Implementing circular practices in a construction clients' organisation

Strategic interventions on intra-organisational barriers for operationalising TU Delft's circular campus ambitions

Kokhuis, Karlijn; Van den Berghe, Karel; Straub, Ad

DOI
10.1108/JCRE-11-2024-0038

Publication date
2025

Document Version
Final published version

Published in
Journal of Corporate Real Estate

Citation (APA)
Kokhuis, K., Van den Berghe, K., & Straub, A. (2025). Implementing circular practices in a construction clients' organisation: Strategic interventions on intra-organisational barriers for operationalising TU Delft's circular campus ambitions. *Journal of Corporate Real Estate*, Article 38. https://doi.org/10.1108/JCRE-11-2024-0038

Journal of Corporate Real Estate

Implementing circular practices in a construction clients' organisation. Strategic interventions on intra-organisational barriers for operationalising TU Delft's circular campus ambitions

Received 12 November 2024
Revised 17 April 2025
Accepted 19 May 2025

Karlijn Kokhuis, Karel Van den Berghe and Ad Straub
Faculty of Architecture, Management in the Built Environment, Delft University of Technology, Delft, The Netherlands

Abstract

Purpose – Owing to the many involved stakeholders, major challenges in the transition to a circular construction (CC) sector have an organisational nature. This study aims to better understand how intra-organisational changes can advance the transition.

Design/methodology/approach – The Delft University of Technology's (TU Delft) circular campus ambition serves as a single case study. Construction projects are examined through desk research and interviews. Barriers to circular strategies are analysed using a framework that combines the R-Ladder for hierarchies of CC practices with organisational levels used for transition management.

Findings – Most barriers occur on the operational and tactical level, while most possible interventions are located on the tactical to strategic level. Current endeavours mostly target mid-R-Ladder strategies at the operational and tactical level. The linear accounting and project development frameworks remain significant tactical barriers within the campus real estate and facility management (CRE&FM) department. Moreover, strategic tooling such as consistent monitoring and forward dashboarding is lacking. Furthermore, CRE&FM is leading the implementation but is dependent on its parent organisation, in which measurable goals, understanding of their implications, as well as a circular financial framework, are largely missing.

Practical implications – The study provides valuable insight and practical recommendations for (semi-) public RE owners to support the CC transition from within their organisation.

Originality/value – This study advances knowledge on intra-organisational transition management and offers a new analysis framework that combines circular strategies and different management levels.

Keywords Circular construction and renovation, Real estate development management, Intra-organisational change, Semi-public construction clients, Sustainability, Campus

Paper type Research paper

1. Introduction

The circular economy (CE) has gained recognition as a potential solution to environmental, economic, and societal challenges. Despite decades of efforts, the use of at

Funding: This study is funded by the TU Delft Sustainable Campus Program.

Journal of Corporate Real Estate
Emerald Publishing Limited
1463-001X
DOI 10.1108/JCRE-11-2024-0038

least secondary instead of primary materials has been regressing from 9.1% in 2018 to 7.2% in 2023 (Fraser *et al.*, 2024). The Netherlands is not on track to reach the 2030 target of 50% circularity either (Hanemaaijer *et al.*, 2023; Hanemaaijer *et al.*, 2025). Policies and the economic framework need to shift focus from recycling to strategies that retain value higher up in the material cycle (Hanemaaijer and Kishna, 2023; Hanemaaijer *et al.*, 2025). In The Netherlands, the construction sector is found responsible for producing 35% of the CO_2 emissions and consuming 50% of the raw materials, 40% of the energy and 30% of the water (Nelissen *et al.*, 2018). While policymakers and practitioners have tried to operationalise circular construction (CC), in 2019, only 8% of construction materials were secondary, and a mere 5% from renewable sources (Arnoldussen *et al.*, 2022).

Challenges that complicate the implementation of a CE for CC are the lack of common definitions (Ossio *et al.*, 2023), different views on what a CE looks like (Calisto Friant *et al.*, 2020), the limited policy instrumentalization throughout governance levels (Bucci Ancapi, 2023) and the uncertainty related to geopolitics and on what scale one can and needs to organise the consumption and (re)manufacturing of materials (van den Berghe and Verhagen, 2021). Compared to more product-focused sectors, the uniqueness of every building, long use phase and the wide range of involved stakeholders throughout the life cycle complicate the transition (Charef *et al.*, 2021). Furthermore, this sector is relatively conservative and risk-averse (Eikelenboom and van Marrewijk, 2023; Kanters, 2020), which makes adopting innovations and necessary role changes difficult.

The list of barriers encountered in the construction sector is therefore long as scholars like (Munaro and Tavares, 2023; Wuni, 2022) show in their summary of decades of research. Currently, we do see successful exemplary projects, products and digital innovations, and the development of (inter)national regulations. The most pressing remaining barriers, therefore, concern cultural, financial and organisational aspects (Çetin *et al.*, 2021; Charef *et al.*, 2021; Hart *et al.*, 2019). Because the transition to a CC involves many actors and their respective organisations, connecting organisational sciences more to transition theory is seen as an important research field (Kooter *et al.*, 2021). In this stakeholder web, the construction client has been recognised as important (Kanters, 2020), although clients are not always aware of their pivotal role (Adams *et al.*, 2017) and are lacking knowledge or willingness to divert from established processes (Dokter *et al.*, 2021). The role of the real estate (RE) owner-developer is particularly interesting because they are overseeing and responsible for the whole life cycle of buildings. Moreover, (semi-)public clients could – in line with their public responsibilities – potentially integrate environmental values in their strategic decision making and procurement (Coenen *et al.*, 2021). A well-known course of action for RE-clients is their procurement strategy, formalising how they work with other organisations (Alhola *et al.*, 2019; Oppen and Bosch, 2020). Çetin *et al.* (2021) found that many of the obtained barriers in their study lie within their own organisation and need more study, confirming a previous research of Kirchherr *et al.* (2018). In the sometimes-paralyzing complexity of the transition as a whole, overcoming these internal barriers would be largely within the agency of this stakeholder type.

To better understand how (semi)public RE owner-developers can contribute effectively to the transition to a CC sector, the implementation of Delft University of Technology's (TU Delft) circular campus ambition serves as a single case study. To construct our analysis framework, theory on CC strategies and transition management from an organisational perspective will be discussed in the next section. To find out what

interventions in what part of the organisation could speed up the transition, drivers and barriers for implementation of circular strategies on the TU Delft campus are mapped and analysed using this framework.

2. Analysis framework

To understand what internal barriers an organisation needs to work on to implement CC practices, it is necessary to first understand what attempts have been made and why they were or were not successful. By combining two existing frameworks, the drivers and barriers will be related to different organisational levels.

2.1 Circular strategies in construction: the R-ladder

The definitions of what a CE is, and how to implement and measure it, have developed over time (Ellen Macarthur Foundation, 2019, 2023; Raworth, 2017; Stockholm Resilience Centre, 2023). These ongoing attempts are also apparent by the step-by-step adoption of circular principles and key performance indicators (KPIs) within the TU Delft campus RE and facility management (CRE&FM) department and in campus construction projects (Delft University of Technology, 2016; Geldermans *et al.*, 2022; Hacquebord, 2024; Hänsch, 2020; Sustainability Coach Campus Zuid, 2022; UN Studio, Arup and BBN, 2018; van der Vlies, 2021; van Ellen, 2020a; Veeze, 2016; EI-13; SI-F; SI-K). As a result, there is a lack of comparable quantitative data. Therefore, a more qualitative way to evaluate the circularity of campus RE-projects is needed.

Both internationally and in The Netherlands, the R-ladder framework is widely adopted to categorise CC practices and policies for narrowing, slowing and closing resource loops (Coenen *et al.*, 2022; Ossio *et al.*, 2023). The higher up the ladder, the more favourable a strategy is for keeping resources circulating and avoiding the use of virgin materials. As Reike *et al.* describe (2018), pollution and waste problematics drew early attention to the bottom R-strategies in the 1970s. With a more globally connected world, growing insight into the interconnectedness of environmental and social problems and the depletion of resources, focus shifted towards higher R-ladder strategies in the last decades. The amount of "R's" grew and became more detailed over time and varies per user from 3 to 9 (Reike *et al.*, 2018) or 14 (Çimen, 2023), which are commonly used in the construction sector. The R-strategies can be recognised in national and international standards, where they are often accompanied by actions and criteria that make these strategies executable in a later life cycle. Examples are "releasability" and "potential for re-use" in the voluntary Dutch New Normal framework for CC (Cirkelstad, 2024), or requirements for Building Information in the EU taxonomy framework (European Union, 2025). The development of these standards to steer towards the highest value retention strategies is still ongoing. This can be illustrated by a difference between the EU taxonomy framework and the Dutch New Normal. Whereas the taxonomy framework requires further specification of non-virgin origin to re-used, recycled and biobased, the Dutch New Normal gathers these groups still under one KPI, differentiating less between the R-ladder hierarchies.

To incorporate the transition to renewable bio-based materials, Çimen (2021) introduced an extra R: "Replace", which was also adopted by the Dutch governmentally funded organisation for knowledge distribution on environmental matters (Milieu Centraal, 2023) (see also Figure 1). These R-ladder steps will be used in this research to map drivers and barriers.

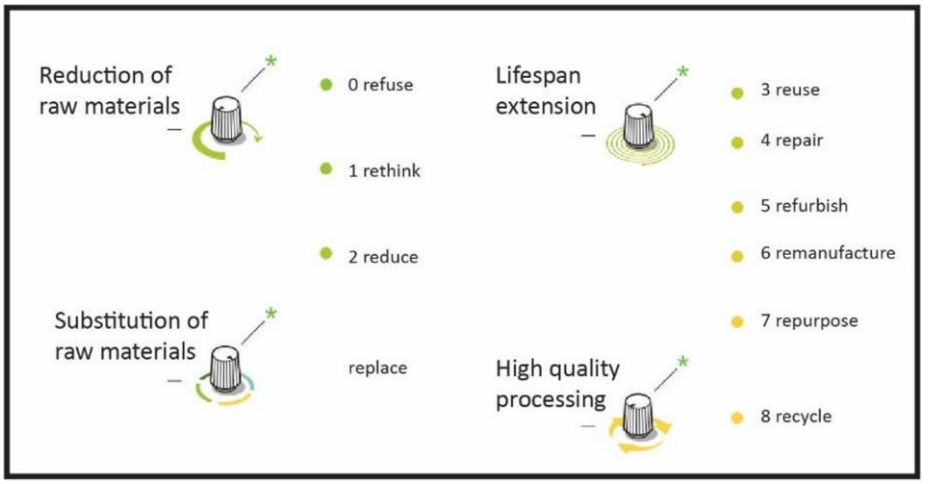

Figure 1. Strategies for narrowing, slowing and closing resource loops, regularly used in the construction sector

Source: Authors' own work, Image based on Milieu Centraal (2023), translated by the author

2.2 Governance framework for dealing with transitions as organisational lens

The multitude of strategies and how to operationalise them in the complex and risk-averse production chain implies a lot of organisational changes. Besides the growing body of research on inter-organisational construction projects, Kooter *et al.* (2021) emphasise the need for further study on intra-organisational aspects of the transition. To initiate change, organisations often use the instrument of a temporary program and related projects as a safe space next to standard business operations (Martinsuo and Hoverfält, 2018). However, the connection with their parent organisation and integration of lessons is crucial, but can be complex.

Sankaran *et al.* (2021) describe in their literature review on project management and sustainability transitions why it is so complex to really integrate sustainability. Sustainability transitions require the integration of risks and benefits of "others" outside of the organisation's traditional target groups into one's business model. Only adding sustainability as another requirement to regular projects will have a limited effect because overarching objectives, traditional processes, decision-making and lack of support will hinder implementation. The new ISO 59000 family of standards and guidelines (International Organization for Standardisation (ISO), 2024a, 2024b, 2024c) also reflects this need for structural change. Besides explaining the systemic shift in which we recognise the levels of value retention from the R-ladder, this family of standards emphasises that organisations need to change their business strategies and value models. It furthermore provides practical guidelines to adopt systems thinking, ensure equal sharing of benefits and track and manage resources.

The examples of challenges faced by construction clients in section 1 require changes on different intra-organisational levels. Transition management literature describes activities on three management levels: the strategic, tactical and operational levels (Loorbach and Wijsman, 2013). This framework (Figure 2) is often used to study and manage transitions in larger publicly governed systems but also helps to manage transitions in organisations in their transitioning context. In essence, the strategic level within businesses creates a vision that aligns with societal transition goals and provides support for fundamental changes in the organisation. Secondly, changes to

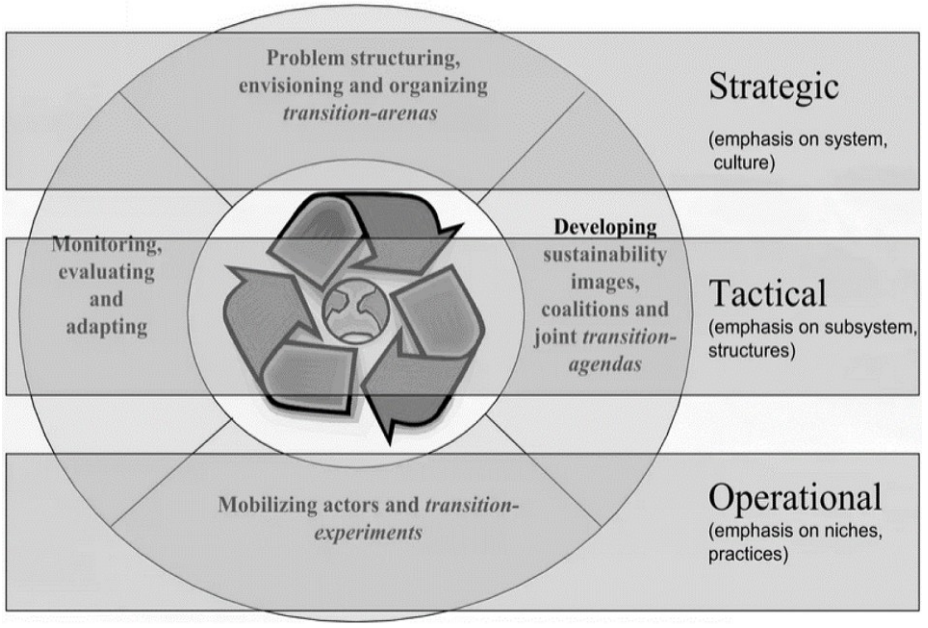

Figure 2. Governance framework for dealing with transitions, basics of transition management by DRIFT and Erasmus University Rotterdam on 11–12–2007 based on Loorbach (2007)
Source: Adapted from Loorbach, 2007, Governance framework for dealing with transitions, Drift, 11-12-2007

organisational structures, stakeholder relations, standard processes, policy and regulatory frameworks are necessary on the tactical level. On the operational level, pilots, tests and innovations take place within projects. Lessons ideally feed back into policy making on the tactic level, where changes are consolidated as the new standard. Reflexive and learning activities connect all three levels, shifting the focus beyond merely tracking KPIs that indicate whether an organisation is performing "less bad", as Loorbach and Wijsman (2013) put it. Instead, the focus should be on the extent to which the organisation aligns with strategic transition goals – both internally and within society at large.

This framework can be illustrated with some examples from CC literature. Kooter *et al.* (2021) point out that to consolidate lessons from pilot or niche projects, it is important to "bring lessons home" to the parent organisations and to structurally embed them. If this does not happen, the structural effect is limited and involved stakeholders lose their motivation. Scholars point out that going from a linear to a circular process, stakeholders on the operational level need to collaborate more, knowledge, skills and roles need to change and stakeholders need to be involved earlier or throughout more life cycle phases (Ding *et al.*, 2023; Eikelenboom *et al.*, 2024; Leising *et al.*, 2018). To standardise CC, more time and budget early on in projects need to be reserved to come to well-defined and shared circular objectives, thorough material inventories and for the acquisition of secondary materials. This different way of working together can be formalised in contracts that facilitate risk sharing and stimulate further innovation (Eikelenboom and van Marrewijk, 2023).

2.3 Analysis framework

As many drivers and barriers in the construction sector are known, this study seeks a deeper understanding by placing them in their organisational context. Drivers and barriers related to attempted circular strategies are therefore mapped against two axes: the R-ladder and the different organisational levels (see Figure 3). Structuring the analysis in this way, the discussion of where barriers occur and where interventions should take place could be better facilitated.

3. Methodology

3.1 Case study introduction

The implementation of the TU Delft circular campus ambitions is a relevant case study for multiple reasons. Firstly, The university is both the (spatial) policymaking and urban area-managing entity, as well as the client commissioning construction and renovation projects. It therefore has far-reaching control over its own portfolio and has similar characteristics to other large (semi) public portfolio owners/developers. TU Delft can be an example for and/or team up with these key stakeholders on the demand side in this transition (Adams *et al.*, 2017; Kanters, 2020) to create a critical mass for change. Second, the TU Delft sustainability plan (van den Dobbelsteen and van Gameren, 2022) states that the university wants to lead the way to a more sustainable society, not only in absolute terms but also by helping to remove barriers in society. By studying its own RE management organisation practices, the institute acknowledges it is essential to look inwards to connect sustainability transitions to

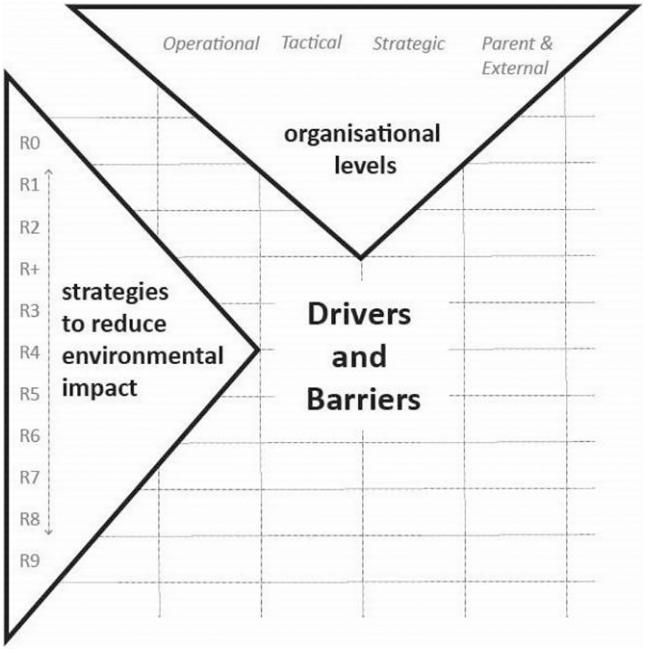

Figure 3. Analysis framework for CC practices, showing on what level R-ladder strategies are applied or attempted, and on what organisational level the related drivers and barriers occur

Source: Authors' own work

organisational change. Last but not least, there is a large TU Delft community conducting research and education on circularity in the built environment and advising on national policymaking. As such, knowledge on circularity strategies and organisational aspects of the transition is closely available and by its outreach TU Delft can influence the sector and involved actors in multiple ways nationally and internationally.

The TU Delft campus encompasses 161 hectares and hosts a population of 35,000 users. Most buildings and public spaces are owned, developed and managed by CRE&FM. The Sustainable TU Delft, Mission Vision and Action plan was launched in 2022, accompanied by a €95m financial injection within TU Delft's RE strategy. Part of that plan is to manage all campus resource and waste streams circular by 2030 (van den Dobbelsteen, 2022). For construction and renovation, the aim is to integrate CC principles in new building designs, to use material passports, and to adopt a circular approach in optimising and repurposing campus facilities. However, just as at the national level, following recent studies (Alba Concepts, 2024; Grover, 2020), it seems that there is still a large gap for building practices to reach the 2030 circularity goal.

The focus of this study is the part of the Delft campus that is owned, developed and managed by CRE&FM. Within CRE&FM, different organisational layers can be identified: the strategic in which new user wishes are assembled, the overall portfolio is managed and projects are initiated; the tactical in which the project- and policy cadres are defined; and the operational in which the projects are further developed, executed and maintained. For CRE&FM, the parent organisation of TU Delft functions as the first "external" layer where the overall visions and strategic plans are made, in which RE is facilitating the primary process of education, research and valorisation (Delft University of Technology, 2024). The legal, finance and procurement departments are working in close collaboration with CRE&FM to (re)develop the campus and to set up central monitoring and reporting. Furthermore, the eight faculties and ten services can be considered as internal clients for construction projects.

3.2 Approach

Using the TU Delft circular campus ambition as a single case study provides the opportunity to perform an in-depth analysis of multiple construction projects as well as studying the involved RE management organisation and its processes. Owing to the evolving policy frameworks and KPIs, there is no comparable quantitative data available. Therefore, to analyse the success and failures of circular strategies, a qualitative approach was chosen.

RE and spatial policy, and project documents in seven projects were examined. These seven projects form a representative selection of project types that are (re)developed, owned and maintained by TU Delft. The first three projects were fully finished and evaluated at the time of study and cover the three standard processes: for renovation, new-built and public space projects. However, due to the often long development period, these projects are not fully representative of the latest policy, technical and organisational development, nor do they cover all experiments that are relevant for advancing circular building practices. To include those developments, a less in-depth analysis of 4 projects was added, even though final results were only partially ready.

Projects following standard CRE&FM process:

- Renovation of office floors for one of the faculties (2020–2022).
- Construction project for shared study spaces and lecture halls (2015–2022).
- Public space renewal project and public space toolbox (policy) update (2018–2023).

Additional projects: ongoing or with non-standard/innovative characteristics:

- Public space redesign project, diverging from standards by extra focus on re-used materials, ecology and climate adaptation (2024).
- Generic education building (lecture halls, study spaces, facilities) in the design phase (2022–2026).
- Service building for campus waste flows in the execution phase (2024).
- Small generic education building. First leased project on campus (2023).

The review of project documentation and policy documents helped to understand the timeline, changes in project scope, the organisation and the decision-making processes. 15 Explorative interviews (30–60 min) were held using the snowball method to better prepare 20 semi-structured interviews (45–75 min, June 2023 – February 2024, see supplementary appendix B) to obtain a list of mentioned drivers and barriers and to find missing information on the projects, policy development, circular strategies and their success (see Table 1).

To label and analyse the retrieved drivers and barriers from recording transcripts (semi-structured interviews) and notes (explorative interviews), a simplified set of categories was adopted (see Table 2), based on the literature reviews of Munaro and Tavares (2023), Wuni (2022). For traceability and more detailed input for specific interventions, the drivers

Table 1. Overview of roles of interviewees for the semi-structured and explorative interviews. To improve readability of the following text, these interviews will be referred to as "SI-[letter]" for the structured interviews or "EI-[number]" for the explorative interviews

Interviews			
Semi-structured, interviewee #	Role	Explorative interviews, Participant #	Role
A, B	TU delft sustainability coach	1, 2, 15	TU delft policy developer or advisor
D,K	TU delft sustainability advisor earlier days	6	TU delft sustainability monitoring advisor
P, T	TU delft asset manager/team manager	5	TU delft developer
I	TU delft housing manager	7	TU delft manager RE maintenance
C, E	TU delft project developer	8, 11, 12, 13	TU delft asset manager
F, G, O	TU delft project manager	3, 9	TU delft financial professional
S	External project manager	10	TU delft team lead strategy and policy
L, R	External designer	14	TU delft sustainability program lead
M, N, Q	External project manager construction company	4	TU delft member employee council (focus on RE)
H	External sustainability of ficer deconstruction company		
J	TU delft officer furniture and moving-in		
20x	*Total*	*15x*	*Total*

Source(s): Authors' own work

Table 2. Overview of categories used for the categorisation of drivers and barriers, based on the literature reviews of Munaro and Tavares (2023), Wuni (2022)

Category used for analysis	Short description/examples
Culture	Entrenched ideas, customs and lifestyles, attitude of the construction industry and the stakeholders, such as risk aversion, resistance to change, lack of interest for or perceived poor quality of recycled and remanufactures products
Supply chain/collaboration/ stakeholders	Interplay between organisations, stakeholders, (changing) activities, fragmentation and integration, cohesive FL+RL network and facilities, collaboration, cooperation, communication, information and resource sharing, data transparency/confidentiality, adequate network
Knowledge and learning	Skill gaps and knowledge deficits. Technical expertise and capabilities, knowledge on circular strategies, services, materials, awareness, training
Management: leadership, vision and ambitions	Vision and ambition forming and propagation, commitment and support
Management: steering, KPIs and monitoring	Administration and coordination tasks. Standard indicators and performance assessment, decision making support, evaluations
Tender/contract	Circular procurement and strategies, barriers to successful tenders such as number of suppliers
Organisational: Policy and tools	Policy making and evaluation, tooling such as administrative, monitoring, financial or digital tooling
Organisational: Process design	Standard processes, procedures or planning
Organisational: Costs/funding, financial and accounting	Funding challenges, resources, investment constraints, financial disincentives, new business models. Short vs long term economic benefits, higher costs sustainable alternatives, uncertain returns
Technical/operational	Technical know-how or complexity, scaling difficulties, operationalising known concepts/techniques
Technological, innovation	Appropriate access to enabling technology and tools, technological readiness, proven technology, information systems, innovation capacity, digital solutions
Regulatory (external)	(external) steering mechanisms. (external) Policies, legislations, regulatory framework, national goals or targets, taxes, institutional support, enforcement
Market/Economic/Value	Demand and supply forces. Competition or market pressure, uncertain demand or supply, immature market
Observations/Other	

Source(s): Authors' own work, based on the literature reviews of Munaro and Tavares (2023), Wuni (2022)

and barriers were labelled to stakeholder and project type. The full list of mentioned drivers and barriers was stored in an Excel list, of which an example can be found in Appendix C.

4. Results

The analysis has resulted in an inventory of circular strategies and close to 500 individual, but not entirely unique mentions of drivers and barriers. These were organised by the categories from Table 2 and labelled per stakeholder type and project type (public space, new-built and renovation). This labelling allowed for a better understanding to what organisational levels these drivers and barriers were connected as some similar mentions occurred in specific and others in multiple settings. The drivers and barriers confirm the

general conclusions from the literature review, showing that this construction client and its projects are not exceptional in the transition to a CC.

For a better understanding of the context, Section 4.1 starts with the development of the campus and sustainability policy. Section 4.2 describes to what extent the circular strategies in the seven projects were successful and what related barriers and drivers were found at which organisational level. Section 4.3 shows what present or missing relations between organisational levels are found. After synthesizing and discussing the findings in Section 5.1, generic interventions relevant for all projects will be discussed in Section 5.2. Examples of attempted strategies per project can be found in Supplementary appendix A. Examples of the inventory of drivers and barriers can be found in Supplementary appendix C.

4.1 Campus and sustainability policy development

After the transfer of ownership of all properties from the state to TU Delft in 1995, CRE&FM gradually became a RE developing department instead of mainly focussing on maintenance and facility management (EI-12; Meurs *et al.*, 2018). After 1995, TU Delft started to rethink public space quality and liveability. Also housing, social and food facilities were added to offer a more attractive campus. Another remarkable change affecting the CRE&FM organisation was sharing educational facilities between faculties. This was initiated for cost optimalisation, but later also to facilitate growth (EI-12). The portfolio of shared spaces created a first campus-wide strategic asset management role as opposed to the traditional single building and internal client-centred approach. How to create the best campus environment with a mix of own space, shared space and "online space" remains subject to ongoing investigation (den Heijer, 2021). Other important changes towards a more mature RE-department in which the three organisational levels from the framework become more visible were the start of a strategic portfolio management team; standardisation of the project development process; introduction of the strategic planning cycle of subsequently the 20 year horizon campus vision, the ten year horizon campus strategy, and the 3–5 year horizon housing plans per building; more integral spatial planning; and about five years ago the introduction of total cost of ownership method (TCO) for investment decisions (EI-3; EI-10; EI-15; I-3; EI-10; EI-15).

Sustainability policy on campus evolved since 2008 (Dobbelsteen and Gameren, 2022; Geldermans *et al.*, 2022; Hänsch, 2020; Hellinga, 2014; Sustainability Coach Campus Zuid, 2022; van den Dobbelsteen; van Ellen, 2020b) under influence of national policy and societal debate. The 2018 TU Delft strategic framework called for a broader and more integral scope than the up to that point predominantly energy focused policy and announced the Sustainable Campus Program (Delft University of Technology, 2018). In the years after, circularity for RE projects was taken up on various organisational levels. The project documents of several analysed projects (Projects 1, 2, 5 and 6) and explorative research of Hopff *et al.* (2019) on the relation between campus development and the concept of circularity show how at that time both the understanding of circularity, a vision on the metalevel and concrete KPIs were missing. Furthermore, Hopff *et al.* (2019) already signal that circularity of campuses was merely an organisational issue, whereas it was predominantly approached as technical issue. Over the following years, more tangible circular ambitions and KPIs were developed through iterations of projects (as can be observed in Projects 2, 5 and 6), handbooks, policy evaluations, feasibility checks and participation in national knowledge networks. The Vision, Mission and Action plan for TU Delft (Dobbelsteen and Gameren, 2022; van den Dobbelsteen, 2022) has filled the gap of the lacking metavision and has set objectives for CRE&FM. However, some interviewees reported that the 2030 goals are open to multiple interpretations (EI-15; SI-A; SI-B; SI-S). Early 2024, the campus circularity policy is still under development. Lessons from projects 1, 2, and 6 regarding disassembly of building

elements and the need for an internal component and material marketplace will be incorporated into new policy, contracting standards and tooling in the next period. Other ongoing endeavours focus on the integration of building, renovation and maintenance planning, monitoring tools, process guidelines and cost figures for circularity in all projects.

4.2 Drivers and barriers for implementing circular strategies

The initial ambitions of the 2018 and 2022 vision documents contain an integrated and regenerative definition of circularity. Policy on the tactical level that was developed after focusses on sub-themes. Moreover, theme specific goals and KPIs are aimed at reaching neutrality or the least possible impact instead of regeneration. Conflicts between ambitions on the plot level, such as choosing between resource-intensive solar-energy production versus ecology and climate adaptive measures, show a need for integral, spatial and project overarching assessment, linking back to the overarching long term (spatial) vision of TU Delft on the strategic level.

A significant quantitative gap between current practice and ambitions is suspected based on several project evaluations (Grover, 2020; van Eesteren and Ketting, 2022; Vlasman, 2022) and a report comparing two projects on campus to a scenario in which market ready circular solutions are applied (Alba Concepts, 2024). Especially the strategies of re-use and replace (and "releasability" for future re-use) turned out to be lower than aspired. Financial, knowledge, collaboration and management challenges, and external market-related barriers were mentioned as main causes. This study's qualitative analysis revealed efforts on all R-ladder steps, although to a different extent and with a different success rate.

4.2.1 High up the R-ladder. The highest R-ladder strategies of refuse and rethink were partially incorporated in the initiation phase of projects. However, the internal clients often focused on their own primary process, without incorporating portfolio wide optimizations. These higher R-ladder strategies were not integrated on the strategic portfolio level yet, except to some extent for shared educational facilities and via a campus wide public space toolbox. The success of the upper R-ladder strategies within individual projects as well as the application of the "design for disassembly" strategy cannot be fully evaluated today, since finished projects will only face major renovations after 2030. However, due to technical and budget challenges, projects were not entirely designed for disassembly. The strategy of "replace" by biobased materials was not accounted for yet in the standard processes and guidelines. Because of limited knowledge and familiarity, higher investment costs and technical and maintenance challenges, this strategy was only implemented scarcely.

4.2.2 Mid-R ladder strategies. The largest set of barriers was found while implementing the middle R-ladder strategies. These strategies were mainly attempted on the operational level in renovation project 1. At that time, awareness about circularity and willingness to experiment was felt in society as well as in the project and policy-making department (EI-11; SI-H; SI-K; SI-M; Delft University of Technology/CRE&FM, 2023; van Uffelen, 2019). The aim was to reuse or repair elements as much as possible. The results of many attempted strategies ended up at lower levels or even on the recycling level. Internally, limited available time in the standard process posed challenges such as conducting accurate material inventories and feasibility studies, sourcing secondary products and conducting disassembly, construction or assembly tests (EI-11; SI-C; SI-H; SI-K; Stolwijk, 2022, 2023; van Eesteren and Ketting, 2022; Vlasman, 2022). Moreover, mature internal and external markets, storage space and material flow management was lacking. Legal barriers such as changed building regulations, certification and insurance issues complicated the realisation of these mid-R ladder strategies further. Successes in this R-ladder range can partially be attributed to external factors. A delay in a tender provided extra time to realise 90% recycled furniture in

Project 2 and the COVID pandemic relieved pressure on time and floor space to handle and store materials in Project 1. Insights from project 1 were major input for the current day endeavours on a tactical level to prescribe necessary steps in the process guide for sustainable projects and to set up an internal materials marketplace. The number of stakeholders involved in mid-R-ladder strategies is large and this complexity made realising strategies in this mid-range slow, complex and time-consuming. The 10-year leasing contract for project 7 showcases how different ownership models can move the incentive for the (design for) re-use of materials to the contractor. It also brings to light some conflicts between standardisation and the specific requirements of TU Delft (SI-G) that are "fixed" policies on the tactical level.

4.2.3 The bottom of the R-ladder. Most projects followed the Dutch market standards for recycling. This often means downcycling, for example by using crushed pavement and concrete as foundation for infrastructure projects. Internal re-use of public space material already takes place to a high degree (SI-T). Some small improvements were observed in the renovation project where contractors were challenged to elaborate on their waste handling strategy, waste flows were mapped and contract specifications were updated accordingly (van Eesteren and Ketting, 2022; Vlasman, 2022; SI-H). Lessons from these projects on an operational level only partially led to changes of standards on a tactical level.

4.3 Coherency between the different organisational levels

In the first projects with circular ambitions, knowledge on circularity was brought in mainly through hiring consultants. Later, tender documents show how knowledge of contractors on circularity became a more important selection criterion. Implementing these ambitions together with contractors on the operational level helped to verify and improve policy and processes on a tactical level (SI-D; SI-F; SI-K; SI-L). Well-defined upfront specifications were seen as a key driver for diverse circular strategies by interviewees (SI-F; SI-H; SI-L; SI-S). Project 3 shows how standard requirements and standard contracting determine the level of circularity of smaller projects within a framework contract. Here, faster decision-making based on standardised offers is largely cost-driven. Framework contracts did contain an ambition of shared learning on sustainability, suggesting a continuous learning cycle between the operational and the tactical level. However, the minimal collective evaluation and innovation likely impeded progress on circularity (SI-A; SI-B; SI-M; SI-M; SI-Q). The fast turnover of staff and limited quantitative monitoring were mentioned as extra barriers that complicated this feedback loop between implementation and policy development (SI-F; SI-H; SI-L; SI-S).

Necessary role changes of stakeholders were considered to some extent on a pilot-basis (EI-15; SI-B; SI-F; SI-L; SI-N; SI-S), but were not embedded in process and contracting standards yet. Contractors sometimes mentioned that they were disappointed that working with TU Delft was less innovative than expected because of risk avoidance and traditional processes. Furthermore, they mentioned that elsewhere they were participating in earlier or later project phases to collaboratively define the most circular principles upfront, to better integrate forward and backward logistics, or to stay involved in monitoring and maintenance (SI-M; SI-N; SI-S). Personal motivation and high ambitions were the main driving forces and sometimes accompanied by occasional supplementary funding or a pilot status (EI-11; SI-C; SI-H; SI-K; Stolwijk, 2022, 2023; van Eesteren and Ketting, 2022; Vlasman, 2022).

At the project level, some interviewees noted tensions between different sustainability ambitions (SI-B; SI-I; SI-T). They also feared the sum of all projects would not add up to reaching the overall campus-wide ambitions. On a positive note, the new public space toolbox optimises material use and impact. It also shows how campus-wide policy can promote choices high up the R-ladder (e.g. less pavement, less furniture, temporary or shared

space use) and stimulate the simultaneous realisation of multiple thematic ambitions in the definition phase (i.e. enhanced ecology, climate adaptation, reduction of material use).

The lack of consistent campus-wide monitoring and forward dashboarding is a closely related set of barriers, hindering informed decision making and policy evaluation at the strategic level. Learnings on KPIs and monitoring in projects helped to develop the current framework for new-built projects at the south of the campus (EI-15; SI-K). However, thorough and campus wide implementation needs further attention.

Finally, valuation, financing and accounting challenges were mentioned as a significant group of barriers. This includes not accounting for full life cycle or externalised costs and benefits (environmental and health-related value), not considering end-of-life value and treating end-of-life costs as negligible. Although ambitions to include shadow costs and decision-making based on TCO instead of investments are set on a strategic level and the level of the parent organisation, knowledge and accounting challenges arose on an operational level. Related barriers are the not yet fully adopted TCO method, unclear cost estimates for circularity in projects, limited adaptation of circular business models and warranties on refurbished elements that do not align with depreciation times.

5. Discussion

5.1 Synthesis

In Table 3, the findings are summarized, showing to what extent the different R-Ladder strategies were implemented, what management levels can influence these strategies and what main barriers for their successful implementation were found.

Most attempted circular strategies are found on the crossover of the mid R-Ladder steps and the operational and tactical organisational levels. Here, the full list of barriers is long and detailed. Most likely this has to do with the large amount of internal and external stakeholders involved. External regulatory and technical barriers are felt here the most. Stakeholders depend on national and EU-level platforms and authorities for clear guidance on regulations, financing, taxation, and reporting standards. Concurrently, they rely on market-driven solutions that are affordable, and they need reuse flows large enough to meet existing demand. These external factors are hard to influence at the operational level. Most internal barriers found here are related to process design, knowledge and skills. Noteworthy is that interviewees working on the operational and tactical levels mention “circular thinking” by decision makers and policy makers multiple times as lacking but very essential. One interviewee phrased this as “It’s about internalising the new normal instead of doing a bit better in comparison to doing badly” (SI-T).

Furthermore, the analysis shows strategies high up in the R-Ladder are hindered by barriers on the strategic level and at the level of the parent organisation. Barriers related to monitoring, informed decision-making and the accounting and financial conditions are present on all organisational levels and R-Ladder steps but are mostly influenced at the strategic level and the level of the parent organisation. Although most actions and financial means for physical projects on campus are distributed via CRE&FM, this department is dependent on the parent organisation: Faculties and service departments for a circular demand; the finance department for the overarching circular valuing, accounting and financing cadres, and the executive board for circular decision making, budgeting, and support for transforming internal processes.

Recurring drivers include the high ambitions and strong reputation, personal motivation, incidental extra budget, early circular project strategies, innovative collaborations with contractors, and well-specified agreements with contractors.

Table 3. Organising barriers along different categories of circular strategies and management levels

SUCCESSFULL?	STRATEGY	MANAGEMENT LEVEL* O	T	S	E	MAIN BARRIERS
Sometimes on project level, not really on portfolio level	*0. refuse*					RE primarily facilitates primary process of research and education and added up client driven demand is leading.
To some extent, mainly at generic facilities and public space	*1. rethink*					Circular principles embedded in new public space toolbox and process guides, but not in campus strategy.
						Project level monitoring isn't connected to forward dashboarding and strategic steering.
Mainly per project, after program and element are decided upon	*2. reduce*					Increased by TCO approach and synergy with cost reductions. Limited integration of scope 3. Mainly optimising or sobering already chosen elements.
						High and rigid external and internal standards.
Very limited, no policy or standards	*3. Replace (biobased)*					Limited knowledge on possibilities and higher upfront costs and limited possibilities to compensate in current accounting, valuing and financing system.
Partially	*design for reuse***					Limited implementation of financial & accounting tooling.
Mainly for furniture and interior finishing (via circular framework contracts or take back guarantees). Limited for other elements.	*4. reuse*					Complex internal stakeholder structure (relatively autonomous clients, disconnect between projects and maintenance management).
	5. repair					Limited operationalisation of reuse tooling (BIM, data handling, interconnecting project plannings, digital marketplace and storage/hub under way).
	6. refurbish					Limited early time and budget for inventories, buying and storing elements.
	7. re-manufacture					Relatively traditional tendering and contracting w.r.t. new roles and not always selecting frontrunners.
						Limited insight in available components on and off campus.
						Limited familiarity with circular KPIs, circular strategies and products, R-strategies and market ready solutions both in own organisation and (framework)contractors.
						Limited familiarity with monitoring and KPIs in projects.
						Technical incompatibilities (mainly for labs or hazardous substances).
	8. repurpose					Building regulation changes, certification and guarantees, insurability and liability issues, limited market (both demand and supply).
Small improvements on NL-standards	*9. recycle*					Limited skills at contractors to dismantle for maximum recycling rate.
						Limited time, budget or container/handling space
						Limited mapping and insight in handling of waste flows Limited tender/contract criteria to improve w.r.t. standards

Note(s): *Operational(O), Tactical(T), Strategic (S) levels within CRE&FM; External (E) = TU Delft Parent organisation + region/NL/EU; **Design for re-use added as sub category because this strategy is applied but only affecting circularity of future projects
Source(s): Authors' own work

Whereas the EU taxonomy and CSRD reporting obligations can be seen as external drivers to commercial parties that are dependent on external financing, this regulatory pressure does not apply (yet) to a (semi)public institution like TU Delft. TU Delft does feel the responsibility to disclose sustainability metrics over the coming years. However, like for many (semi-)public clients that are under pressure of safeguarding procedural and performance values within limited publicly funded budgets, sustainability could counter intuitively be on the "most likely" list to be traded off (Kuitert *et al.*, 2018).

5.2 From barriers to recommended courses of action

Four groups of barriers can be identified that hinder the thorough adoption of CC in the organisation:

(1) *A measurable goal definition is lacking*. Together with the lack of a good monitoring and forward dashboarding system, this makes it hard to assess success and steer towards ambitions on a strategic level. This is rooted in rapid internal and external knowledge and definition development in the last decade. Policy cycles

and the next update of the TU Delft sustainability vision could be used to better define and communicate the goals.

(2) *Circular strategies high up the R-ladder are mainly applied per project and not on the portfolio level.* It is only partially possible to apply the high-R ladder strategies refuse and rethink within a given project definition. The project and internal client-driven approach to projects is rooted in the traditional TU Delft organisational structure of relatively independent faculties and services. Moving to more centralised, portfolio-wide rethink and refuse strategies can contribute significantly to realising the organisation's sustainability goals.

(3) *An integral campus-wide plan is missing that shows the combined viability of quantitative and qualitative aspects of all ambitions and helps in setting priorities per project.* This relates to the fundamental critique of Corvellec *et al.* (2022) that ignoring the complexity of different elements of a CE and their possible interactions or trade-offs is a common policy-maker's pitfall. Understandably, policy was developed and detailed thematically to get a better grip. Now it is recommended to bring these themes back together again at the campus level.

(4) *Insights, tooling and knowledge* that link operations to the strategic portfolio level and parent organisation are not thoroughly implemented yet or are lacking. Further development and implementation can provide structure and guidance for stakeholders on the tactical and operational level, and important steering information on the strategic level.

- *Monitoring is being developed mostly per project.* The available monitoring data is limited and represents the status quo of the past. Forward dashboarding on the portfolio level is limited. It does not support effective steering towards the 2030 and 2050 goals. For example, current focus lies on the rather complex mid R-ladder strategies of re-use, refurbish etc, while nationwide estimates indicate that the re-use of elements and materials could *theoretically* only account for 53% of the demand for utility buildings (Arnoldussen *et al.*, 2022).Therefore, limiting the demand for building and renovation activities and a serious increase of substitution by biobased materials is needed.
- *The overall financial framework* for campus RE development and maintenance within which CRE&FM operates *is largely based on linear economic and financing principles*, not incentivising or even limiting circular strategies. *Tooling for circular accounting and decision-making is not fully adopted yet* (TCO, internal CO_2 taxation) or is still being explored. (end of life value, CO_2 budgets and CO_2 certificates)
- *Knowledge:* People applying this tooling in projects seem to be not fully familiar with them yet, and decision-makers are not always steering by these criteria yet.

These four barrier groups affect all projects and are positioned on respectively the interface between the strategic level and the lower organisational levels (lack of forward dashboarding, missing/limited tooling), on the strategic level (limited integral spatial policy and not incorporating higher R-ladder strategies at the portfolio level enough) and on the interface between the strategic level and the parent organisation (lack of clear goal definition and a financial cadre based on linear economics and accounting).

Within TU Delft two sustainability programs are currently running: the TU Delft-wide Sustainable Campus Program and the CRE&FM sustainability program. Objectives like reducing space and material use per capita might align well with anticipated budget constraints. Nevertheless, when sustainability stays within the programmatic, new, complex or add-on sphere, the current drivers might not be strong enough to keep on progressing. While continuous efforts at the tactical and operational levels are needed, structural changes at both the strategic level and within the parent organisation are essential to structurally embed CC, as Kooter *et al.* (2021), Martinsuo and Hoverfält (2018) point out. This is the point where the more fundamental changes to businesses need to be addressed to really align to the strategic transition goals in the organisation and society, as both literature (Loorbach and Wijsman, 2013; Sankaran *et al.*, 2021) and recent guidelines like the ISO 59000 family emphasise.

As well-known educational and research institution, TU Delft's influence extends beyond its own operations. Education, innovation, and technology are seen as important for this transition, and involvement in the public debate allows for addressing external barriers. However, going back to the fundamental critiques on the adoption of the concept of circularity in the introduction, TU Delft as an institute does not state what a CE should look like and how the physical form of the campus contributes to that.

5.3 Limitations and further research

One limitation of the research method is the single case study approach. The authors see this study as a small step in better connecting organisational sciences and CC science within the scope and timeframe of this study. To test and further develop the proposed framework and to validate the outcomes, it would be very relevant to expand the research to other institutes for higher education that own and develop their portfolio as well as to other (semi)public construction clients or even commercial owners and developers. Based on knowledge exchange via academic networks such as the Dutch Campus NL and 4TU networks, the European IDEA League, and also the practical exchange network for Dutch RE and facility management departments of higher education institutes, the authors see how insights from this single case study could be relevant for other campuses. Secondly, the involvement of the interviewees with this construction client could have influenced their answers. To create room for criticism, interviewees were informed about the protection of their data and statements from interviews are pseudonymised and summarised. Validation of results with the aforementioned construction clients that develop and manage their own portfolio would be a valuable next step to address these two limitations.

The case itself has limitations that are inherent to the construction sector. Firstly, there is a significant delay between policy making, the implementation of tooling and the delivery of finished projects that can be thoroughly analysed. This common delay underscores the importance of setting high ambitions since every project initiated now will be renovated after 2030, potentially leaving the organisation with a non-circular heritage towards their next renovation cycle. The second case-related limitation is the absence of comparable quantitative data, which is also not uncommon due to the developing definitions for circularity and regulatory frameworks. Furthermore, to enable circular portfolio management, circular valuation and accounting methods could be subject of future research.

6. Conclusion

During the past years, policymakers and practitioners have tried to implement circularity the construction sector. However, progress remains limited. Barriers found in previous studies are manyfold. Because of the complex and multi-stakeholder nature of the transition,

scholars are highlighting intra-organisational aspects as a major challenge. To better understand how (semi) public RE owner-developers can contribute more effectively to the transition to a CC sector, the implementation of Delft University of Technology's (TU Delft) circular campus ambition serves as a single case study. Drivers and barriers for the implementation of circular strategies have been analysed in a framework that combines the R-ladder framework for CC with organisational levels from transition management studies.

Current endeavours mostly target barriers for mid-R-Ladder strategies at the operational and tactical level, while most additional interventions are located on the tactical to strategic level. The linear accounting and project development framework remain significant tactical barriers within CRE&FM. Moreover, strategic tooling such as consistent monitoring and forward dashboarding is lacking. Furthermore, CRE&FM is leading the implementation but is dependent on its parent organisation in which measurable goals, understanding of their implications, as well as a circular financial framework are largely missing.

The findings of this study contribute to the knowledge on intra-organisational challenges in the transition to a CC sector and, more specifically, how semi-public organisations that commission and manage RE property can help to bring about the transition.

Acknowledgements
The authors are very thankful to all interviewees for their cooperation.

Declaration of competing interest
The authors declare to have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adams, K.T., Osmani, M., Thorpe, T. and Hobbs, G. (2017), "The role of the client to enable circular economy in the building sector".

Alba Concepts (2024), *Advies En Kengetallen Circulair Bouwen (Internal Document) (2023-0326.010-V1.0-LQ/DvL)*, Alba Concepts.

Alhola, K., Ryding, S.-O., Salmenperä, H. and Busch, N.J. (2019), "Exploiting the potential of public procurement: opportunities for circular economy", *Journal of Industrial Ecology*, Vol. 23 No. 1, pp. 96-109, doi: 10.1111/jiec.12770.

Arnoldussen, J., Endhoven, T., Kok, J., Groot, P., Blok, M. and Kamps, M. (2022), "Materiaalstromen in de bouw en infra", *Materiaalstromen, Milieu-Impact En CO2-Emissies in 2019, 2030 En 2050, Economisch Instituut Voor De Bouw and Metabolic.*

Bucci Ancapi, F. (2023), "Ex ante analysis of circular built environment policy coherence", *Buildings and Cities*, doi: 10.5334/bc.337.

Calisto Friant, M., Vermeulen, W.J.V. and Salomone, R. (2020), "A typology of circular economy discourses: navigating the diverse visions of a contested paradigm", *Resources, Conservation and Recycling*, Vol. 161, p. 104917, doi: 10.1016/j.resconrec.2020.104917.

Çetin, S., Gruis, V. and Straub, A. (2021), "Towards circular social housing: an exploration of practices, barriers, and enablers", *Sustainability*, Vol. 13 No. 4, p. 2100, available at: www.mdpi.com/2071-1050/13/4/2100

Charef, R., Morel, J.-C. and Rakhshan, K. (2021), "Barriers to implementing the circular economy in the construction industry: a critical review", *Sustainability*, Vol. 13 No. 23, p. 12989, available at: www.mdpi.com/2071-1050/13/23/12989

Çimen, Ö. (2021), "Construction and built environment in circular economy: a comprehensive literature review", *Journal of Cleaner Production*, Vol. 305, p. 127180, doi: 10.1016/j.jclepro.2021.127180.

Çimen, Ö. (2023), "Development of a circular building lifecycle framework: Inception to circulation", *Results in Engineering*, Vol. 17, p. 100861, doi: 10.1016/j.rineng.2022.100861.

Cirkelstad (2024), "Het nieuwe normaal, circulaire ambities binnen handbereik", Cirkelstad. Retrieved 08-08-2024 from, available at: www.hetnieuwenormaal.nl/over-hnn/

Coenen, T., Visscher, K., and Volker, L. (2021), "Introducing circular innovation in the construction industry: the case of the circular viaduct", *Proceedings of the 37th Annual ARCOM Conference*.

Coenen, T., Visscher, K., and Volker, L. (2022), *Circular Economy or Circular Construction? How Circularity is Understood by Construction Practitioners 38th Annual ARCOM Conference*, Glasgow, UK.

Corvellec, H., Stowell, A.F. and Johansson, N. (2022), "Critiques of the circular economy", *Journal of Industrial Ecology*, Vol. 26 No. 2, pp. 421-432, doi: 10.1111/jiec.13187.

Delft University of Technology (2016), *TU Delft Circulariteit – Work in Process Copy – 10 Geboden Van Circulariteit (Internal Document)*, TU Delft.

Delft University of Technology (2018), *TU Delft Strategisch Kader 2018-2024, Impact Voor Een Betere Samenleving*, T. Delft.

Delft University of Technology (2024), *Strategic Agenda TU Delft 2024-2030, Impact for a Sustainable Society [Policy Document]*, D. U. O. Technology.

Delft University of Technology/CRE&FM (2023), "Duurzame renovatie van de EWI-hoogbouw: toekomstbestendig icoon", TU delft Campus. Retrieved 06-07-2023, available at: www.tudelftcampus.nl/nl/campus-development/projecten/actuele-projecten/duurzame-renovatie-van-de-ewi-hoogbouw-toekomstbestendig-icoon/#zes

den Heijer, A. (2021), "Campus of the future, managing an matter of solid, liquid and gas. TU delft, faculty of architecture and the built environment", *Department of Management in the Built Environment.*

Ding, L., Wang, T. and Chan, P.W. (2023), "Forward and reverse logistics for circular economy in construction: a systematic literature review", *Journal of Cleaner Production*, Vol. 388, p. 135981, doi: 10.1016/j.jclepro.2023.135981.

Dobbelsteen, A.V.D. and Gameren, D.V. (2022), *Sustainable TU Delft, Vision, Ambition and Action Plan for a Climate University*, Delft University of Technology.

Dokter, G., Thuvander, L. and Rahe, U. (2021), "How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy", *Sustainable Production and Consumption*, Vol. 26, pp. 692-708, doi: 10.1016/j.spc.2020.12.032.

Eikelenboom, M. and van Marrewijk, A. (2023), "Creating points of opportunity in sustainability transitions: reflective interventions in inter-organizational collaboration", *Environmental Innovation and Societal Transitions*, Vol. 48, p. 100748, doi: 10.1016/j.eist.2023.100748.

Eikelenboom, M., Oosterlee, M. and van Marrewijk, A. (2024), "Demolishers or 'material experts'? Project actors negotiating changing roles in sustainable projects", *International Journal of Project Management*, Vol. 42 No. 4, p. 102605, doi: 10.1016/j.ijproman.2024.102605.

Ellen Macarthur Foundation (2019), "Circular economy systems diagram. Ellen Mc Arthur foundation", Retrieved 30-10-2023 from, available at: https://emf.thirdlight.com/link/7kvazph93afk-owveai/@/preview/1?o

Ellen MacArthur Foundation (2023), "Circular economy introduction. Ellen MacArthur Foundation", Retrieved December 2023 from, available at: www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

European Union (2025), "EU taxonomy compass, activity of construction of new buildings", Retrieved 21-03-2025 from, available at: https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/350/view

Fraser, M., Conde, Á., and Haigh, L. (2024), *The Circularity Gap Report 2024*, Circle Economy foundation in collaboration with Deloitte.

Geldermans, B., Kuil, R., and Linssen, H. (2022), *Linear till Proven Circular: Wicked Challenges from Construction Practice: TU Delft Campus*, Building Beyond Borders Fall Symposium 2022, Hasselt, Belgium.

Grover, R. (2020), "Towards zero carbon buildings, reducing the embodied carbon footprint of a construction", Master Thesis, TU Delft, Delft.

Hacquebord, A. (2024), *Wegwijzer Naar Duurzame Ontwikkeling, Een Praktische Handleiding Voor Projectmatig Werken Bij CREFM (Internal Document)*, D. U. O. Technology.

Hanemaaijer, A. and Kishna, M. (2023), "Reflectie op het nationaal programma circulaire economie 2023-2030", Planbureau voor de Leefomgeving (PBL), available at: www.pbl.nl/publicaties/reflectie-nationaal-programma-circulaire-economie-2023-2030

Hanemaaijer, A., Kishna, M., Koch, J., Lucas, P., Rood, T., Schotten, K. and Sluisveld, M. (2023), "Integrale circulaire economie rapportage 2023, hoofdboodschappen en bevindingen [assesment](PBL-publicatienummer: 5032). Planbureau voor de leefomgeving (PBL)", available at: www.pbl.nl/publicaties/integrale-circulaire-economie-rapportage-2023

Hanemaaijer, A., Muller, M., de Krom, M., Mangnus, A., Schotten, K. and In 't Veld, D. (2025), "Integrale circulaire economie rapportage 2025".

Hänsch, M. (2020), "KPI's en criteria verduurzaming campus tu delft – cre (internal document)".

Hart, J., Adams, K., Giesekam, J., Tingley, D.D. and Pomponi, F. (2019), "Barriers and drivers in a circular economy: the case of the built environment", *Procedia CIRP*, Vol. 80, pp. 619-624, doi: 10.1016/j.procir.2018.12.015.

Hellinga, C. (2014), "Energieverduurzaming van de TU delft campus", Beleidsdocument TU Delft – juni 2014 (Internal document). In: FMVG, Delft Energy Initiative (DEI).

Hopff, B., Nijhuis, S. and Verhoef, L.A. (2019), "New dimensions for circularity on campus—framework for the application of circular principles in campus development", *Sustainability*, Vol. 11 No. 3, p. 627, available at: www.mdpi.com/2071-1050/11/3/627

International Organization for Standardisation (ISO) (2024a), "ISO 59004:2024 circular economy — vocabulary, principles and guidance for implementation", In (Vol. ISO 59004:2024), Vernier (Geneva) ISO.

International Organization for Standardisation (ISO) (2024b), "ISO 59010:2024 circular economy — guidance on the transition of business models and value networks", In (Vol. ISO 59010:2024), Vernier (Geneva) ISO.

International Organization for Standardisation (ISO) (2024c), "ISO 59020:2024 circular economy — measuring and assessing circularity performance", In (Vol. ISO 59020:2024), Vernier (Geneva) ISO.

Kanters, J. (2020), "Circular building design: an analysis of barriers and drivers for a circular building sector", *Buildings*, Vol. 10 No. 4, p. 77, doi: 10.3390/buildings10040077.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A. and Hekkert, M. (2018), "Barriers to the circular economy: evidence from the European Union (EU)", *Ecological Economics*, Vol. 150, pp. 264-272, doi: 10.1016/j.ecolecon.2018.04.028.

Kooter, E., Uden, M.V., Marrewijk, A.V., Wamelink, H., Bueren, E.V. and Heurkens, E. (2021), "Sustainability transition through dynamics of circular construction projects", *Sustainability*, Vol. 13 No. 21, p. 12101, available at: www.mdpi.com/2071-1050/13/21/12101

Kuitert, L., Volker, L. and Hermans, M. (2018), "Taking on a wider view: public value interests of construction clients in a changing construction industry", *Construction Management and Economics*, Vol. 37 No. 5, pp. 1-21, doi: 10.1080/01446193.2018.1515496.

Leising, E., Quist, J. and Bocken, N. (2018), "Circular economy in the building sector: three cases and a collaboration tool", *Journal of Cleaner Production*, Vol. 176, pp. 976-989, doi: 10.1016/j.jclepro.2017.12.010.

Loorbach, D. (2007), "Transition management: new mode of governance for sustainable development", PhD. thesis, available at: http://hdl.handle.net/1765/10200

Loorbach, D. and Wijsman, K. (2013), "Business transition management: exploring a new role for business in sustainability transitions", *Journal of Cleaner Production*, Vol. 45, pp. 20-28, doi: 10.1016/j.jclepro.2012.11.002.

Martinsuo, M. and Hoverfält, P. (2018), "Change program management: toward a capability for managing value-oriented, integrated multi-project change in its context", *International Journal of Project Management*, Vol. 36 No. 1, pp. 134-146, doi: 10.1016/j.ijproman.2017.04.018.

Meurs, P., Doorn, G. V D G. J. V. and Zwarteveen, B. (2018), *Technische Universiteit Delft, Cultuurhistorisch Onderzoek*, Steenhuis Meurs.

Milieu Centraal (2023), "Factsheet circulaire economie", Online: Millieu Centraal, available at: www.milieucentraal.nl/professionals/factsheets-en-rapporten/factsheet-circulaire-economie/

Munaro, M.R. and Tavares, S.F. (2023), "A review on barriers, drivers, and stakeholders towards the circular economy: the construction sector perspective", *Cleaner and Responsible Consumption*, Vol. 8, p. 100107, doi: 10.1016/j.clrc.2023.100107.

Nelissen, E., Griendt, B. V D., Oppen, C. V., Pallada, I., Wiedenhoff, J., Waal, VD., Quist, J., Engelsman, L., Schaafsma, M., Dreumel, M. V., Terwisscha, P., Broere, P., Fraanje, P., Mars, P. V D., Hoof, S. V. and Bögl, T. (2018), "Transitie-agenda circulaire bouweconomie", *Supported by Rijksdienst Voor Ondernemers (RVO).*

Oppen, C. V. and Bosch, S. (2020), *Circular Procurement in 8 Steps, Guideline for Residential and Non-Residential Construction*, N. E. Agency.

Ossio, F., Salinas, C. and Hernández, H. (2023), "Circular economy in the built environment: a systematic literature review and definition of the circular construction concept", *Journal of Cleaner Production*, Vol. 414, p. 137738, doi: 10.1016/j.jclepro.2023.137738.

Raworth, K. (2017), "What on earth is the doughnut?…. Raworth, Kate. Retrieved 16", 02-2024, available at: www.kateraworth.com/doughnut/

Reike, D., Vermeulen, W.J.V. and Witjes, S. (2018), "The circular economy: new or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options", *Resources, Conservation and Recycling*, Vol. 135, pp. 246-264, doi: 10.1016/j.resconrec.2017.08.027.

Sankaran, S., Jacobsson, M. and Blomquist, T. (2021), "The history and future of projects as a transition innovation: towards a sustainable project management framework", *Systems Research and Behavioral Science*, Vol. 38 No. 5, doi: 10.1002/sres.2814.

Stockholm Resilience Centre (2023), "S.U., based on Richardson *et al*. 2023, Steffen *et al*. 2015, and Rockström et al. 2009. The evolution of the planetary boundaries framework. Stockholm resilience Centre", Retrieved 12-02-2024, available at: www.stockholmresilience.org/research/planetary-boundaries.html

Stolwijk, L. (2022), "Dechargeformulier V70386 inrichten etage 9 tot en met 22 EWI hoogbouw (internal document)".

Stolwijk, L. (2023), "Projectevaluatie V70377 en V70386 – concept (internal document)", In V70377 – Brandwerend + inbouwpakket etages HB 36 project 3; V70386 – Inrichten etage 9 t/m 22 EWI hoogbouw.

Sustainability Coach Campus Zuid (2022), *Ambitiedocument Kluyvergebied (Internal Document)*, Delft University of Technology, Delft.

UN Studio, Arup and BBN (2018), "Voorlopig ontwerp | ontwerpboek TU Delft – Echo (internal document)", In Documentnummer: B01-90.01.

van den Berghe, K.B.J. and Verhagen, T.J. (2021), "Making it concrete: analysing the role of concrete plants' locations for circular city policy goals", *Frontiers in Built Environment*, Vol. 7, doi: 10.3389/fbuil.2021.748842.

van den Dobbelsteen, A. (2022), "Programma inzet middelen duurzaamheid uit campusstrategie 2022 (internal document)", *Decision Memorandum of the TU Delft Executive Board*, TU Delft, Delft.

van den Dobbelsteen, A., and van Gameren, D. (2022), *Sustainable TU Delft, Vision, Ambition and Action Plan for a Climate University*, Delft University of Technology.

van der Vlies, R.K. (2021), *Leidraad Circulair Amoveren V1/2021 (Internal Document)*, in Hänsch, R.J. G.M. (Ed.).

van Eesteren, J. and Ketting, E. (2022), "Verslag circulariteit en duurzaamheid renovatie gebouw 36 faculteitsgebouw EWI TU delft (internal document)".

van Ellen, L. A. V. (2020a), "Roadmap circulaire campus 2030".

van Ellen, L. A. V. (2020b), "Roadmap circulaire campus 2030 (internal document)".

van Uffelen, C. (2019), "Een toekomst voor elektro?", Retrieved 06-07-2023, available at: www.delta.tudelft.nl/article/een-toekomst-voor-elektro#

Veeze, D. (2016), "Programma van eisen new education Centre – 2019 (concept) (internal document)".

Vlasman (2022), "Eindrapport EWI (internal document)".

Wuni, I.Y. (2022), "Mapping the barriers to circular economy adoption in the construction industry: a systematic review, pareto analysis, and mitigation strategy map", *Building and Environment*, Vol. 223, p. 109453, doi: 10.1016/j.buildenv.2022.1094153.

Supplementary material

The supplementary material for this article can be found online.

Corresponding author

Karlijn Kokhuis can be contacted at: k.kokhuis@tudelft.nl