
Roadmapping: Transformative Strategic Tool for diverse actors in Circular Construction

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Abstract: Roadmaps have been examined as strategic tools for organisational development and, more recently, as tools for circular development. However, studies have not acknowledged how roadmaps for industrial circular development can capture the multi-level agency needed for sociotechnical change or how a design approach can strengthen such roadmaps. This study addresses these research gaps and develops a design-based roadmap for the construction industry to foster circular development through concrete element reuse. The main method is participatory action research. The primary contributions of this study are a strategic roadmap for concrete element reuse and a design-based framework for roadmap development, highlighting multi-level agency in circular sociotechnical developments. These contributions address both circular construction and circular development research.

Keywords: Circular development; roadmap; reuse; circular construction; design approach; multi-level socio-technical transition

Paper

1. Introduction

Many industries must move towards sustainable development due to planetary boundaries, decreasing natural resources, and climate change. The construction industry is one of the world's largest environmental polluters, consuming natural resources and generating enormous volumes of solid waste. In response, the industry has increasingly turned towards the circular economy (CE) and begun to harness various circular strategies, for example, shifting to the recycling and reuse of materials and extending material lifetimes via maintenance and repair (Bocken *et al.*, 2016). One circular solution emerging within the industry is the reuse of concrete building elements, which offers a significant opportunity to extend the lifespan of materials and reduce reliance on virgin resources (Huuhka, Aarikka-Stenroos and Lahdensivu, 2023). However, despite the well-known need for a circular transition, implementing the CE in construction is arduous, as it requires vertical integration across the value chain, new forms of coordination, and engagement and orchestration among diverse actors (Harala *et al.*, 2023). Circular industrial development is characterised as a sociotechnical transition (Geels, 2020) that needs changes and developments at multiple levels of society. This view posits that circular development through reuse does not only concern technology implementation. Consequently, studies have increasingly indicated the importance of societal factors, such as competence and regulative development, for circular construction (Huuhka *et al.*, 2023; Harala *et al.*, 2023).

When the sociotechnical transition approach is applied to circular developments, such as the implementation and adoption of building component reuse within the construction industry and society, multiple levels of society and diverse actors are involved on each level. Circular development requires changes among individual organisations and individuals (micro level), value chains (meso level), and stakeholders in society more broadly (macro level) (Ghisellini, Ripa and Ulgiati, 2018); Huuhka *et al.*, 2023; Harala *et al.*, 2023). Each level has a different agency and is understood as an actor with the capacity to act and actualise changes and developments towards circularity during the transition (Geels, 2020).

As the transition towards circularity is a long process, a roadmap approach has been suggested as a method to steer and engage the actors involved (Abu-Bakar *et al.*, 2024). This approach has been found to provide benefits for systemwide change, making it a valuable tool for CE transitions. Roadmapping, in general, as a strategic tool, provides a visual, temporal, and hierarchical structure for organising the required steps in a transition and integrating diverse perspectives, and it helps coordinate activities, establish shared agendas, and communicate strategic pathways (Kerr, 2023b).

Roadmaps have been used in multiple CE contexts (Abu-Bakar *et al.*, 2024), and various visual methods, such as canvases, have been suggested as design tools for circular developments (Bocken *et al.*, 2023). However, two research gaps remain: (1) there is a limited understanding of the design aspects of the roadmap method, particularly the role of visual design; and (2) no agency- and sector-specific approach engaging the

diverse actors needed for circular development research, especially in built environment transitions, has been developed.

This study aims to build a comprehensive picture of how the roadmap approach is used for circular innovation to support strategic alignment, create shared direction, and activate actor agency for circular development in the construction sector to increase the implementation and adoption of concrete element reuse. This study applies a particular design-empowered lens to the roadmap approach, as this is lacking in the literature. We pose two research questions:

RQ1: How can a roadmap be designed to support the transition toward circularity by enabling engagement across multiple levels and diverse actors (here, the construction sector, specifically precast concrete element reuse)?

RQ2: How does visual design support the development and strategic interpretation of roadmaps for circular economy transitions among diverse industry actors?

Thus, the study aims to increase understanding of the roadmap approach for circular innovation and development by using a multidisciplinary lens that connects innovation management, circular innovation, and visual design.

The main contributions of this study are a strategic roadmap for concrete element reuse and a design-based framework for roadmap development, highlighting multi-level agency in circular sociotechnical developments. These contributions address both circular construction and circular development research. The study adds to relevant research streams, highlighting sustainable, circular development and strategising, and has practical relevance for companies and ecosystems seeking to develop their operations and business towards circularity through circular strategies and principles. Further, it integrates the design literature with the roadmapping and circular construction research, in addition to circular innovation, circular technology, and business development research. In this regard, first, it generates a comprehensive picture of roadmaps as a strategic vehicle for circular innovation and development within an industry; and second, it develops a deeper understanding of the visual and communicative functions of roadmaps and provides novel insights into engaging actors and empowering their agency for development via the roadmap approach.

2. Theory

2.1. Roadmaps as a strategic visual approach

The study starts by discussing roadmaps in general as a strategic visual approach and then connects them to circular development. Roadmaps are an established method used by both practitioners and academics to address business, technological, and organisational challenges. The concept of technology roadmapping is commonly traced back to Motorola in the 1970s, where it was developed as a technique to improve

alignment between technological capabilities and product planning ((Willyard and McClees, 1987). As a result, roadmapping initially emerged as a firm-level management tool with a strong focus on technology strategy.

Since then, the application of roadmapping has expanded significantly. It has been used in a wide range of contexts and at multiple levels, from individual product development to sectoral and national-level programmes. The Cambridge Centre for Technology Management has been a leading hub of roadmapping research, reporting in 2018 that it alone had published more than one hundred roadmapping-related papers during the preceding ten years (Centre for Technology Management, 2018). Robert Phaal, a leading scholar in the field of roadmapping at Cambridge, has collaborated with over 300 companies through the Cambridge programme and has reviewed more than 400 roadmaps as part of his research. Based on this extensive empirical work, Phaal et al. (2004) developed a categorisation of roadmaps according to their purpose, identifying types such as product planning, service planning, strategic planning, and long-range (foresight) planning. This categorisation illustrates the versatility and power of roadmaps across different use cases.

Roadmaps are commonly conceptualised as structured spatial canvases in which information is captured, positioned, and connected (Kerr, 2023b). Their analytical strength lies in the way their spatial structure allows complex information to be organised into meaningful categories while making interdependencies between those categories visible. Typically, this organisation is expressed through thematic layers arranged along a vertical axis, with each layer offering a distinct but interconnected perspective on the phenomenon being examined (Phaal and Muller, 2009).

A defining characteristic of roadmaps is their orientation towards time. Information within a roadmap is temporally arranged, enabling questions such as ‘what needs to be done first’ and ‘what leads to what’ to be addressed visually. This spatial–temporal logic allows both sequences of activity and causal relationships to be communicated clearly (Phaal, Farrukh and Probert, 2004). Time in roadmaps is typically represented through multiple horizons, such as short-, medium-, and long-term perspectives, or through distinctions between the present state and desired future states (Phaal and Muller, 2009). While other strategic planning tools, such as Gantt charts and Program Evaluation and Review Technique (PERT) charts, also support the representation of sequences and causal relationships, roadmaps are distinguished by their explicit emphasis on time as a structuring dimension (Phaal, Farrukh and Probert, 2004). This temporal framing supports future-oriented thinking, facilitates the identification of gaps between current capabilities and future ambitions, and provides a shared reference point for discussing goals, initiatives, actions, and resource requirements (Ghobakhloo *et al.*, 2024).

The structured and temporal properties of roadmaps underpin their fundamentally strategic character. Phaal and Muller (2009) conceptualise roadmaps as lenses through which organisations and systems can be viewed to support strategic planning and decision-making. By integrating diverse types of information, roadmaps provide a coherent overview of complex systems, or what Phaal and Muller (2009) describe as a ‘one-page’ high-level view of the system overall. Such a view helps stakeholders develop

a shared understanding of strategic challenges and opportunities while supporting alignment across organisational boundaries. In this sense, roadmaps function not only as analytical tools but also as communicative artefacts that facilitate coordination and consensus-building among multiple actors (Phaal et al., 2004).

By their nature, roadmaps are visual artefacts in which information is embodied and communicated in graphical form. Phaal and Muller (2009) distinguish between two layers of visibility: (1) an underlying information-based structure and (2) an overlaying graphical layer. The underlying structure refers to the spatial canvas and forms the foundation for knowledge creation by enabling the synthesis of complex information. The overlaying graphical layer concerns how this information is visually expressed through elements such as layout, colour, typography, and imagery.

Although roadmaps are sometimes approached from a purely functional perspective, where the primary goal is to convey information rather than ensure visual appeal, such a view underestimates the importance of visual communication principles. Research in visual communication demonstrates that effective visual design plays a crucial role in clarity, comprehension, and engagement (Dyrud and Worley, 2006). These aspects are particularly important when roadmaps are used to support organisational change or strategic alignment. As visual imagery encourages viewers to engage with data (Moere and Purchase, 2011), helps convey specific messages, and enhances memorability, well-designed graphical elements can add interpretive value and reduce cognitive effort (Bateman *et al.*, 2010). Accordingly, the aesthetic qualities of a roadmap's design may contribute to positive subjective impressions and enhance communication (Phaal and Muller, 2009).

Academic research on roadmaps and roadmapping has primarily concentrated on two areas: the retrospective analysis of existing roadmaps and the study of roadmapping as a co-creation process within organisations. These two fundamental research streams can be considered relatively mature in the roadmapping literature. In contrast, the visual design and designers' perspectives of roadmaps have received comparatively limited scholarly attention. Visual design is understood here as the practice of arranging elements such as colour, typography, imagery, and layout to communicate ideas clearly and create an engaging visual experience (Kress and Van Leeuwen, 2005).

This gap was already noted by Phaal and Muller (2009), who observed that roadmapping research largely focuses on processes and case descriptions while offering limited treatment of graphical elements. Kerr and Phaal (2017) later made one of the first known attempts to define and empirically assess the 'visual design goodness' of a roadmap, yet such efforts remain rare.

More recently, Kerr (2023a) examined the use of strategic roadmapping visuals in the context of NASA. Although this work explicitly concentrated on visual aspects, it adopted a retrospective perspective and could not fully account for the design reasoning, such as design choices and underlying rationales, which are often accessible only from the position of the roadmap's creators (Kerr and Phaal, 2017). As a result, the designer's perspective remains largely absent from existing roadmapping theory.

From a creator's or designer's perspective, roadmap development typically follows a non-linear and iterative design process. This process involves phases of problem framing and divergent thinking, in which questioning and creativity are used to expand the decision space, as well as phases of convergent thinking, where ideas are synthesised into practical and communicable solutions (Dorst and Cross, 2001; Lawson, 2012). In this context, visual thinking, defined as the cognitive process of processing information through mental images, spatial relationships, and visual representations is likely to play a significant role. When visual artefacts such as roadmaps are designed, visual thinking and design thinking are therefore closely intertwined.

As roadmapping originated primarily in company-level settings, much of the existing literature continues to emphasise product-, organisation-, and firm-level applications. In contrast, this study applies roadmapping at the ecosystem level to support a transition towards circular construction. Prior research has demonstrated the applicability of roadmapping beyond individual organisations. For example, Spaniol and Rowland (2022) used roadmapping to support the development of a Baltic Sea business ecosystem, engaging a broad range of actors in a shared planning process.

Furthermore, roadmapping has long been used within organisations to connect different hierarchical levels, from senior management to employees (Simões Freitas *et al.*, 2022). Building on this body of work, it is reasonable to assume that roadmapping can also function as an effective coordination and alignment mechanism across organisational boundaries, supporting collective action among diverse ecosystem actors in sustainability transitions.

2.2. Roadmaps in circular development

Design approaches have increasingly been proposed as key enablers of circular transitions (Bocken *et al.*, 2023). These approaches are often discussed through the lens of design thinking, which has emerged as a novel approach for organisations aiming to solve complex and open-ended problems (Tim, 2008). Diehl & Christiaans (2015) have, for example, discussed the new role of designers as co-creators of sustainable business models and strategies. To support this role, they propose the use of tools such as roadmapping and future-oriented visualisations to create shared understanding among team members and stakeholders. Similarly, Bocken *et al.* (2023) have examined a broad range of design-oriented tools supporting circular innovation and identified twelve commonly used design thinking tools, including personas, system maps, and the Circular Collaboration Canvas.

Roadmaps have received growing attention in the context of circular development. Abu-Bakar *et al.* (2024) analysed over 300 strategic documents related to circular transitions, both textual and visual, and referred to them as Circular Economy Roadmaps (CERNs). From the perspective of operational boundaries, they distinguished between national, municipal, regional, and sectoral CERNs. They further emphasised the importance of multi-level governance, multi-stakeholder collaboration, and cross-sectoral learning, highlighting the need for coordinated circular economy transitions that can cascade from national visions to localised and actionable strategies.

In addition, researchers have proposed multiple frameworks for developing roadmaps aimed at sustainable and circular economy futures (Okada et al., 2022; Abu-Bakar & Charnley, 2024) and specific roadmap types have also been introduced. For example, Taranic et al. (2016) introduce the CEPS framework (Circular Economy Progress for Stakeholders), which seeks to reduce the complexity of the circular economy by mapping specific circular activities against the diverse needs and expectations of different stakeholder groups. Such approaches are frequently discussed at the policy level, where roadmaps are often used to articulate long-term visions. There is, however, also a need for sector-specific, industry-level implementations. Mackenbach et al. (2020) for example, explicitly refers to roadmaps for modular construction as a tool for advancing the circular economy.

2.3. Circular development considered through the multiple levels of sociotechnical transition and agency, particularly in the construction sector

Circular development in construction is not solely dependent on technological implementation and adaptation. Rather, due to sociotechnical sustainability transitions, circular development involves complex interactions among technological, business, and societal implementations and adaptations ((Huuhka, Aarikka-Stenroos and Lahdensivu, 2023); (Alkki *et al.*, 2025)). Consequently, circular development in the construction industry should be understood as concurrent technological and societal development and adoption at multiple levels: the micro level (individuals and organisations developing and adopting solutions) and the macro level (industry-wide and societal development) (e.g., (Kassem and Ahmed, 2022); Annosi et al., 2023) .

Multi-level frameworks incorporating micro, meso, and macro levels have been applied in the CE transition and circular construction research (e.g.,(Ghisellini, Ripa and Ulgiati, 2018); (Harala *et al.*, 2023)). These studies show that circular development entails changes at all three levels. At the micro level, it reshapes individual firms' production processes, operations, and business models. At the meso level, it restructures sectoral supply and value chains and broader industrial systems involving multiple firms while activating industry development through sector-specific circular practices, skills, and industry norms. At the macro level, it requires regions and nations to address infrastructure development, sustainability goals, policy, and regulation-enhancing developments.

Furthermore, a crucial role is played in sociotechnical transitions by agency, which refers to an actor's capacity to contribute to transition processes (Mignon and Bastås, 2025). Such agency in sustainability transitions can range from individual human actors to companies, administrative bodies, collective actors, and organised groups that pursue articulated goals and cohesion to constitute an entity or drive change (Annosi et al., 2023; Geels, 2020).

2.4. Synthesis: A priori framework (strategic visual structure) for a roadmap of agency and diversified multi-level sociotechnical developments

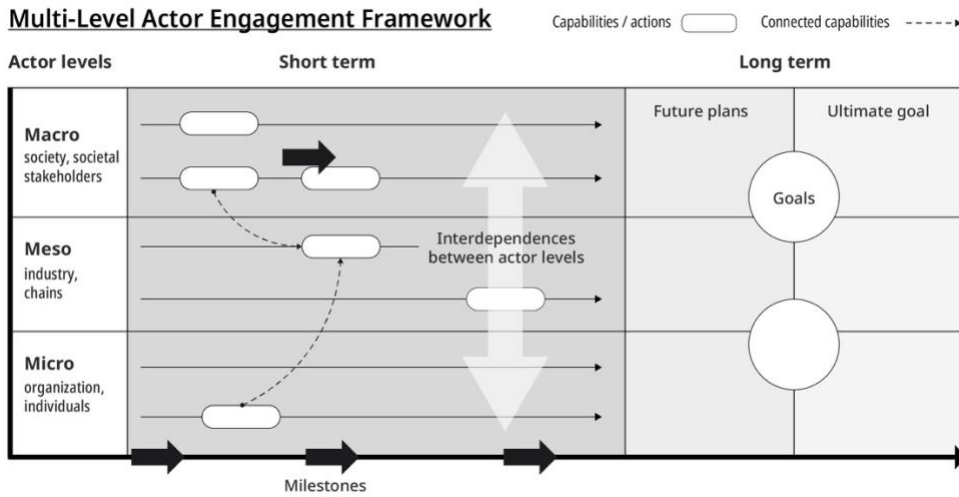


Figure 1 A framework and roadmap (strategic visual structure) presenting diversified agency and multi-level sociotechnical developments

To develop a roadmap for circular construction development through concrete element reuse, we synthesise the key elements of our approach into a framework, that covers the following building blocks: 1) multiple levels (macro, meso, micro) of circular development, each with a different agency for such development; 2) different domains of circular development (technologies, business, competencies, regulations, etc.) interconnected due to system dynamics, leading to the interdependencies between levels illustrated by connection lines between steps; 3) the timeframe and temporality of circular developments, sequential relationships among steps within and between different levels, and division into the short and long term; 4) the actual steps taken, shown as capabilities, skills, and actions on the roadmap; and 5) the strategic narrative built from multiple components, such as milestones, to provide a clear sense of goals and direction.

This framework was developed into a design-empowered roadmap for the development of concrete element reuse through an action research study. The study posits that seeing the complex phenomenon of a sociotechnical, systemic transition divided into structural components regarding themes and time, as well as seeing one's own responsibilities, motivates agency, making individual steps more meaningful and motivating.

3. Methods

To create the roadmap, an action research design (Lewin, 1946) was chosen. This approach was selected because it enabled us to co-develop the roadmap with a multidisciplinary team of researchers and industry stakeholders, generating deeper insights into each element of our framework/roadmap. Action research is defined as a collaborative

process that combines action and reflection to address real-world problems, aiming to create practical, actionable knowledge by identifying gaps and seeking solutions. It typically follows cyclical phases of planning, acting, observing, and reflecting, in which findings are analysed to inform subsequent iterations. (Kemmis, Stephen and McTaggart, Robin, 1988) The methodology of action research has many similarities with the design thinking approaches used in design studies to develop new products, services, or business ideas. Design thinking is commonly defined as an iterative and non-linear problem-solving approach (Dorst, 2011).

The roadmap was created within the EU-funded project ReCreate, which represents a state-of-the-art CE initiative in construction by focusing on concrete element reuse in Europe. The project aims to develop commercially viable processes for the reuse of concrete elements while simultaneously accelerating industry-wide circular transformation, and it has conducted real-life reuse pilots in four countries. Specifically, it focuses on improving the technical and economic feasibility of deconstructing precast concrete structures that were not originally designed for disassembly. The reuse of elements requires the development of new processes, technologies, and business models, as it disrupts existing linear practices. Scaling up reuse is particularly challenging, as it needs systemic changes across the entire ecosystem.

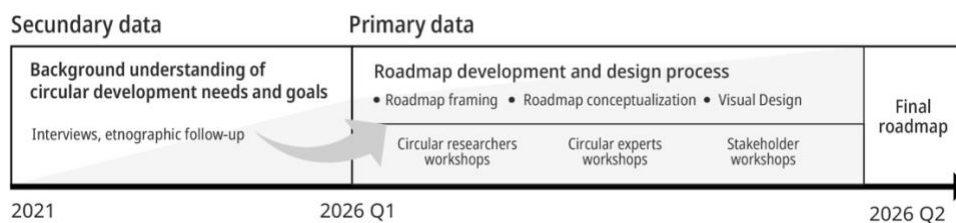


Figure 2 Figure showing the data-gathering and roadmap development process

The ReCreate project is a five-and-a-half-year initiative, running from 2021 to September 2026. The second author has been involved in the project since its beginning, and the first author joined the project in 2024. During the workshops, knowledge from prior research was transferred to the authors, enabling a close collaboration between the roadmap makers and other project researchers. The understanding that underlies the current study was thus developed during the ReCreate project and subsequently synthesised and translated into the roadmap within this action research process. The roadmap framing was initially informed by this understanding and further developed through multiple workshops.

Accordingly, both primary and secondary empirical data were used in the project. The primary data include interactive focused workshops conducted during the research process to engage companies, industry actors, and researchers to develop the roadmap and its elements. The secondary data comprise relevant, diverse background interviews and ethnographic follow-up carried out during the ReCreate project. The datasets are listed in Table 1. Secondary data played a significant role in the process, as the roadmap was created

as a synthesis of knowledge accumulated over the course of a five-and-a-half-year research effort.

Table 1
Overview of data sources

| <i>Data type</i> | |
|---------------------------------------|--|
| Primary data | |
| Workshops | <p>Four workshops (WS)</p> <p>WS 1: Meeting with paper authors and the ReCreate project's business and management researchers</p> <p>WS 2: Feedback session for a work-in-progress presentation on the paper at a local research seminar (Mance) with a CE researchers</p> <p>WS 3: Workshop with the ReCreate project's business and management researchers (2h)</p> <p>WS 4: Workshop with ReCreate researchers from other disciplines and key business partners</p> |
| Secondary data | |
| Interviews with actors in the process | 11 individual interviews with pilot project key actors and 2 individual interviews with other industry representatives |
| Observation, ethnographic follow-up | 4 group interviews with pilot project key actors |
| Minutes and reports | <p>Attending country-cluster meetings involving all ecosystem actors</p> <p>Attending country-cluster demolition planning meetings</p> <p>Attending country-cluster demolition planning meetings</p> <p>Project plans (2) Meeting memos (22) (4/2021–9/2022)</p> |

The roadmap was developed through an iterative, cyclical process characteristic of both action research and design research. Prior knowledge from the ReCreate project informed the interpretation of the literature and guided key design decisions. In this process, knowledge creation emerged through the continuous interplay between existing insights and new empirical findings from workshops, enabling ongoing refinement. This process reflects an abductive reasoning approach.

The roadmap's multi-level view across micro, meso, and macro levels was informed by the existing literature, and its overall structure was informed by established roadmap frameworks (Phaal, Farrukh and Probert, 2004). The visual design of the roadmap, in contrast, emerged from the authors' internal design process. This process was informed by

observations conducted during workshops as well as by the researcher-designers' ethnographic engagement with the multidisciplinary Recreate research project. The identification and mapping of steps (capabilities, skills, and actions) were based on multiple data sources, including workshops, internal author discussions, and insights derived from prior ReCreate research. These were complemented by findings from three ongoing research projects focusing on artificial intelligence (AI) in circular construction, imitation and benchmarking in circular construction, and organisational learning during transitions to circular construction.

Alongside this process, an important aspect of action research concerns the researchers' position in relation to participants. In action research, the researcher takes an active role in shaping the outcomes of the study (Lewin, 1946). The approach shares characteristics with ethnographic research, as researchers immerse themselves in the research environment to observe phenomena and, in this case, to co-develop solutions. This is also a fundamental aspect of design-oriented approaches, where the role of the researcher, often acting as a designer, is central to achieving effective solutions. In design studies, empirical grounding is inherently embedded in the designer's process of exploring and refining solutions. From a critical perspective, the interpretations and decisions made by the designer may reflect subjective preferences; however, the iterative process and continuous engagement with participants function as mechanisms for refining and validating the outcomes.

The research process proceeded in three phases and resulted in a final version of the roadmap. In design studies, such outcomes are conceptualised as design artefacts. Each phase of the process produced a distinct version of the roadmap, reflecting the iterative development and refinement of the artefact. In the Results section below, we present the development process and the insights generated during it.

4. Results

4.1. Overview of roadmap development

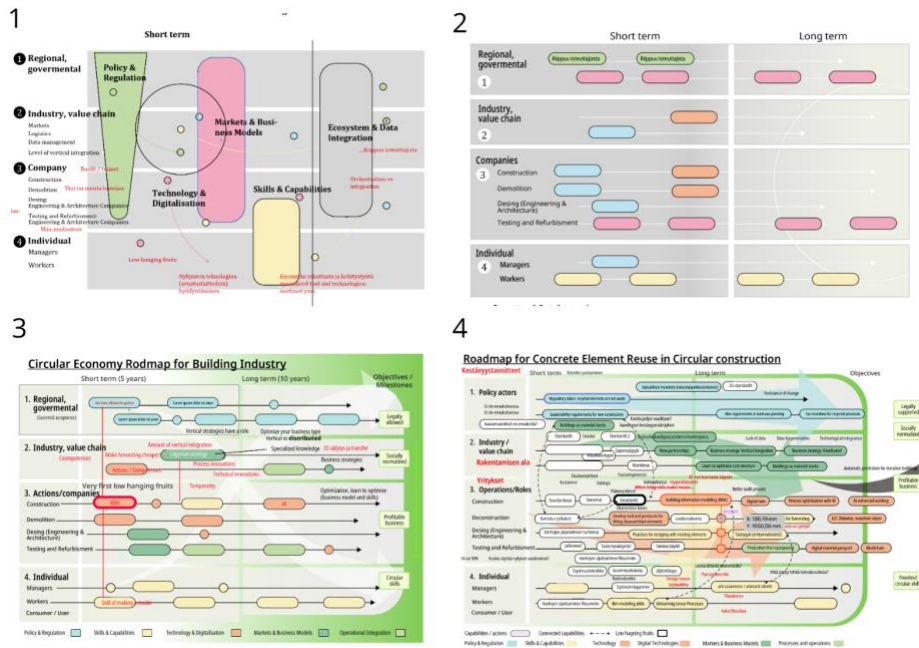


Figure 3 The sketches from four design development stages of the roadmap

The development of the roadmap for concrete element reuse followed four phases, as shown in Figure 1. In the first phase, the structure of the roadmap was ideated and explored internally between the authors. This phase is referred to in this paper as *roadmap framing*. The idea of targeting the roadmap to different actors and organising them into a micro–meso–macro hierarchy emerged at this early stage, informed by the authors’ observation that roadmaps rarely clarify who needs to act and what actions they should take. Additionally, the authors recognised that the steps of the roadmap should be divided into short- and long-term activities, reflecting the need to identify ‘low-hanging fruit’ that could be implemented immediately as well as longer-term goals that could not realistically be achieved in the short term.

At this stage, the medium and format of the roadmap were also discussed. The roadmap was designed to be both a printed image and digitally viewed as a vector image, allowing zooming and close examination. Other formats, such as a web application, were excluded, as they would increase barriers to use. The initial plan was to produce two roadmaps: one offering a general overview of the big picture and a second detailing the action steps. This approach would have been practical from the perspective of readability, given that font sizes smaller than 6.5 points are generally considered unreadable on A4 paper. However, to create a single tangible artefact that could be easily used and showcased in multidisciplinary environments, the paper size was scaled up to A3, and all content was incorporated into a single roadmap.

The second phase began with workshops involving researchers from the business and management work package. These workshops further developed the structure of the

roadmap based on collective insights. Other roadmap elements, such as domains and a more refined temporal structure, began to take shape. Before mapping steps to the roadmap, it was important to identify some by category and establish an initial understanding of their temporal characteristics. Actor levels were also assigned initial labels (e.g., policy, industry). At the end of this phase, the roadmap was presented to a multidisciplinary group of CE researchers, who expressed a particular interest in the intersections and the interdependence between the levels.

In the third phase, the steps were mapped during internal workshops and workshops with other ReCreate project researchers, industry stakeholders, and experts. The central questions addressed to industry stakeholders during this phase were the following: ‘What do stakeholders want to see in the roadmap?’ and ‘Which are the first easy steps (“low-hanging fruit”) that need to be taken?’ By the end of this phase, the need to emphasise the strategic dimension of the roadmap also became apparent, including clarifying its purpose and identifying milestones to motivate actors.

The fourth and final phase involved consolidating all the ideas into the final version of the roadmap and refining the details. Numerous simplifications and generalisations were required to integrate the diverse needs and suggestions of the participants. The final version of the roadmap is presented in the Synthesis and Discussion sections.

In the next section, we introduce each roadmap element type, discuss how they were developed, and outline the insights gathered during the process.

4.2 Roadmap elements

Multiple levels of circular development through element reuse

The micro–meso–macro levels create the core structure of the roadmap. The levels were named after the actors to emphasise who needs to take action. They illustrate how different actors are required to achieve change and show how links can be built among these actors. In this way, the levels offer an important high-level perspective on change.

At earlier stages, the levels were given rather academic names, reflecting the management literature, but these proved difficult to understand in a multidisciplinary environment. As a result, the naming evolved during the second and third phases to become more descriptive, as it became evident that actor roles need to be clearly expressed in ordinary language for participants from different disciplines to understand their responsibilities.

Steps and tracks of circular development through element reuse

Steps are the capabilities, skills, and actions that are mapped to the timeline on the roadmap. They represent the most detailed information on the roadmap and constitute the primary content of the canvas. It became clear that it was important to give a descriptive title to the steps; hence, the terms capabilities, skills, and actions were used. We initially presented the steps as white placeholders, but this caused uncertainty in the workshops about what content was intended for these boxes. This seemingly simple but revealing

question prompted discussion on what the steps should be named, what kind of content they should include, and how they should be communicated.

In the early stages of development, it already started to become apparent that the steps needed to be organised into tracks (or so-called swim lanes), which acted as subject-oriented subcategories within each level. These tracks helped connect individual steps into meaningful timelines and made interdependencies within each track explicit, thereby creating logical ‘first this, then this’ hierarchies.

Domains of circular development through element reuse

Domains are the categories that present the different types of steps. Categorisation was already important when the earliest versions of the roadmap were devised, as it enabled discussion of the steps before they were mapped. Domains also helped us to perceive and discuss how different types of steps spread across different levels, with some variation in emphasis. Initially, the domains were illustrated as areas on the canvas to show their cross-cutting nature, but it soon became clear that this fixed the positions of steps too rigidly. Therefore, the domains were converted into colour labels. This solution maintained the visibility of the cross-cutting nature of domains while integrating them more directly with steps.

During the third development phase, the domains were defined as Policy and Regulation, Skills and Capabilities, Technology, Digital Technology, and Market and Business Models. The basis for this division was recognised at an early stage; however, the exact naming of the domains was refined during workshops. For example, the Technology domain was divided into digital and technical categories to emphasise the need for separate development paths and to address different professional audiences.

Temporality of circular development through reuse

The temporality of the roadmap is embedded in multiple ways. The first level of temporality is the division between short- and long-term steps, represented by dividing the roadmap into two sections. The second level is the temporal hierarchy, that is, the order of steps within each track. At later development stages, it started to become clear that tracks could not be used in the long-term section, as they communicate a precise hierarchy, which is problematic when things become more uncertain further into the future. Instead, we divided the long-term section into two subparts, which enabled us to provide a more defined horizon without using tracks. The steps to be evaluated were relative to these subparts rather than to each other.

The third level of temporality focuses on the relationships between steps across different levels and tracks. Due to the physical constraints of text boxes, these cross-level relationships may not be perfectly accurate, highlighting the importance of visually modelling information so that viewers are not misled.

As regards temporality, it was challenging to keep the information accurate while still allowing for generalisation, since the exact order of steps could not be mapped with complete certainty, particularly for long-term developments, which are inherently speculative.

Interdependencies between steps and levels for circular development through reuse

Interdependencies between steps and levels were illustrated by connecting lines. At certain points, actors must act simultaneously, and some steps need to progress across multiple levels for development to be effective. Connecting lines were therefore used to link major shared actions, such as building information modelling (BIM), which primarily takes place at the company level but also requires new skills at the employee level and supportive regulations at the policy level to enable effective adoption. Visually small, but significant in terms of information, the arrows show the direction in which information flows between steps.

Strategic narrative capturing circular development through reuse

The strategic narrative, an essential element of the roadmap, is built from multiple components to provide a clear sense of goals and direction. The need for a strategic narrative became apparent in later development stages, when the roadmap began to feel structurally complete but lacked motivation and a clear goal. For example, in the last workshop, the architect of the Recreate project pointed out that element reuse in the context of circular construction should be seen in the roadmap: “If we think about long-term activities, concrete element reuse connects to other types of element reuse.” This comment prompted reflection on the roadmap’s overarching message, specifically, what kind of context would motivate diverse actors and make their efforts feel meaningful.

Inspired by this discussion, the short-term section of the roadmap was titled ‘Making Concrete Element Reuse Feasible’, defining a concrete and short-term target. The long-term section was titled ‘Circular Construction’ to signal a broader sociotechnical transition towards circularity, in which concrete element reuse evolves from an isolated solution into an integrated practice. This transition was visually represented as a thick arrow passing through the roadmap.

The narrative was further strengthened in three ways. First, illustrations were used. The short-term section was illustrated with a single building utilising reused elements, whereas the long-term section shows multiple buildings, illustrating an industry-wide shift. These visual elements help make a speculative future more tangible and meaningful for participants. Second, some steps were arranged into meaningful groups and reformulated as milestones, providing thematic structure that made individual steps more understandable, purposeful, and motivating. Third, during the fourth development phase, some of the long-term groups were elevated into explicit goals, such as framing cities as ‘urban mines’, representing a fundamentally different approach to material and mineral sourcing, further strengthening agency within the roadmap.

4.3 Steps for circular development through element reuse

In the roadmap, steps represent the actions, capabilities, and skills required to enable concrete element reuse as part of circular construction. Some of the steps are in groups called milestones.

At the policy level, the short-term roadmap includes two main milestones: the removal of barriers and the provision of economic incentives. The removal of barriers is logically the priority, as these steps are required to even test, pilot, and plan concrete element reuse. The most important step in this milestone is the ‘changing regulatory status of reused elements’. This step is identified as a low-hanging fruit, as clarifying regulatory status can play a significant enabling role for reuse practices, even though the regulatory process itself is time-consuming.

Within the policy level, the steps are divided into two parallel tracks representing national-level and EU-level actions. This distinction is important because regulatory development occurs across multiple governance levels and often follows different timelines. Economic incentives include sustainability requirements for new buildings, which would create competitive advantages for actors adopting more sustainable construction practices.

At the building industry level, the roadmap includes steps that must occur within the ecosystem. These steps address high-level business development and require broad collaboration and orchestration among multiple actors. Business development is especially closely linked to the company-level construction track, as transitioning to circular construction may require substantial changes in current construction business models.

Within the first industry-level track, the focus is on concrete element-related steps, with the initial milestone emphasising qualification for reuse. This includes the development of new procedures to document and track the history of elements as well as methods to ensure element traceability. These steps are also closely connected to the creation of shared standards for the conformity assessment of reused elements. The second track addresses market development and includes a milestone related to element circulation, which was identified as a significant bottleneck during the workshops. Addressing this challenge requires clear support for both demand and supply, potentially through the introduction of intermediary actors, such as traders who acquire, store, and redistribute elements for later use. Another key industry-level issue concerns contracts and procurement practices, which require new approaches as business logics evolve under circular construction.

The company level is divided into four tracks, each corresponding to a specific area of responsibility within the construction value chain. These responsibilities align with existing company business areas, thereby enabling companies to more easily identify their roles within the roadmap. One milestone shared by construction and design is ‘integration into existing construction’. This represents a necessary starting point and is expected to remain relevant over the long term, as new construction will continue to exceed demolition volumes for the foreseeable future, limiting the supply of reusable elements.

From the construction perspective, this integration involves understanding hybrid buildings that combine new and reused components. From the design perspective, it requires improved knowledge of existing building systems as well as new ways of thinking about how reused elements can be intelligently incorporated, including the design of technical connections and logistics solutions that facilitate transport and installation. Over time, construction practices would also benefit from more standardised components, as consistent attributes, such as dimensions, would significantly ease element reuse. In design,

this transition necessitates a shift between highly tailored solutions and standardised modular systems.

The deconstruction track includes the development of new survey tools and quality control methods, while the refurbishment track focuses on updating testing procedures for reused elements and addressing the challenge of assessing whether reused elements meet contemporary technical and regulatory requirements.

BIM constitutes a distinct and significant group of steps and an entire stream within the roadmap, connecting company-level actions to industry-level and policy-level developments, as data requirements may eventually require regulatory intervention. BIM addresses the milestone of data integration and data flows, enabling more seamless reuse through shared digital models, standardised modelling practices, and data normalisation.

In the long-term section, the company level includes the steps of so-called Industry 4.0 technologies. These encompass robotics, the Internet of Things, digital material passports, digital twins, AI-enhanced workflows, and blockchain-based solutions. Most of these technologies remain speculative within the scope of the ReCreate research project, which is why they are positioned in the long-term section. Robotics forms a partial exception, as simplified forms, such as human-controlled machinery, have already been used. Similarly, digital twins have been applied in a limited manner in construction and new-building modelling, and digital material passports were actively discussed during the research project.

The final major and particularly significant group of steps relates to scaling up the business of concrete element reuse. This milestone is positioned between the short-term and long-term sections, reflecting its role as a critical transition point. During the workshops, it was identified as one of the strongest connectors between short-term actions and long-term transformation. These steps involve the potential restructuring of business models and risk-sharing mechanisms. Unless companies are willing to take calculated risks and ‘take a leap’ towards circular construction practices, new best practices cannot be established, and the costs of reuse cannot be reduced through learning and scale effects.

5. Synthesis

Roadmap for Precast Concrete Element Reuse in Circular Construction

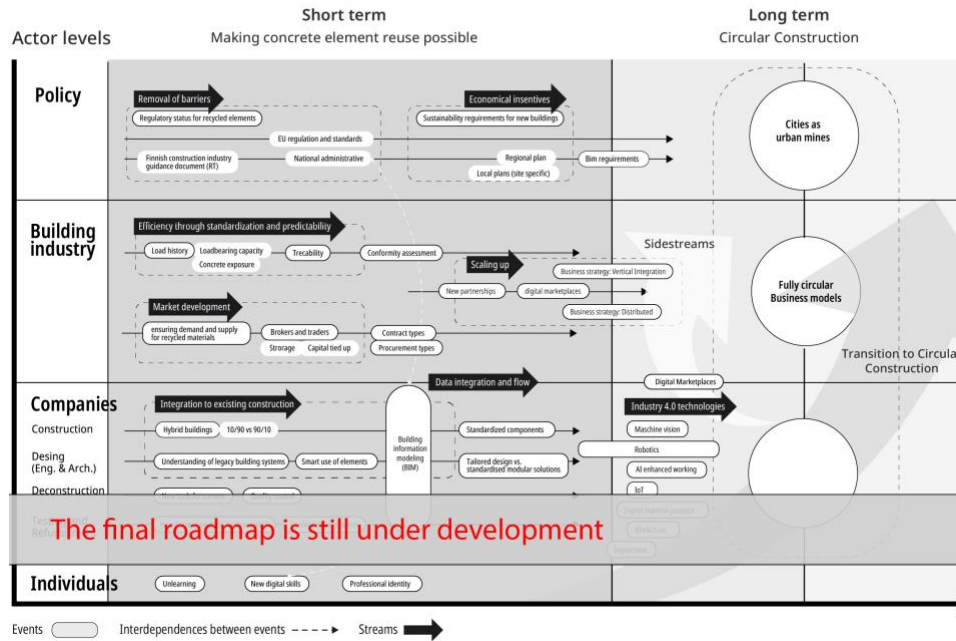


Figure 4 Final version of roadmap

The final version of the roadmap is built around an a priori multi-actor transition framework and incorporates the key roadmap elements and steps co-created during the workshops. The structure of the roadmap divides the canvas into four actor levels: Policy, Building Industry, Companies, and Individuals, explicitly encouraging commitment to the transition towards circular construction across all the levels. Each actor level can identify its own steps while simultaneously exploring how these steps connect to and depend on actions at other levels.

The roadmap is divided into short-term and long-term sections, and the steps are positioned in a timeline in sequential order to show which actions are needed first and which follow. The steps are set within tracks, grouped as milestones to help the actors see the broader transition logic rather than focusing solely on individual actions. In the long-term section, each actor level is assigned a goal that provides direction towards the overarching objective of circular construction. In this way, the roadmap offers a strategic, high-level view of the transition and helps align ecosystem actors around a shared goal. Simultaneously, it provides a multidisciplinary perspective on the transition and highlights interdependencies between the required actions. Visual illustrations help concretise abstract future states. Together, these elements support agency by making progress visible, clarifying priorities, and reinforcing the strategic narrative that connects short-term actions with long-term systemic change.

6. Discussion

6.1 Design advancing feasible roadmap development for concrete element reuse

Visual design played a central role in the development of the roadmap. When a complex set of information was compressed into a single visual artefact, several design decisions were required in relation to principles of visual design, including colour, spacing, composition, scale, and hierarchy. Together, these principles directly influenced the roadmap's readability, interpretability, and ability to communicate the intended strategy.

During the roadmap development, when content was gathered from workshops, it was a constant challenge to balance the vast amount of information generated with the need for clarity. Evaluating and balancing different visual ideas against the varying characteristics of the information also proved challenging. There was a continual search for connections and relationships within the data to identify and shape meaningful visual structures. The aim of visually connecting ideas supported the overall thinking process, but it required ongoing refinement to prevent the roadmap from becoming overly complex.

Within this process, visual hierarchy emerged as the most influential design principle. It required ongoing evaluation of the role and importance of different pieces of information: whether an element represented a minor detail that should remain visually subtle or a major finding that needed to be more prominent. As a result, continuous attention was paid to determining what users should see first to understand how the roadmap functions and how it should be read. Visual hierarchies were used to guide attention and structure interpretation. Colour supported grouping and showed connections between elements without the need for extra text or visual elements. Similarly, spacing and composition were adjusted so that information could be layered clearly on top of the underlying structure. In this way, hierarchy not only guided the visual layout but also became part of the thinking and knowledge-creation process.

Challenges related to hierarchy were also present during the intermediary design stages. When too many elements were shown on the design canvas at the same time, it became difficult to identify the most important components. To address this, grouping steps and themes was adopted as a key design strategy. Grouping helped reduce visual noise and made relationships between elements easier to see. This concern for readability proved particularly important during periods of co-creation. When visual representations were unclear, participants found it harder to trace and discuss ideas or understand how individual contributions related to the overall system. Therefore, visual clarity played a direct role in supporting shared sense-making throughout the research process.

6.2 A roadmap highlighting the agency and agentic actor at multiple levels, enabling circular developments

When designing the roadmap with agency in mind, we placed special emphasis on communicating the narrative of change: how the individual actions of each actor (at different levels and/or the same level) together contribute to a desired future. At the same time, it was essential not to lose sight of the concrete steps that form the basis of this narrative. Ideally, these two levels of information support one another, enabling users either to focus on individual actions or to step back and engage with the broader story. To allow

both perspectives, the visual structure needed to present the narrative and the actions at the same time while keeping them clearly separate. For this reason, a conscious design decision was made to place the narrative of agency more visibly, while the actions were positioned, from a visual perspective, as lower-priority elements within the hierarchy.

Overall, these observations demonstrate that the design choices made were not merely decorative. Visual design was closely tied to how information and knowledge were constructed and modelled. The roadmap functioned as a visual canvas in which hierarchies, dependencies, groupings, and relationships were made explicit. As such, the roadmap served not only as a representation of information but also as a visual construction of concepts.

7. Conclusion

The main contributions of this study are a strategic roadmap for concrete element reuse and a design-based framework for roadmap development for circular developments. These instruments highlight the multi-level agency that is inherent to circular sociotechnical developments and temporality because the actors' activities are interlinked and interdependent. These contributions address both circular construction research (e.g., Harala *et al.*, 2023; Huuhka, Aarikka-Stenroos and Lahdensivu, 2023) and circular industry development research as well as specific research streams examining visual tools to advance circular development (e.g., Kerr & Phaal, 2017; N. Bocken *et al.*, 2023).

This study provides multiple new insights for circular construction (seeking to harness reuse) and, more broadly, circular developments. (1) The roadmapping process creates a shared understanding of needed developments and innovative actions (in our case, for concrete element reuse) and their timing. (2) The structure of the roadmap and visual design choices (hierarchy, colouring, spatial grouping, explicit agency for action) capture the strategic intent and support in stakeholder engagement. (3) The roadmap functions as a boundary object, facilitating collaboration among actors who previously lacked a shared vocabulary. (4) Design reasoning captures the process of the design decisions needed to plan effective roadmap visuals that construct meaning. (5) The roadmap covers diverse circular innovation and development objects (from developing and adopting circularity enabling technologies, products, services, processes, and business models).

As a practical implication, this study developed a pragmatic, co-created, feasible map for the construction industry, its companies and employees, and other individuals as well as for relevant stakeholders in society (policymakers, regulators, authorities) on how they can enhance concrete element reuse. The roadmap provides the practical steps required for change across multiple levels: regional and governmental actors, industry value-chain actors, companies, and individuals. By specifying who should act, when, and in what way, the roadmap functions as a tool that activates stakeholder agency and supports decision-making.

Furthermore, the research offers practical guidance on how visual design can support and improve understanding and sense-giving through the use of hierarchy, structure,

colours, symbols, and overall visual clarity. In this way, the proposed design supports stakeholder agency and engagement in circular transition processes.

We are also aware of the limitations of the study. The study is based on an action research study conducted as part of a concrete element reuse-oriented project. As most of the involved actors were positively oriented to the issue and motivated to roadmap development, they had some positive bias. Research settings with potential negative orientations among the actors could have yielded a different roadmap design. Furthermore, the study results could have benefited from a validation interview/workshop round.

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