

## **(Re)organizing circular design projects**

### **Four tool applications and reflections**

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#### **Publication date**

2022

#### **Document Version**

Final published version

#### **Published in**

The state of circularity

#### **Citation (APA)**

van den Berg, M., Schraven, D. F. J., Schultheiss, F. G., & Frese, T. (2022). (Re)organizing circular design projects: Four tool applications and reflections. In S. Shahnoori, & M. Mohammadi (Eds.), *The state of circularity: The content of "the 2nd International Conference on Circular Systems for the Built Environment"* (pp. 169-181). Technische Universiteit Eindhoven.

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# (Re)organizing circular design projects: Four tool applications and reflections

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**Abstract**— Buildings and infrastructures need to be optimized for closed-loop material flows. Designing such circular constructions is nevertheless challenging because of several organizational barriers. Construction professionals need practical solutions to organize circular design projects – or reorganize linear ones. Four practical tools have therefore been proposed by a circularity community of practice in the Netherlands called Platform CB'23: an ecosystem compass, Business Model Canvas, value matrix and information needs matrix. This paper aims to illustrate the use of these four tools to (re)organize circular design projects. Through applying the tools to a circular interior design case project and reflecting on their potentials, it is concluded that practitioners can gain insights into organizational issues such as the ecosystem workings, business models, value exchanges and information exchanges. Such insights could subsequently be used to take transformative action in circular design.

**Keywords**— *circular economy, design, organizations, project management, tools*

## I. INTRODUCTION

Design projects need to be reorganized to facilitate a transition towards a circular built environment. The construction industry is a backbone of economic and social development by delivering buildings and infrastructures to society. This, however, brings about enormous environmental impacts. The industry is responsible for consuming almost half of the total amount of raw materials extracted annually while simultaneously generating about one third of all solid waste [1]. It also contributes about a quarter of the total CO<sub>2</sub> emissions produced by global economic activities [2]. The consequences of these impacts can become catastrophic in the long term, but already lead to problems – such as (local) scarcity of building materials – in the here and now. To avert these problematic practices, buildings and infrastructures need to be optimized for closed-loop material flows. Designing such ‘circular’ constructions remains quite challenging nonetheless. That is, there are still few practical tools available to organize circular design projects.

Research into circular design has mainly revealed strategies and barriers instead. The seminal work of Brand [3] shows how buildings are being reshaped (or retired) over time. His schematization of buildings into layers with different life-cycles has subsequently inspired researchers to develop design strategies that allow building transformations and recovery practices. The design for disassembly strategy [4, 5], for example, strives to increase the future rates of material and component reuse. Design for change focuses explicitly on maximizing the transformable properties of a building design [6]. And designing with reused components sees existing structures

as reservoirs of materials that can be mined and put to use again [7]. Implementing such strategies is nothing trivial, a growing body of research into circular design barriers shows [see e.g., 8, 9]. Among the most significant barriers are organizational issues, such as: fragmented construction supply chains, short-termism of clients/developers and a ‘silo’ approach of undertaking design, construction, facility management and end-of-life activities [10].

This paper therefore aims to illustrate the use of four practical tools for organizing circular design projects. These tools were developed by a working group of Platform CB’23, a circular community of practice in the Netherlands in which the authors actively participated. The paper discusses the workings of this community of practice in detail in the methodology, but first goes on to present a background section on roles and collaboration modes in circular design. The results show the illustrated use of the tools for a real-world project centered around the reuse of reclaimed building materials for a circular interior design. The paper ends with a discussion and conclusion on the potential of these tools for (re)organizing design projects.

## II. THEORETICAL BACKGROUND

The European Commission has expressed its ambition for Europe to become climate-neutral by 2050. As outlined in its Green Deal, the circular economy (CE) is a core pillar of this sustainable transition [11]. Material feedstocks (e.g., recycled or reused) and lower resource demand are essential building blocks for low-carbon industries [12, p.21]. Circularity goals also reverberate in national policies. The Netherlands, for example, aims to realize a fully circular economy by 2050 and set an intermediate goal of 50% reduction primary resource usage for 2030 [13]. In light of such (inter)national ambitions, a community of practice called Platform CB’23 (Circular Construction 2023) was established in The Netherlands. This community of practice aims “to anchor circular thinking and actions in daily construction practice” before 2023. During earlier yearly trajectories, its so-called action teams had co-developed guidelines on various circularity topics, such as measurement tools and material passports. From September 2020 to July 2021, the authors of this article have actively participated in writing a part of the latest guideline on circular design. That guideline proposes, among others, four new tools to (re)organize roles and collaboration modes in design projects for circular buildings or infrastructures. It can be found in full via the website of Platform CB’23 [14]. The four tools are embedded in ongoing scientific debates below.

### 1) *Ecosystem compass*

The first tool addresses the need to better understand the organization of ecosystems for circular design. An ecosystem connects firms with disparate capabilities with one another to offer a coherent, customer-facing solution [15]. An ecosystem perspective matches with the prospective of a circular economy and provides an alternative for supply chain or project-based perspectives. The ecosystem requires new roles and new forms of collaboration. That particularly applies to parties that belong to the traditional scoping as they lack concerns, awareness and/or knowledge about closing material flows. In other words, they may find themselves as locked in linear roles and business models [16]. Outside guidance is required to rethink any effective systemic change.

The thought of an ecosystems perspective has inspired such change efforts in various lines of literature, like innovation ecosystems [17] and network approaches [16]. For a meaningful change, an overview is first needed of the potential actors to collaborate with. For example, circular design projects may benefit from atypical input from new firms – such as data miners – or existing ones with new roles – such as demolition contractors that offer design advice [18]. Firms that play a role in circular design, therefore, need to understand who could populate the relevant ecosystem. To this theoretical background, an ecosystem compass was developed in the Platform CB’23 circular design guideline.

### 2) *Business Model Canvas*

The second tool addresses the need to get insights into business models around circular design. Once an ecosystem is mapped, it needs guidance on how to collaborate. Leising et al. [19] describe five steps in their collaboration tool for establishing a circular project: Preparation & Vision development; Involve market & supply chain; Process design & collaboration; Business model & implementation; and Usage & prepare for next use. This tool was expanded into a practical steppingstone tool for circular business model development [20]. According to Jonker et al. [21], a circular business model has five aspects: realizing cycles, striving for multiple value creation, choosing an appropriate strategy, shaping the organization between the parties, and developing revenue models (through time or creating value together). Den Hollander [22] distinguishes five types of circular business models for preserving product integrity: classic long life, hybrid, gap exploiter, offering access, and performance. The use of a model depends on the case.

From the above, it can be discerned that two practical traits have to be established for an ecosystem to guide a circular design project. First, it requires for each actor that wishes to contribute to a circular design project, to formulate their value propositions. In contrast with the linear economy, which often emphasizes financial and manufactured values, the circular economy distinguishes six capitals: financial; manufactured; intellectual; human; social and relationship; and natural [23, 24]. Separate actors typically depict these types of value through a Business Model Canvas. This is a conceptualization for a party to create specific values that can be viable and repeated structurally. A business case refers to the viability for a particular product. If a business case is no longer feasible,

the process stops. Several variations of this canvas exist nowadays [see e.g., 25]. The Platform CB'23 guideline describes two types of the Business Model Canvas: one for a newly formed company and one for an existing one.

### 3) *Value Matrix*

The third tool addresses the need to understand how different types of value are exchanged in circular design. A business model is particularly beneficial for single organizations. However, as argued above, circular design projects revolve around many new actors and roles. Therefore, it requires more than simply one business model for a circular design project. Actors in a supply chain have invested roles and dependencies to one another. These bilateral dependencies originate from business model dependencies [16]. Finding these dependencies would be an essential task to forming a productive ecosystem of actors. A company provides value propositions in their business models. Herewith, the value is proposed as a contribution to an ecosystem of actors revolving around the circular design project. In this way, value is a means of exchange between the actors. Value is created from one actor to another, while the receiving actor effectuates the value to their benefit. This applies to various types of value [23, 24]. For example, a contribution with financial value (such as a payment) can be exchanged for a contribution with intellectual value (such as advice). To capture value exchanges in an ecosystem, the Platform CB'23 action team proposed a value matrix tool that logs the value as it is created by one actor and effectuated by another.

### 4) *Information needs matrix*

The fourth tool addresses the need for insights into exchanging information. Previous research has shown that closing materials loops goes hand in hand with ensuring closed-loop information flows [26]. Information originates from processing “data which are relevant, specific, timely and concise” [27]. Common types of information in construction involve drawings, reports or Building Information Models (BIM). Both the quality and quantity of information can be problematic in circular design, given that constructions (and their individual elements) have life-cycles extending for years or even decades. During such timespans, change is the only constant. New regulations come in place, businesses emerge or go bankrupt and consumer preferences follow fashion trends.

Circular design requires different actors to deal with the resulting information imbalances. For managing circular building projects, design firms need information from both previous and later demolition stages [28]. Demolition contractors can inform designers, on the one hand, about the availability and characteristics of recovered building materials and, on the other hand, about the disassemble-ability potential of any future constructions. The Platform CB'23 action team has subsequently proposed a matrix to provide all involved actors an overview of such information needs.

### *Synthesis*

All the aspects taken together, circular design can be seen as a practice with particular organizational challenges. Designing a circular building or infrastructure object needs an ecosystem with actors who create designs with value propositions aimed at keeping resources in the loop. To that end, four practical tools – which target those organizational challenges – have been proposed (Figure 1).

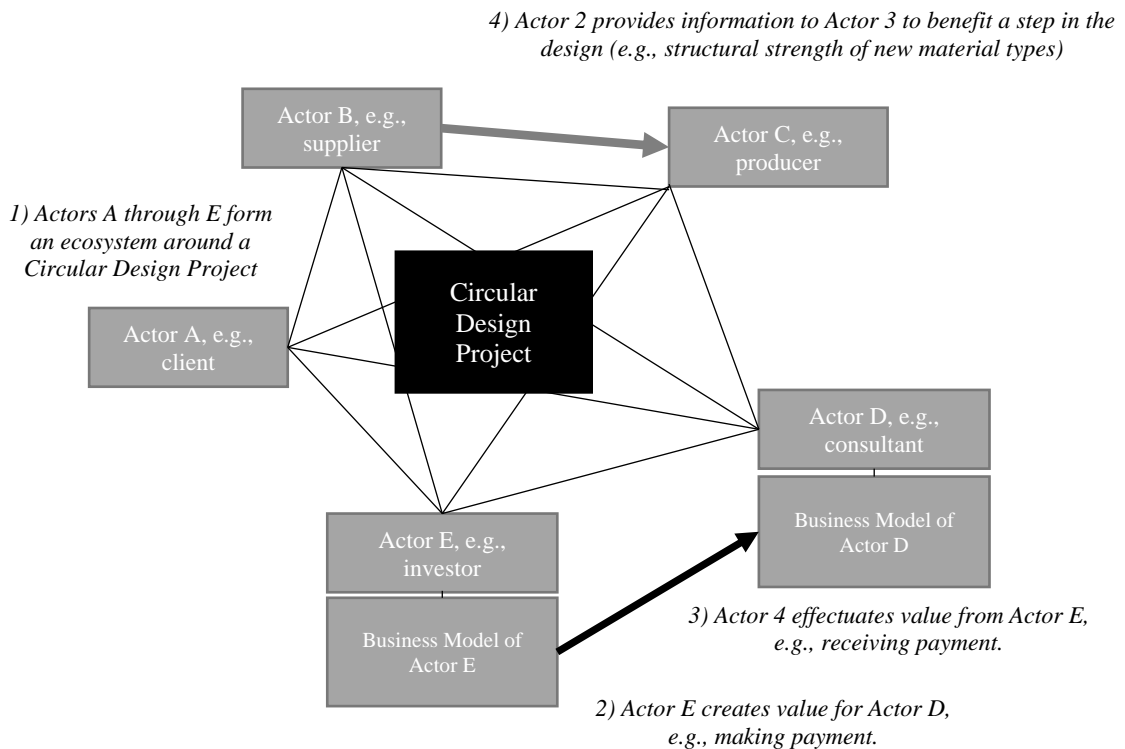


Fig. 1. Schematic representation of tools and relationships: (1) a circular design ecosystem with (2) businesses creating value as part of their business models, (3) other firms effectuating that value and (4) information exchanges to benefit the design

### III. METHODOLOGY

This paper aims to illustrate the use of four tools to (re)organize circular design projects through applying them to a case and reflecting on their potentials. This section first outlines the workings of Platform CB'23 and the role of the authors in this community of practice. It then presents the rationale for a case-study approach for augmenting our understanding of organizing circular design.

#### A. Context: tools developed by Platform CB'23

Platform CB'23 is a community of practice committed to fostering the uptake of circularity in the (Dutch) construction industry (see: <https://platformcb23.nl/english>). It does so by developing knowledge, identifying barriers and putting them on the agenda, and drafting sector-wide working agreements. To that end, diverse industry representatives – such as designers, contractors, suppliers and knowledge institutes – get together in working groups to collaboratively write a guideline on a specific topic. A larger action team regularly provides feedback on intermediate products. Underlying basic principles of these processes are: a transparent process, directed at practicable action and consensus building. The latest guideline on circular design was composed by three working groups [14]. These working groups delivered chapters on: Design Strategies, Roles and Collaboration, and Preconditions.

1. Design Strategies describe six relevant strategies that can be applied to include circularity in design projects.
2. Roles and Collaboration is about how the composition and organization of design teams changes when incorporating circularity.
3. Preconditions discuss the preconditions in the preliminary phase that are essential to make an optimal circular design.

All authors of this paper were members of the second working group. This working group developed the four tools presented in this paper.

#### B. Case selection

The authors of this paper have extended the previous work of Platform CB'23 by applying the four tools to a small-scale practical case and reflecting on their potentials. A case was selected based on two criteria. First, the case must involve a real-world, small-scale circular design project. Demonstrating the use of the tools can best be done for a project with limited practical complexity – so that changes are possible before scaling up. The minimum

number of actors would be two, creating at least one value matrix between two actors. This has the most illustrative power. Second, a case needs ideally an available applicant that can directly fill in the tools about the same project. This would allow for a demonstration of the tools to be shown as a complete case with connected results. Given these two criteria, a project was selected in which the fourth author was directly involved (as an active participant) – and data was thus abundantly available. This project concerned the use of reclaimed building materials for refurbishing an office building at the Media Park in Hilversum, the Netherlands. The tools were (retrospectively) applied to this project intending to illustrate their usages. To minimize potential biases, researcher triangulation was applied by critically discussing and reflecting on the case by all authors [29].

#### IV. RESULTS

The selected case project concerned refurbishing an office building (located at the Media Park in Hilversum, the Netherlands) with reclaimed materials. An interior designer was in the lead for this project. The building owner had tasked her with the assignment to create an interior design with a warmer ambience. She wanted to do that in a circular manner. That is, by reusing reclaimed building materials. Therefore, she enquired with a demolition contractor group, a long-term partner, whether there were any suitable, reclaimed materials available. The demolition contractor group consists of several firms specialized in transportation, (reused) materials supply and demolition services.

The reuse supplier received an assignment in 2020 via the interior designer to source reclaimed inner doors and wooden floor coverings (Figure 2). Specifically, this consisted of 72 door parts and 100 m<sup>2</sup> of recovered wood for wall decoration. The demolition contractor had disassembled the floor elements from the deconstruction of a museum depot and put these element in storage; the doors had various origins. The contractor had invited the interior designer to observe and select the stored materials. In addition, it was agreed with the designer that the wooden floor elements had to be refurbished on the visible side through a machine-based brush treatment. The materials were brought to the Media Park by the transportation firm and placed on location with the help of a truck-mounted crane. In the end, 26 doors appeared redundant, and these were brought back to the reuse supplier. The project lasted from March 2020 to June 2020. This case provides the backdrop for the (retrospective) application of the four tools.



Fig. 2. Reuse of recovered doors (left) and floors (right) to decorate walls in a circular interior design project (Media Park)

##### *Tool 1: Ecosystem compass*

The goal of the so-called ecosystem compass is to identify which actor in the ecosystem pursues which design strategy at which phase of the project. Four generic types of stakeholder groups are proposed: initiators, advisors, controllers and executors. These categories each have more detailed roles, which is case-dependent and differs per circular design project. The ecosystem compass positions these roles on the vertical axis. At the initiators' side, the (professional) client play an important role in the chosen case. There are also two types of advisors involved: the interior designer and the supplier of materials. As an executor, the demolition contractor is mentioned. The controller role is assumed by the professional client. The executor role is fulfilled by the general contractor and the demolition contractor. The horizontal axes represents the design strategies and project phases. Six relevant design strategies are derived from the circular design guideline:

- Design for prevention;
- Design for reduction;
- Design for reclaimed materials;
- Design with renewable resources;
- Design for futureproofness;
- Design for reuse.

The phases are depicted as: the initiative phase, design phase, realization phase, use phase and transition phase. In the end, the compass tells the life of the ecosystem surrounding the circular design project as observed by the

cross table. The matrix provides an overview, but the interpretation is more informative, if described by a narrative extracted from this matrix.

#### *Application*

The tool has been applied to the case of Media Park Hilversum (Figure 3). With data collected by the active participant, the matrix shows that three (out of six) circular design strategies were focused on. The ecosystem of the Media Park Hilversum project consists of two groups. On the one hand, the initiators and advisors, who pursue specific design strategies on reclaiming materials, future proofing and reuse. On the other hand, the executors and controllers, who have minimal design strategies in mind (only one from the demolition contractor to reuse). Other design strategies, like design for prevention, were overlooked.

Regarding phases, the ecosystem also has two clear groups. The initiator, advisors and demolition contractor (executor) are involved in the early phases of initiation and design. The interior designer remains active throughout the project phases. The professional client becomes active after design in the stage as a controller. It shows that sub-level roles can be the same actual company, but they switch roles at main level. Furthermore, the interior designer takes on two roles simultaneously in the last three phases (controller and advisor). The guideline also put forward a way to visualize the matrix (i.e., in a figure that actually looks like a compass), but that was not done for this case.



Roles		Design strategies						Phase				
		Design for prevention	Design for reduction	Design with reclaimed materials	Design with renewable resources	Design for futureproofness	Design for reuse	Initiative	Design	Realization	Use	Transition
Initiator	Professional client											
Advisor	Interior designer											
Advisor	Interior designer											
Advisor	Supplier											
Executor	Demolition contractor											
Controller	Professional client											
Executor	General contractor											
Executor	Demolition contractor											
Controller	Supervisor regulations											
Controller	Interior designer											

Fig. 3. Ecosystem compass for circular interior design case (Media Park) with dark grey colors indicating stakeholders' focal design strategies and light grey colors indicating their involvement during specific project phases

### Reflection

The compass helps to define which strategies are pursued by which role. It explicates focal design strategies and levels of involvement, which can be useful to set – or reset – project ambitions. The active participant noted that the respondent's company pursued their strategy in the first instance: design for reuse. Interestingly, during the realization phase the company did accompany the interior designer in their mission by exploring more design strategies: refurbishment and harvesting materials. A question that still arose during the compass was: What needs to happen with the insurance of the material value? In this case, in the end the interior designer assumed this role. A practical solution regarding the demountability was by designing the doors to fit mechanically, and not by glue. The floors were also demountable. Regarding the tool itself, the respondent did not experience any problems.

### Tool 2: Business Model Canvas

The Business Model Canvas tool is a table consisting of multiple sections that a company must fill in for its business model to become clear and complete. It starts with describing the circular value proposition of the company in the middle of the table. Then, on the left-hand side, the tool describes all the company's needs to deliver on that promise. The items include: partners, key activities, key resources. On the right-hand side, the wishes of the customer are described. The items here include: client segments, customer relationships and channels. Finally, on the lower bottom, the impact evaluation and cost structure and revenue streams are provided as artefacts of the operation of the business.

### Application

In Figure 4, one exemplary business model is depicted. The overall model is filled in for the general contractor involved in the case project. The business model type that is worked out is the example of a 'classic long life'. The circular value proposition says "deconstruction, transportation, and storage of circular materials". The company had partners in interior design and circular materials miners with hub. The company designed the circular interior with reclaimed doors and wooden floors, specialized deconstruction services and refurbishment as key resources. The company defined its customer as the end user and had a relationship with the end-user through the professional client, website and circular hub. The impact of the project was described in terms of the specification of materials and financial feasibility.

<b>Business Model Canvas for circular design (based on: classic long life)</b>		<b>Supplier:</b> demolition contractor	<b>Receiver:</b> professional client	<b>Date/place:</b> Hilversum, 2020
<b>Partners:</b> Interior designers and circular materials miner with hub	<b>Key activities:</b> Designing circular interior	<b>Circular value propositions:</b> Deconstruction, transportation and storage of circular materials	Customer relationships: professional client	Client segments: End-user
	<b>Key resources:</b> Reclaimed doors and wooden floors; Specialized deconstruction services; Refurbishment		<b>Channels:</b> website and visit to circular hub	
<b>Cost structure:</b> Market value + profit			<b>Revenue streams:</b> Based on market value, availability and appearance	
<b>Impact evaluation:</b> Available flooring with specifications (thickness, length and condition) coupled with technical and aesthetic design requirements; financial feasibility depending on cost estimations				
<b>Supply:</b> Reclaimed doors and wooden flooring		Integration	<b>Demand:</b> 100 m2 recovered floor parts and 72 recovered doors	

Fig. 4. Business Model Canvas for a general contractor in circular interior design project (Media Park)

#### *Reflection*

The canvas had quite some remaining unknowns for the active participant. Questions arose about who are partners? What are the profits and costs for this case? The revenue stream did lead to a discussion. Especially on this point it was difficult to determine the market value precisely. The respondent could eventually make an educated guess, based on the expertise that he accumulated in the business. Therefore, filling out the canvas was not that difficult from the position of the respondent. Upon review, it was noted that the impact evaluation, but also the circular value proposition, missed other outcome and value types than just financial, like social values.

#### *Tool 3: Value matrix*

The value matrix is a matrix that shows the value exchanges between different stakeholders in a circular design project. These stakeholders have different roles that create or effectuate value. On the column side the roles are lined up as parties that receive a specific value after an exchange. These parties are the same for both sides. In the case it was chosen to line up the parties as: the initiator, the advisor, the building contractor and the user. These actors can be categorized into the main roles mentioned above: initiator, advisor, executor and controller. However, the participant deviated slightly from this in the building contractor and user.

#### *Application*

The matrix in Figure 5 contains rich value exchange information. For example, it is shown that the initiator creates financial value for the advisor and contractor; and circular value to the user. As another example, the building contractor delivers value to the initiator by building the parts for easy disassembly later, and delivered value to the advisor by following through on the chosen design.

#### *Reflection*

The value matrix deviates in role description from the compass in this case. This shows that the value matrix requires filling in the details from a higher level of detail, instead of the main class of roles alone. Two types of value exchange were recognized the most in this case: financial value and circular proposition value. Financial value is provided as profits, and circular value is defined more at a surface level as the known descriptions of the design strategies or some solutions. The effect side of the value description is not yet noted.

		Value effectuation for			
		Initiator	Advisor/Designer	General contractor	End-user
Value creation by	Initiator		Financial profit for research, advice & design	Financial profit for reuse	Usage of a circular office (commercial-marketing) value
	Advisor/Designer	Building with circular materials (status) + financial profit for material after disassembly		Possibility and experience to build with reclaimed materials + marketing & commercial value	Design for multi-functional usage
	General contractor	Building for disassembly	Value through correct fulfillment of the design		
	End-user	Fulfill the negotiated preferred wishes + rental contract	Maintenance of the new interior		

Fig. 5. Value matrix for circular interior design project (Media Park)

#### Tool 4: Information needs matrix

The information needs matrix plots both supply and demand for circular design information in a matrix. All actors from the circular design ecosystem are plotted both on the horizontal and the vertical axes, representing supply respectively demand. The cells in the matrix indicate what type of information needs to be exchanged. Through color coding those cells, the preferred information exchange format – like drawing, report or Building Information Model – could (optionally) be visualized. The information exchange matrices can be made at the start (kick-off) of a project and then regularly repeated during subsequent design project phases.

#### Application

The information exchange matrix in Figure 6 shows essential types of information that different actors require in the case project. Depending on their role and position in the circular design ecosystem, the involved organizations have different information needs. The materials supplier, for example, needs information regarding the availability of recovered materials. This party can get that information from the demolition contractor who, in turn, needs to get the design brief from the interior architect. The matrix also reaffirms the key interior architect as a key player: she requests information from all other disciplines and eventually hands over the processed information to the client.

Actor		Information supply						
		Client	Interior architect	Demolition contractor	Materials supplier	Structural engineer	Supervisor regulations	General contractor
Information demand	Client		Final design, cost estimation and project management	Materials specifications				
	Interior architect	Plans and budget		Reusability and disassemble-ability	Availability, specifications and refurbishment possibilities	As-is conditions and possibilities	Requirements from rules and regulations	Assemble-ability possibilities
	Demolition contractor		Design brief					
	Materials supplier		Design brief	Availability of recovered materials				Wishes assembly for refurbishment
	Structural engineer		Wishes and building characteristics	Dis- and re-assemble-ability possibilities	Ownership and use of materials		Requirements from rules and regulations	
	Supervisor regulations		Future plans					
	General contractor		Design brief					

Fig. 6. Information needs matrix for circular interior design project (Media Park)

*Reflection*

The matrix was seen as a helpful tool to understand information flows in the project. It could be used to formulate agreements about information management. It was, however, also recognized that information does not only originate from other actors. For example, for reusing materials from the depot in the office building, it is necessary to understand the current conditions of those materials (as-is). The origin of that information is thus the building – with its materials – itself. The matrix is, however, limited to actors in the circular design project. The tool can nonetheless illustrate the flows of information in the project.

**V. DISCUSSION**

This paper has illustrated the use of four practical tools to (re)organize circular design projects. In the past few years, interest into circularity has proliferated among policy-makers, practitioners and researchers – yet particularly in Europe and China. Circularity is a core part of the European Commission’s Green Deal, for example. Such increased interests have spurred research and development efforts around the globe, most notably to identify design strategies and systemic barriers. Relatively little scientific attention has been paid to better understand how practical tools can support (re)organizing circular design projects. This paper has attempted to address that gap.

Four tools were presented: an ecosystem compass, Business Model Canvas, value matrix and an information needs matrix. These tools had been developed by Platform CB’23, a circularity community of practice in the Netherlands in which the authors actively contributed. The tools aim to provide practical guidance in circular design projects. The ecosystem compass does so by plotting (potential) project partners in a matrix and indicating both

their focal design strategies and the project phase they can contribute most. The business model of any firm in that ecosystem can be depicted in a Business Model Canvas, which structures the firms' activities around a circular value proposition. The value is not only limited to finances, but also extends to manufactured, intellectual, human, social and relationship, and natural capital values [23, 24]. The value matrix plots how different firms create and effectuate such values. The information needs matrix is similar of structure and provides insight into how circularity-related information is exchanged between various parties. These tools complement earlier circularity works – such as an empirically-based collaboration tool [19] or CE strategies and implementation databases [30] – with a focus on organizational aspects of design projects.

The tools were applied to a real-world case project and then reflected upon. The project covered the interior design of a refurbished office building at the Media Park in Hilversum, the Netherlands. Though this project was considered 'circular', the ecosystem compass highlighted that only three (out of six) circular design strategies were targeted: design with reclaimed materials, design for futureproofness and design for reuse. Other opportunities for circular design, such as design with renewable resources, had been overlooked. The tool also confirmed that the interior designer had a key role in the project and that the involvement of most other firms, such as the general contractor, was limited to one life-cycle phase. This may explain why that general contractor had adopted the archetype business model "classic long life" [22]: by creating value with a long lifetime potential, it can minimize its involvement in other life-cycle phases. The value matrix captured exchanges of different types of value as well, although still with a predominant focus on financial values. It appears more difficult to make other types of value tangible. Furthermore, applying the information needs matrix to the case revealed that information is not only exchanged between different organizations. For example, to advise on reuse potentials, the demolition contractor needed to get information about the as-is conditions of the office building – a "non-human actor" in actor-network theory [31]. Following that theory, the building also possesses agency within the network (or ecosystem) and has rights and responsibilities on its own. The idea of attributing identity to materials has previously been manifested in the concept of a material passport [32]. We complement that they are also suppliers of information that could be added to the information needs matrix.

The paper is subject to several limitations that point to future research directions. First, the four tools were applied to a case retrospectively. This means that it is still unknown how and to what extent they can improve circular design processes. More research should therefore implement applications of the four tools in actual projects and record the impacts. Second, the authors' involvement in compiling the tools (as part of Platform CB'23) and one of the authors' participation in the case project may have led to certain biases. Even though the scope of our work has been clarified and researcher triangulation was applied, it is possible that others could derive different insights. It is thus recommended to further validate our results through testing the tools in more and other settings, particularly with practitioners without any stake in (or knowledge about) them. Third, the synthesis of the tools has been tested insufficiently. Four problems motivated the development of the tools, but little remains known about whether these are the most prominent ones for practice or not – and whether they altogether provide a recipe for circularity successes. Future studies should thus investigate in more depth what the most prominent problems are and how the combined tools (in sort of a toolbox) could contribute to resolving those.

## VI. CONCLUSION

Organizational issues are among the greatest barriers for realizing circularity targets through design. This paper has introduced four new tools for dealing with such barriers. These tools include: an ecosystem compass (to map design strategies over project phases), a Business Model Canvas (to represent a business model), a value matrix (to explicate value exchanges) and an information needs matrix (to explicate information exchanges). These tools had previously been developed by a working group of the Dutch community of practice Platform CB'23. This research offers a next step by applying the tools to a real-world case project and reflecting on their potentials. Even though actual effects remain unclear, it is concluded that the tools can offer insights into organizational issues such as the ecosystem workings, business models, value exchanges and information exchanges. Practitioners could use such insights to take action and (re)organize their circular design projects.

## ACKNOWLEDGMENT

The four tools presented in this paper have been developed by a working group of Platform CB'23 (in which the authors took part) and improved with feedback from a wider action team. The authors express their gratitude to the other working group members as well as the action team.

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