lafci. 2022. "Analyzing the Drivers of Smart Sustainable Circular Supply Chain for Sustainable Development Goals Through Stakeholder Theory." *Business Strategy and the Environment* 31, no. 7: 3335–3353.

King, D. 2013. *It's time to ban the empty word 'sustainability'*. Conversation. https://theconversation.com/its-time-to-ban-the-empty-word-sustainability-17612#:~:text=It%20has%20become%20so%20corrupted,beyond%20the%20present%20sustainability%20indicators.

Korhonen, J. 2001. "Four Ecosystem Principles for an Industrial Ecosystem." *Journal of Cleaner Production* 9, no. 3: 253–259. https://doi.org/10.1016/S0959-6526(00)00058-5.

Korhonen, J., A. Honkasalo, and J. Seppälä. 2018. "Circular Economy: The Concept and Its Limitations." *Ecological Economics* 143: 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041.

Korse, M., R. J. Ruitenburg, M. E. Toxopeus, and A. J. J. Braaksma. 2016. "Embedding the Circular Economy in Investment Decision-Making for Capital Assets—A Business Case Framework." *Procedia CIRP* 48: 425–430.

Ladyman, J., J. Lambert, and K. Wiesner. 2013. "What is a Complex System?" *European Journal for Philosophy of Science* 3, no. 1: 33–67. https://doi.org/10.1007/s13194-012-0056-8.

Lee, S. E., A. D. Quinn, and C. D. Rogers. 2016. "Advancing City Sustainability via its Systems of Flows: The Urban Metabolism of Birmingham and its Hinterland." *Sustainability* 8, no. 3: 220.

Lejardi, E. S., M. Franke, Q. Deng, and R. M. Rial. 2021. "Circularity Protocols for Extending the Useful Lifetime of Obsolete Large Industrial Equipment and Assets." In *In 2021 26th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, 1–8. IEEE.

Lockhart, D. 2023. "Mark Carney: *Value(s)—Building a Better World for All* Public Affairs, Hatchett Book Group, 2021." *Business Economics (Cleveland, Ohio)* 58, no. 1: 61–62. https://doi.org/10.1057/s11369-022-00271-6.

Luhmann, N. 1995. "The Paradoxy of Observing Systems." *Cultural Critique* 31, no. 31: 37–55. https://doi.org/10.2307/1354444.

Mazzucato, M., and C. C. R. Penna, eds. 2015. *Mission-oriented finance for innovation: new ideas for investment-led growth*. Policy Network.

McMillan, S. E. 2019. "Closing the Loop: The European Union & the Circular Economy." *SciTech Lawyer* 15, no. 4: 4–8.

Mead, M. 1968. "The Cybernetics of Cybernetics." In *Purposive Systems*, edited by H. von Foerster, J. D. White, L. J. Peterson, and J. K. Russell, 1–11. New York: Spartan Books.

Meadows, D. H., and D. Wright. 2009. *Thinking in systems: a primer*. Earthscan.

Moodley, K. (2014) Is ISO 55000:2014 The New Dawn in Asset Management. *Infrastructure Asset Management*, 1(2), 21–22. 10.1680/iasma.14.00019 Paper 1400019. ICE Publishing.

Moraga, G., S. Huysveld, F. Mathieux, et al. 2019. "Circular Economy Indicators: What do They Measure?" *Resources, Conservation and Recycling* 146: 452–461. https://doi.org/10.1016/j.resconrec.2019.03.045.

National Archives 1993. UK Public General Acts. Clean Air Act https://www.legislation.gov.uk/ukpga/1993/11/contents.

Ness, D. A. 2019. *The impact of overbuilding on people and the planet*. Cambridge Scholars Publishing.

Ness, D. A., and K. Xing. 2017. "Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model." *Journal of Industrial Ecology* 21, no. 3: 572–592.

Nilsen, P. 2015. "Making Sense of Implementation Theories, Models and Frameworks." *Implementation Science: IS* 10, no. 1: 53–53. https://doi.org/10.1186/s13012-015-0242-0.

Nosratabadi, S., A. Mosavi, S. Shamshirband, E. K. Zavadskas, A. Rakotonirainy, and K. W. Chau. 2019. "Sustainable Business Models: A Review." *Sustainability* 11, no. 6: 1663.

Okorie, O., J. Russell, R. Cherrington, O. Fisher, and F. Charnley. 2023. "Digital Transformation and the Circular Economy: Creating a Competitive Advantage From the Transition Towards Net Zero Manufacturing." *Resources, Conservation and Recycling* 189: 106756.

Okorie, O., K. Salonitis, F. Charnley, and C. Turner. 2018. "A Systems Dynamics Enabled Real-Time Efficiency for Fuel Cell Data-Driven Remanufacturing." *Journal Of Manufacturing And Materials Processing* 2, no. 4: 77.

O'Leary, M. J., M. Osmani, and C. Goodier. 2024. "Circular Economy Implementation Strategies, Barriers and Enablers for UK Rail Infrastructure Projects." *Resources, Conservation & Recycling Advances* 21: 200195.

ORR. 2006. *Train Derailment at Hatfield. A Final Report by the Independent Investigation Board*. Office of Rail and Road. https://www.railwaysarchive.co.uk/documents/HSE_HatfieldFinal2006.pdf.

ORR. 2020. Office of Rail and Road – Rail emissions 2020–21 https://dataportal.orr.gov.uk/media/1993/rail-emissions-2020-21.pdf.

PHE. 2016. Public Health England. *Working Together to Promote Active Travel*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/523460/Working_Together_to_Promote_Active_Travel_A_briefing_for_local_authorities.pdf.

Pigosso, D. C., and T. C. McAloone. 2021. "Making the Transition to a Circular Economy Within Manufacturing Companies: The Development and Implementation of a Self-Assessment Readiness Tool." *Sustainable Production and Consumption* 28: 346–358.

Pomponi, F., and A. Moncaster. 2017. "Circular Economy for the Built Environment: A Research Framework." *Journal of Cleaner Production* 143: 710–718.

Quaker faith & practice Fifth Edition 1911. *The book of Christian discipline of the Yearly Meeting of the Religious Society of Friends (Quakers) in Britain* Chapter 23 >> 23.61 available at: https://qfp.quaker.org.uk/passage/23-61/.

Railway Gazette. 2012. Chiltern Railways puts refurbished MKIII coaches into service. https://www.railwaygazette.com/passenger/chiltern-railways-puts-refurbished-mk-iii-coaches-into-service/36974.article?adredir=1.

Robertson, M. 2014. iBUILD/Leeds Report

RECLAIM. n.d. "Horizon 2020 research and innovation programme under grant agreement N°869884." https://www.reclaim-project.eu/project/#about.

Roci, M., N. Salehi, S. Amir, F. M. Asif, S. Shoaib-ul-Hasan, and A. Rashid. 2022. "Multi-Method Simulation Modelling of Circular Manufacturing Systems for Enhanced Decision-Making." *MethodsX* 9: 101709.

Roda, I., and M. Macchi. 2018. "A Framework to Embed Asset Management in Production Companies." *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability* 232, no. 4: 368–378.

Rose, C. M., and J. A. Stegemann. 2018. "From Waste Management to Component Management in the Construction Industry." *Sustainability* 10, no. 1: 229.

Rosen, R. 2011. *Anticipatory systems. Anticipatory systems: Philosophical, mathematical, and methodological foundations*, 313–370. New York, NY: Springer New York.

Rosenhead, J. 1996. "What's the Problem? An Introduction to Problem Structuring Methods." *Interfaces (Providence)* 26, no. 6: 117–131. https://doi.org/10.1287/inte.26.6.117.

Ruggieri, A., A. Braccini, S. Poponi, and E. Mosconi. 2016. "A Meta-Model of Inter-Organisational Cooperation for the Transition to a Circular Economy." *Sustainability* 8, no. 11: 1153.

Sackett, D. L., W. M. C. Rosenberg, J. A. M. Gray, R. B. Haynes, and W. S. Richardson. 1996. "Evidence Based Medicine: What It Is and What It Isn't: It's About Integrating Individual Clinical Expertise and the Best External Evidence." *BMJ (Online)* 312, no. 7023: 71–72. https://doi.org/10.1136/bmj.312.7023.71.

Schlindwein, S. L., and R. Ison. 2004. "Human Knowing and Perceived Complexity: Implications for Systems Practice." *Emergence (Mahwah, N.J.)* 6, no. 3: 27.

Schmidt-Bleek, F. 1994. How to reach a sustainable economy. Wuppertal Papers, 24.

Skene, K. R. 2018. "Circles, Spirals, Pyramids and Cubes: Why the Circular Economy Cannot Work." *Sustainability Science* 13, no. 2: 479–492. https://doi.org/10.1007/s11625-017-0443-3.

Stahel, W. 2010. *The performance economy*. Springer.

Stahel, W. R. 1997. "The Service Economy:'Wealth Without Resource Consumption'?" *Philosophical Transactions of the Royal Society of London, Series A: Mathematical, Physical and Engineering Sciences* 355, no. 1728: 1309–1319.

Stahel, W. R. 2007. "Sustainable Development and Strategic Thinking." *Chinese Journal of Population, Resources and Environment* 5, no. 4: 3–19. https://doi.org/10.1080/10042857.2007.10677526.

Stahel, W. R. 2008. "Global Climate Change in the Wider Context of Sustainability." *Geneva Papers on Risk and Insurance-Issues and Practice* 33: 507–529.

Stout, L. A. 2012. *The shareholder value myth: how putting shareholders first harms investors, corporations, and the public*. 1st ed. San Francisco: Berrett-Koehler.

Tainter, J. A., T. F. H. Allen, A. Little, and T. W. Hoekstra. 2003. "Resource Transitions and Energy Gain: Contexts of Organization." *Ecology and Society* 7, no. 3: 4. https://doi.org/10.5751/ES-00574-070304.

Thorley, J., J. A. Garza-Reyes, and A. Anosike. 2021. "Circular Economy: A Conceptual Model to Measure Readiness for Manufacturing SMEs." *Benchmarking: An International Journal* 29, no. 4: 1362–1390.

UIC. 2016 International Union of Railways. GRI Indicators Handbook Guidelines for Railway Companies. https://uic.org/IMG/pdf/gri_g4_indicators_handbook_final.pdf.

UK Gov. 2021. UK Government. Global Net Zero Commitments. https://commonslibrary.parliament.uk/global-net-zero-commitments/#:~:text=The%20UK%20has%20a%20legally,focus%20on%20long%2Dterm%20goals.

Ulrich, W., and M. Reynolds. 2010. "Critical systems heuristics." In *Systems approaches to managing change: A practical guide*, edited by W. Ulrich and M. Reynolds, 243–292. London: Springer London.

UN DESA. 2023. *The Sustainable Development Goals Report 2023*. Special ed. New York, USA: UN DESA. UN DESA. https://unstats.un.org/sdgs/report/2023/.

van Loon, P., L. N. Van Wassenhove, and A. Mihelic. 2022. "Designing a Circular Business Strategy: 7 Years of Evolution at a Large Washing Machine Manufacturer." *Business Strategy and the Environment* 31, no. 3: 1030–1041.

Waring, C., and K. Liyanage. 2021. "A Framework to Develop and Evaluate Circular Economy Readiness within the Rail Sector." In *11 Annual International Conference on Industrial Engineering and Operations Management*.

Waring, C., and K. Liyanage. 2022. "A Systematic Literature Review of the Concept of Circular Economic Readiness and a Proposed Circular Economy Readiness Scale." *Advances in Manufacturing Technology* XXXV: 245–254.

Waste Framework Directive. n.d. "(2008/98/EC) of the European Parliament and of the Council of 19 November 2008 on waste." *Official Journal* L312: 3–30.

Webster, K. 2013. "What Might We Say about a Circular Economy? Some Temptations to Avoid if Possible." *World Futures* 69, no. 7–8: 542–554. https://doi.org/10.1080/02604027.2013.835977.

Wiener, N. 1948. *Cybernetics: Or Control and Communication in the Animal and the Machine*. Paris: (Hermann & Cie) & Camb. Mass. (MIT Press).

World Bank Group 2004–08. Who cares wins (English). IFC Advisory Services in Environmental and Social Sustainability issue brief Washington, D.C. http://documents.worldbank.org/curated/en/444801491483640669/Who-cares-wins-2004-08.

Younger, R., C. Mayer, and R. G. Eccles. 2020. *Enacting Purpose within the Modern Corporation*. Harvard Law School Forum on Corporate Governance.

Zayed, J., M. N. Nouvel, U. Rauwald, and O. A. Scherman. 2010. "Chemical Complexity—Supramolecular Self-Assembly of Synthetic and Biological Building Blocks in Water." *Chemical Society Reviews* 39: 2806–2816.

Zink, T., and R. Geyer. 2017. "Circular Economy Rebound." *Journal of Industrial Ecology* 21, no. 3: 593–602. https://doi.org/10.1111/jiec.12545.