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Developing a Framework to Integrate Circularity into Construction Projects

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Abstract: This study provides the first approach to integrating circularity in the early stages of a construction project by the project manager. The circular ambition of the Dutch government stimulates a different approach in project management compared to a traditionally applied approach in construction projects. Design science research (DSR) was used to develop a framework for project managers to integrate circularity in the initial phases of construction projects, and we divided this research into three steps: (1) investigate the problem, (2) design a solution and (3) validate the design. The performed design cycle and formulated design propositions resulted in a framework consisting of two A3 format pages. The framework explains a successful three-step approach: knowledge of circular economy in the construction sector is needed, circularity has to be integrated into the project preparation, and circularity has to be integrated into project management. Furthermore, the framework incorporates extra background information and a checklist with 27 identified success factors. The framework was validated by expert opinions as effective, is ready to be implemented and is described as useful for the current challenges, demands and questions of the market.

Keywords: framework; circular building; project manager; construction sector; initiation and definition phases; design science research; design propositions; fuzzy Delphi method

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1. Introduction

The enormous global economic growth, which has propelled human welfare, has been on a steep growth trajectory initiated by a series of industrial and technological developments [1,2]. The human population continues to use more material resources as the population grows and income increases, which will lead to a scarcity of many material resources, more expensive resources and, in the worst case, material loss for future use [3]. This fast-changing world with a highly unsustainable philosophy and way of living contributed to the writing of various policies to stimulate a more sustainable approach. The Dutch government has set the goal of having a hundred percent circular economy by 2050 and achieving an interim target of a fifty percent reduction in the use of primary raw materials by 2030 [4,5]. The construction sector has been selected as one of the priority sectors to achieve a circular economy since it is unavoidably linked to the (over)exploitation of natural resources [5,6]. The construction sector makes occasional use of less polluting and lower life cycle cost materials, such as biobased materials, composites and wood [7,8]. However, these materials are not used in the majority of construction projects on which this research focused. The building industry roughly consumes 40% of all materials globally while also generating 35% of the world's waste of which most is being landfilled or incinerated [5,9,10]. Several important milestones to reach the ambition of a 100 percent circular economy by 2050 are included in the timeline shown in Figure 1. In

2017, a Dutch raw material agreement was signed by companies and the government to foster the circular economy, which resulted in priority sectors (e.g., the construction sector) and their transition agendas in 2018. Stimulation of circular building started in 2021; in 2023, the government was advised to ask for a circular component(s) in all tenders, and this will be rolled out to all public institutions by 2030.

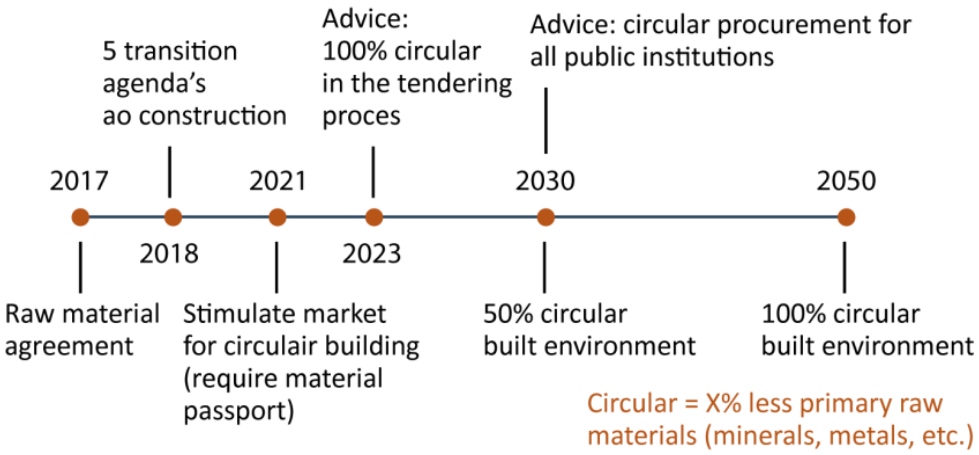

Figure 1. Milestones to become 100% circular by 2050 [11].

The current economy is called a linear economy, which has been sustained by cheap and available resources to create conditions for growth and stability. In this "take–make–dispose" economy, goods are manufactured from raw materials, sold, used for a certain time period and then thrown away or incinerated as waste [12]. Conversely, the circular economy (CE) is an economic system aimed at eliminating waste, pollution and emission and employing reuse, remanufacturing and recycling to create a closed system [13]. The circular economy aims to keep products, equipment and infrastructure in use for a longer period, thus improving the productivity of resources in order to decrease waste generation to the largest possible extent [13,14]. Different definitions are used in research describing the circular economy. However, the definition (and the extensions) defined by the Ellen MacArthur Foundation is used the most and is adopted in this article since it forms a fundamental principle in many studies [15]. "*A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models*" (p.15) [12].

It should be noted that the approach and philosophy of a circular economy are radically different when compared to the linear economy, and these differences can be shown by using the biological and technical resource cycles (Figure 2). The biological resource cycle represents materials that can safely return to the biosphere and can function as biological nutrients for the next cycle. The technical cycle aims to minimize the use of raw materials by extending the lifetime of products, using fewer materials through smart design or reutilizing the materials after their lifetime [16]. The cycles that represent the linear economics intertwine which results in a product that is difficult to recycle unlike the two separate cycles of the circular economy which remain strictly separate [17,18].

Few research studies have addressed the issue of integrating the circular economy in the building industry. The study of Ref. [19] stated that the building industry implements innovations, such as a circular economy, relatively slowly. The research of [9] complemented the slow transition to a circular economy by stating that it has already been applied in many other sectors using frameworks, which refers to organizing (new) ideas in an overall picture to remember and apply the (new) concept, but few frameworks have been developed for the complex problem of the construction industry. The report of [4] set a priority to have knowledge, experience and the right instruments in the right place to transition to a circular

economy. In addition, according to the study of Ref. [3], the client, who initiates a project, has a major force in ensuring circular economy outcomes at a project level by the client's vision and strategy, but the same study concluded that the client does not recognize this as a major factor or does not have the knowledge to implement it. The project manager, whose main task is to advise the client in order to achieve the client's final goal and to manage the process of a project, does not have the knowledge and capabilities to execute circular construction projects either [20]. Previous research recommends observing the involvement of project managers in a circular project and investigating their tasks and their addition in the transition to a circular project [21].

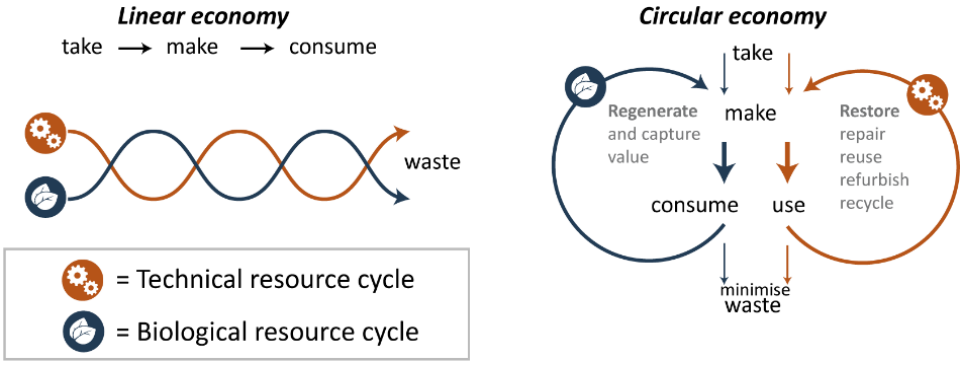

Figure 2. Illustration of the resource cycles representing the biological and technical cycles per economy [11].

A circular building process is assumed to be a different process compared to a traditional building process since it involves other supply chain partners, uses new structures of ownership of materials and products and creates new income flows [21,22]. The study of Ref. [22] implied that the management of circular building processes will not be effective or lead to truly circular results unless it is based on the concept of circular economy. This means that projects managed from a non-circular worldview are unlikely to deliver the performance and benefits of the circular economy.

The mentioned research studies above were focused on integrating circularity in the entire building process, and no study specifically focused on the initial phases of a project, namely the initiation and definition phases. The studies mentioned did provide some factors that should be applied in the early stages of a project, but this knowledge is still very limited. An approach to integrating circularity in building projects is to increase the capabilities and knowledge of project managers. This leads to the problem context for this research: the lack of capabilities and knowledge of project managers, who are involved in construction projects during the initiation and definition phases, to execute circular construction projects according to the concept of circular economy. This research attempted to design and present an instrument in the form of a framework to reduce the problem context. Therefore, this paper focusses on the following question: "How to design and validate a framework for project managers, who are involved in the initiation and definition phases of a construction project, that improves their capabilities and knowledge to realise circular construction projects?".

Three sub-questions were formulated to answer the main research question:

1. Which information needs to be included in the framework for project managers to implement the concept of a circular economy in the initiation and definition phases of construction projects?
2. How to design the framework?
3. How to validate the framework?

Sub-question one investigates the problem using literature, interviews, case-based research and the fuzzy Delphi method and formulates design propositions since it focuses on (i) identifying steps for a circular project approach, (ii) the role of the project manager

in a circular project, (iii) identifying success factors that need to be included in the initial phase to realise a circular building project and (vi) determining the requirements for the framework. The second sub-question designs the solutions by (i) examining which frameworks exist and what they should look like and (ii) creating the framework. The third question validates the created framework using interviews.

As the objective suggested, this research focused on the initial phases of construction projects. The initial phases are the initiation and definition phases and provide the foundation for the next phases of a project, which are defined in this research as the design phase, realisation phase and maintenance phase. The initiation phase is the first phase of the project in which the idea for the project is explored and elaborated, the feasibility of the project is examined, and the goals are translated to a proposal or a project plan [23]. The definition phase is the second phase in which the requirements of the project are specified as clearly as possible, some feasibility studies can be performed, the budget and the programme of the project are defined, and procurement strategies are investigated [23]. Furthermore, the framework was created for construction project managers that are involved in those initial phases of a project.

This article includes three more sections in order to answer the main research question. The following section elaborates on the research methods used and therefore elaborates on design science research, interview methods, case-based research and the fuzzy Delphi method. The section that represents the results is divided into three different phases and focusses on problem investigation (sub-question 1 and phase 1 of the design cycle), solution design (sub-question 2 and phase 2 of the design cycle) and solution validation (sub-question 3 and phase 3 of the design cycle). The final section elaborates on the conclusion, discussion and recommendations of this research.

2. Methods

This article is based on design science research. Scientific research first and foremost deals with describing, explaining or predicting situations. In this way, theory is formed, tested or further elaborated upon. This view of scientific research is broadly accepted in the academic community. Even though the outcome of research is transferred by means of journal publications, congresses, etcetera, most professionals do not make use of these research findings, as they are—to a great extent—impractical in terms of addressing the (day-to-day) problems they deal with. It makes sense, then, that one of the criticisms levelled in the field of (construction) management and organization is that it is too focused on describing or explaining phenomena and not focused enough on developing knowledge that could help professionals solve real-life problems or field problems [24]. Design science research can reduce this gap between theory and practice in the field of (construction) management and organizations, as it has a prescriptive approach [25]. Due to this prescriptive approach, design science research is a methodology that pays attention to the relevance of studies for professionals in organizations [25]. By relevance, we mean that the knowledge that has been developed in the academic world has the capacity to have a significant impact on practices in the wider world, such as in the field of (construction) management and organizations [26].

This does not mean that the emphasis in design science research is placed on relevance instead of rigour, where rigour can be defined as the proper use of research methods [27]. In design research, emphasis is placed on scientific rigour but also on achieving outcomes that are relevant to the field of (construction) management and organization.

The outcome—or solution concept—for a field problem in design science research can take the form of an artefact that can be used by professionals in a specific field. Artefacts form "according to a classical philosophical definition (...) an autonomous class of instances including all and only those objects that do not exist in nature, but are artificial, in the sense that they are made by an artĭfex" (p. 407) [28], or in other words, they are made by a human being. The result of developing and studying these artefacts has a prescriptive nature and is aimed at problem solving by professionals in a specific field [29]. This

research tried to design and present a solution for the field problem of integrating the circular economy into the initial phases of construction projects by creating a framework. For conducting design science research, a design science research cycle is used. Several design science research cycles have been developed; nonetheless, this research used the cycle developed by [30], who mentioned two cycles: the engineering cycle and the design cycle [30,31]. The design cycle consists of the following components: (real-world) problem investigation, treatment design and treatment validation. The engineering cycle elaborates on the design cycle by implementing the treatment and the implementation evaluation [30]. In this study, the focus was exclusively on the design cycle, and the term treatment was replaced by solution since in an engineering environment, it is more common to use the term solution.

The sub-questions, formulated to answer the main research questions, can be categorized into the topics of the design cycle: sub-question one focusses on the investigation of the real world, sub-question two addresses the solution design, and sub-question three validates the solution. The design cycle can be completed several times in design science research but was completed once in this study due to time constraints.

2.1. Case-Based Research

In order to investigate the real-world problem, differences between projects were examined by analysing cases. Since the investigated projects were not examined using averages and variations, it can be concluded that case-based research was chosen [30]. Case-based research used project documents to analyse the project and was complemented by at least two interviews to complete the information obtained from the cases in order to reach triangulation of data [32]. Two terms were used to categorise the project management types:

- Traditional project (management) implies that a project is realised according to the current management and executed according to the take–make–dispose plan, also known as the linear economy. Within a traditional project, circularity does not occur in the questioning (belonging to the initiation and definition phases) or in the realisation or execution of the project.
- Semi-circular project (management) indicates that the managed project consists of (a few) components according to the circular economy.

Based on the theory of [33] stating that analytic conclusions arising from more than one case study will be more powerful than coming from one single case, this research set a minimum requirement of analysing at least 2 cases per project management type. In total, six projects were identified and examined as case studies. Table 1 shows the project code, the type of project management and the phase they operated in during the research.

Table 1. The six case studies examined in this study with their code, type of project management and operating phase [11].

Code of Project	Type of Project	Current Phase
Project A	Traditional project	Realisation phase
Project B	Traditional project	Realisation phase
Project C	(Semi-)Circular project	Realisation phase
Project D	(Semi-)Circular project	Realisation phase
Project E	(Semi-)Circular project	Completed
Project F	(Semi-)Circular project	Design phase

2.2. Interviews

In this study, interviews were conducted using the semi-structured interview approach. The semi-structured interview, which combines the best features of the unstructured and structured types ensures that the area of focus is covered due to the set of predetermined

questions, while the possibility of developing the interview towards other directions of interest remains present.

Interviews were conducted with circular advisors (Interview A) and construction project managers (Interview B) to gain knowledge in order to answer sub-questions 1 and 2. Interview C was used to collect additional information from stakeholders of the analysed cases in order to supplement the case-based research. Interview D was used to validate the framework with experts related to sub-question 3. The interview protocol, with the questions used during the interview, can be requested from the authors.

The purpose of interview A was to gain more insight into circularity in the construction sector and how circularity should be integrated by the construction project managers according to the circular advisors. The purpose of interview B was to gain more insight into construction project managers' knowledge of circularity, which knowledge they need in order to be able to integrate the concept into their projects and what requirements they consider for the framework in order to be able to integrate and apply circularity in construction projects. Interview C was part of the case analysis. As previously mentioned, six cases were analysed, and for every case, two stakeholders were interviewed. The target was to interview the project manager of every project and a second involved person in the project which could be the client. Interview D was used to validate the developed framework with experts. All used experts were construction project managers.

During every interview, the researcher briefly introduced the research, described the aim of the specific interview and explained briefly the content of the interview. Due to COVID-19 restrictions, the interviews could not be conducted face to face but had to take place via Microsoft Teams. All interviews were recorded with the approval of the respondents.

2.3. Fuzzy Delphi Method

In the problem investigation phase of the design science research cycle, we identified several success factors by conducting a literature study, interviews (A and B) and a case study analysis. To obtain an overview of the most important success factors within the initiation and definition phases to enhance circular projects, the fuzzy Delphi method (FDM) was used to assess the identified success factors.

The fuzzy Delphi method is a combination of the Delphi method and the fuzzy set theory [34,35]. The traditional Delphi method is a systematic method of collecting data in a structured way and finding consensus about a certain subject within a group of experts by using a questionnaire [36,37]. Three important features of the Delphi method are anonymous response, iteration and controlled feedback, and statistical group response [38]. It is a valid method for forecasting, and it facilitates collective decision making. However, the Delphi method is limited in resolving the fuzziness of the experts' consensus within the decision-making process [34]. Uncertainties in the Delphi method are mainly caused by the human element, who validate the factors by means of a questionnaire. The fuzzy set theory is suitable to tackle the uncertainties by embracing the fuzziness by adding the fuzzy set theory to the Delphi method [34,36]. Furthermore, by combining these two methods, the quality of questioning and the questionnaire will improve, and this will result in a more efficient and reliable study outcome [34,35]. The fuzzy Delphi method consists of the following five steps [34,38].

1. *Validate predefined list of factors*

The first step of the fuzzy Delphi method is obtaining and selecting the input data. Several success factors were identified by conducting a literature study, interviews (A and B) and a case study research.

2. *Collect opinions of expert group*

The researchers contacted 30 potential respondents, who were circular advisors or construction project managers. Some potential respondents had knowledge about both fields: circular economy and construction project management.

The outcome of an FDM questionnaire might be reliable with a homogeneous group of 10–15 respondents [39]. The five-point Likert scale was used in this research to validate the success factors and is shown with the used description and the corresponding triangular fuzzy numbers in Table 2. The five-point scale was used since this scale can very well function to reflect the opinion of the panel, and the answer options are fewer which makes it easier for the respondent to choose an answer compared to using a seven- or nine-point scale. In this research, the min–max method, which involves asking respondents to give a range for each success factor, was not used due to the size of the questionnaire and the corresponding risk that respondents would not finish the survey [35].

Table 2. The five-point Likert scale with description and corresponding triangular fuzzy numbers [11].

Description Questionnaire	***Very Unsuccessful***	***Unsuccessful***	***Neutral***	***Successful***	***Very Successful***
Value questionnaire	1	2	3	4	5
Fuzzy numbers (a_{ij}, b_{ij}, c_{ij})	(0, 0, 0.25)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1.0)	(0.75, 1, 1)

3. *Set up overall triangular fuzzy number*

The outcome of the questionnaire resulted in a matrix that shows the rated values per success factor for all the different respondents and was as follows:

	$\mathbf{R_1}$	$\mathbf{R_2}$	**…**	$\mathbf{R_n}$
$\mathbf{SF_1}$	L_{11}	L_{12}	…	L_{1n}
$\mathbf{SF_2}$	L_{21}	L_{22}	…	L_{2n}
…	…	…	…	…
$\mathbf{SF_m}$	L_{m1}	L_{m2}	…	L_{mn}

where:

R_i = The i^{th} respondent, $i = 1, 2, \ldots, n$

SF_j = The j^{th} success factor, $j = 1, 2, \ldots, m$

L_{ij} = The linguistic evaluation of success factor j by respondent i

In order to understand the group decision for each success factor, the general mean model was used proposed by [40]. By using the mean model, the evaluation value of one of the success factors by a single respondent was expressed as a triangular fuzzy number (see third row of Table 2 and Formula (1)):

$$\tilde{\omega}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \quad (1)$$

where factor j corresponds to the success factor, given by the respondent, factor i. Where $i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m$. Then the fuzzy weighting $\tilde{\omega}_{ij}$ of j is:

$$\tilde{\omega}_j = a_j + b_j + c_j \quad (2)$$

in which

$a_j = \min\{a_{ij}\}$, $b_j = \frac{1}{n}\sum_{i=1}^{n} b_{ij}$, $c_j = \max\{c_{ij}\}$

4. *Defuzzification*

The next step in the fuzzy Delphi method is converting the triangular fuzzy numbers into single real numbers. This step is called defuzzification. In this research, the simple centre of gravity method by [40] was used to convert the fuzzy weight w_j of each single success factor to single derived numbers s_j where $j = 1, 2, \ldots, m$:

$$s_j = \frac{x}{3} \quad (3)$$

where x is $(a_j + b_j + c_j)$

5. *Screen evaluation indexes*

To select the highest-evaluated success factors for the project manager to realise circular projects and which should be included in the framework, the single derived numbers were tested against a threshold (α).

If $s_j \geq \alpha$ Success factor j is more successful and is included in the framework.

If $s_j < \alpha$ Success factor j is less successful and is not included in the framework.

The literature describes no standard method for setting a threshold. The threshold therefore has to be set on the needs of the study and was mostly based on the researchers' opinion [41,42].

3. Results

The design cycle was chosen to perform design science research and consisted of three phases: real-world problem investigation, solution design and solution validation. Every phase gave input to an upcoming component. The results were categorised according to these phases. The first phase, the real-world problem investigation, consisted of the knowledge question, which implies asking for knowledge about the world as it is. The second phase, solution design, designed the artefact to solve or reduce the problem context. The third phase, solution validation, validated the artefact.

3.1. (Real-World) Problem Investigation

3.1.1. Three Identified Steps for a Circular Project Approach

The real-world problem investigation identified three steps for a circular project approach in the initial phases of a project. Creating awareness and support is the first step to be completed in the early stages of a project and is called "knowledge of circular economy in the construction sector". Once this awareness is present, circular ambitions and objectives should be formulated for the project, which is step two, called "integrate circularity into project preparation". These additional objectives have to be managed and result in consequences for the management aspects, which must be taken into account in the initial phases of a project. For the management aspects money, time, organisation, information, procurement and risks, consequences were collected in this study. This third step is called "integrate circularity into project management".

Step 1—knowledge of circular economy in the construction sector

In the construction sector, a definition is given to circular building and circular construction. Both definitions are supported by the Dutch government advisor on circular construction named Platform Circulair Bouwen 2023. The following definition is given by them for a circular building: "*Circular building means developing, using and reusing buildings, areas and infrastructure without unnecessarily depleting natural resources, polluting the living environment and damaging ecosystems. Building in a way that is economically and ecologically responsible and contributes to the well-being of people and animals. Here and there, now and later*" [43]. This definition of circular building is in line with the given and widely accepted definition of the Ellen MacArthur Foundation [12,44]. The definition of circular building is focused on the built environment but is broad in the sense that buildings, areas and infrastructure are all mentioned. A building does not only have a function but must also seek connection with the context as indicated by [45–47]. However, the definition of circular building is still vague regarding where to start and how a building can be built with a circular approach. A circular construction is defined in a twofold manner by [48]: "*a circular building (i) is designed and executed according to circular design principles and (ii) is realised with circular products, elements and materials*". This definition gives more guidance by referring to circular design principles and the focus on products, elements and materials. The circular design principles, mentioned in this definition, are: prevention, value preservation of materials and value creation of materials. The definition of a circular building focuses more on the different layers of a building as it deals with products, elements and materials and

is therefore more in line with the identified layers by Stewart Brand [49]. Both definitions can be used according to the user preference to explain circularity, but a difference can be made in a broad view where the context is included or the focus is exclusively on the building itself.

The CE advisors of interview A mentioned some circular strategies to focus on in a circular project, which are demountable, modular construction, the use of renewable materials, using biobased materials and building in wood [46,47,50–54]. The literature complements this with building in layers, designing out waste, designing for adaptability, designing for disassembly and selecting materials [11,55–58].

Regarding the butterfly model (Figure 2), the building sector mainly affects the technical cycle, as raw materials are extracted and converted into building materials. In the butterfly model of [12], different levels and options are given to circularity, also called circular design approaches. These circular design approaches are extended in different R-models, models in which all circular design approaches start with an R, and the approaches are prioritised [43,59–62]. For this study, the 10R model [59] was added to the model of [43,61]. The 10R model, which is shown in Figure 3, can be seen as a ladder where the highest possible step would be more ideal for a circular approach.

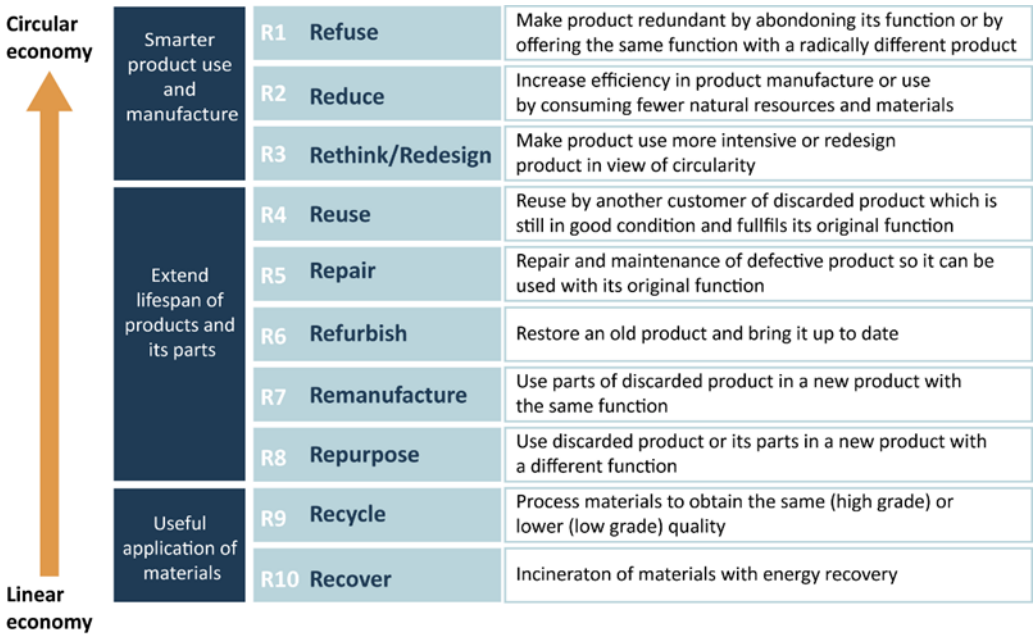

Figure 3. The 10R model [11].

The research of [63] stated that considering the building as a complete object is still the prevalent way of thinking about buildings and that they should be seen as dynamic structures that constantly adapt to current needs. The layer model of [49] divides a building into different levels and consists of six layers. The shearing layers of Brand include: site, structure, skin, services, space plan and stuff. Each layer encloses materials or parts with the same speed regarding maintenance and lifetime duration. Recognising different layers in a building will make it easier to adapt if these layers are also taken into account in the design and construction of a building [49,64]. Figure 4 visualises the shearing layers and their expected average lifespan.

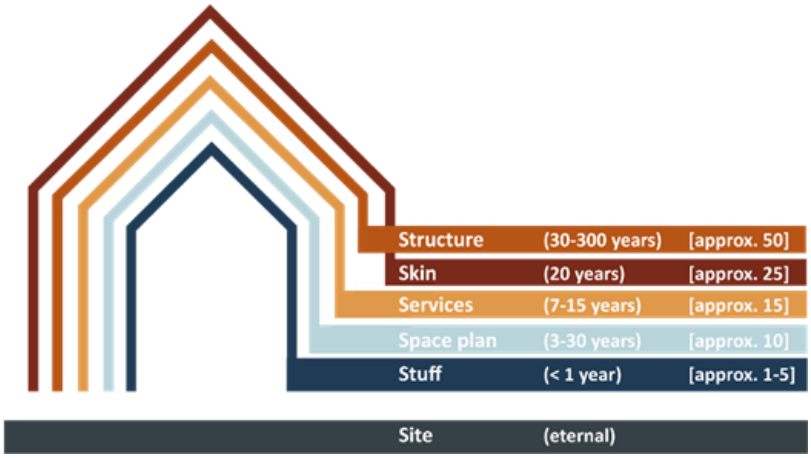

Figure 4. Shearing layers and their expected average lifespan [11].

In addition to the above information, the timeline visualised in Figure 1 and some links need to be included in the framework to enhance the knowledge of the circular economy in the construction sector by the project manager or client. Links to the government website with the climate change agreement document that outlines the need for change, the Ellen MacArthur Foundation website that explains the principles of a circular economy, the website of platform CB'23 and a link for circular project examples of "De Circulaire bouweconomie" need to be added to the framework [43,65–67]. The information gathered in step 1 contributes to the goal of creating awareness and support for a circular approach and should be generated as early as possible in the process, thus the initiation or definition phase of a project. Awareness and support can be created by starting a conversation with the client, in which the need for a circular economy, the definitions of a circular economy and design strategies should ideally be discussed. The working method, when approaching a circular project, will first of all require awareness and support for a circular approach from the client [46,47,50–52]. This is usually achieved through a dialogue in which the customer must be convinced to adopt a circular approach [50]. The initiative for a circular approach can originate from the project manager or from the client [47,50,51]. The following questions should be addressed: "What does circularity mean to you?", "What are your goals?" and "What can be achieved?"

Step 2—integrate circularity into project preparation

Adopting a circular approach in step 1 will (hopefully) lead to circular ambitions. The circular ambitions in the analysed (semi-)circular projects all originated from the client. In order to describe the circular ambitions, the 10R model of [59] and the 6S model of [49] were used [47,50,68,69]. Furthermore, it became clear that a project cannot be 100% circular. Different circular strategies are used in a (semi-)circular project, such as using secondary materials, using renewable materials and detachability, including material passports or the consideration of whether people feel comfortable with the project [68–71]. These strategies were of interest to the research but were not the primary objective of this research. Circular ambitions of a project can be documented in opportunity cards and/or ambition documents [68].

Adopting a circular approach will not result in different work activities but in different starting points whereby circularity is an addition to the current work [50,51]. The circular ambition needs to be translated into circular project objectives. In order to formulate circular objectives, a definition for circularity within the project could be expressed. The following questions could be asked: "What is a suitable definition for circularity in this project?", "What is the target for circularity in this project?" and "How will circularity be included in this project?" A definition of circularity was formulated in project C by the client in contrast to project F where the market parties formulated the definition of circularity.

The circular objectives should be as specific and complete as possible and should be defined, ensured and measured [46,51,52]. Possible requirements are: certain parts of the

building should be demountable, parts should be designed in a modular way, biobased materials should be used, renewable materials should be used, the building should be designed according to the Stewart Brand layers model, the building should consist of x% reused materials, or the amount of reused materials should be based on the monetary value rather than the quantity value [50–52,68]. Within projects C and E, the project team formulated circular objectives, while in projects D and F, the market parties had to formulate the objectives. When the market parties defined the objectives, the projects indicated during interview C that they missed an independent person who could assess the circular objectives. A circular advisor can be added to the process in order to formulate, ensure and measure the ambitions and objectives and operate as the requested independent person [50,51,71]. The formulated objectives have to be ensured which can be done using a qualitative approach (objectives, ambitions, plan of approach) or a quantitative approach (environmental cost indicator, material passport) [50]. Furthermore, indicators should be defined to measure the objectives, such as: GPR, BREEAM, WELL, life cycle analysis, material passport, environmental cost indicator, 10R ladder with a weighting per R, the MPG score, detachability measurements and the CPG-score [46,51,53]. In projects C, E and F, the measurement indicators were determined.

The objectives can be documented in the programme of requirements. The ideal process of the project preparation is visualised in Figure 5.

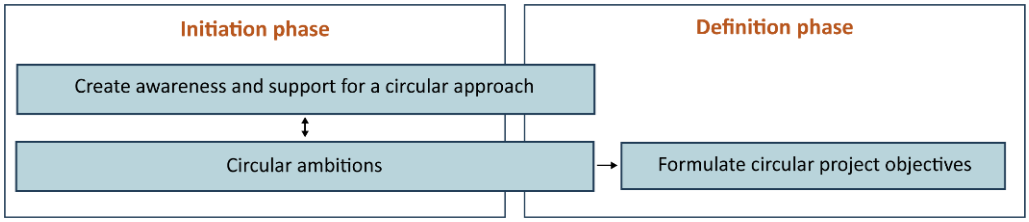

Figure 5. Process of the project preparation [11].

Step 3—integrate circularity into project management

The project management of traditional projects does not need to change in order to manage circular projects, but (circular) objectives need to be added, and this will (most of the time) lead to consequences for the management aspects. When considering the duration of the phases and the planning of the six different projects, no conclusion can be drawn between traditional projects and (semi-)circular projects, since these are different types of projects with their own needs and decisions, and the research did not focus on the planning [68–73]. However, in project C, extra time of 1 to 2 months was needed for drawing up and formulating circular ambitions during the early stages of the project. Similarly, a conclusion could not be drawn about the total budget of projects. However, it can be concluded that financing circularity in the projects is handled differently. Projects C, D and E show that a (semi-)circular project is on average 5 to 25% more expensive. Project F challenges the market to be as circular as possible within the established traditional estimated budget. The extra money needed for projects D and E came from learning and sustainability budgets of their organisation. None of the projects worked with a residual value that might be released at the end of the project's life. The financing concept product as a service was only used in project E for the elevator facilities.

The six projects all used a different approach for tendering market parties and the moment of the procurement. There was no focus on the content of contracts and the selection procedure in this research. Instead, the focus was on the moment of selection, and the different options are visualised in Figure 6. This figure assumes that a circular ambition was adopted in the initiation or definition phase. The traditional projects A and B and the (semi-)circular projects E and F selected market parties after the definition phase. Project C conducted a selection phase for a construction team in the definition phase. Integrating a construction team is a common method when executing circular projects and was also used by the traditional projects. Project D selected the designing parties after the initiation

phase. The maintenance phase shows in Figure 6 the responsible stakeholder, in which the client can also refer to the maintenance team of the client. In addition, the client and the project manager are not included in Figure 6 as this is about the selection procedure, but they are present in all phases. The (semi-)circular projects all used UAC-ic contracts, such as the design, build and maintain contract, and the traditional projects used a UAC contract or a UAC-ic contract.

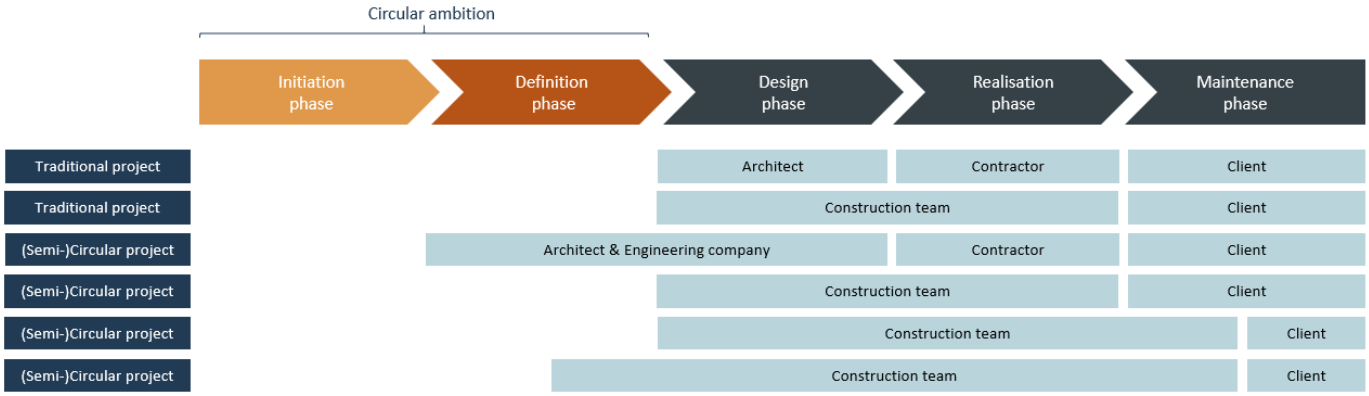

Figure 6. Different approaches to involve market parties [11].

Collaborations with circular advisors and involving market parties (early in the process) are recommended by the circular advisors and construction project managers [51,52,74–78]. In addition, circularity should be integrated within meetings and adopted by the whole project team [52]. Furthermore, it is recommended to document project information and to obtain and create in- and output information of the construction project.

A circular approach will give rise to new risks that need to be managed, for example, obtaining safety certificates and guarantees by reusing used construction materials or the availability of materials [46,70]. The client can take more risks to stimulate the market.

Step 2 and Step 3 interact with each other, as information about the content and management aspects will be needed to have the conversation with the client and formulate the ambitions and goals.

3.1.2. The Role of a Project Manager in a Circular Project and Their Current Knowledge in the Field of Circular Economy

The project manager manages the process of a project from idea to realisation, whereby the project is divided into phases, and certain products need to be delivered per phase [79–81]. When adopting a circular approach, the project manager's task is to encourage circularity, add it formally to the project, provide the client with an impression of circular construction and ensure that a demand arises with circular ambitions for the project [46,50,54].

The interviewed project managers in interview B estimated themselves to be project managers with knowledge of various aspects of the circular concept but needed the help of an expert to include substantive knowledge and to overcome some barriers. These barriers include, but are far from comprehensive, a lack of support from the client, the unwillingness of other stakeholders involved in the project and financial reasons. The worldwide web, circular advisors or colleagues are the information sources of the project managers.

The project manager does not need to know all the technical aspects of a circular approach, but more knowledge is desirable to be able to properly advise the client. The project manager should have basic knowledge of the concept of circularity, understand what the concept attempts to achieve and be able to involve an advisor when necessary since the client must be able to rely on the project manager's knowledge [47,50–53]. Furthermore, a project manager should be aware of the changes that are needed and the shifts that take place regarding the interest in a circular economy [50].

In order to innovate or integrate new concepts, the client has to trust the project manager. The interviewed project managers show initiative for new concepts and are open

to innovate. However, the number of new concepts and the overlap of concepts make it difficult to keep the knowledge up to date. A plan that describes the different steps that need to be taken is desired to integrate a new concept [76]. The project manager should take the lead in the transition to circular projects and should draw the client's attention to a new development such as the circular approach. The client, advisors and project manager(s) are involved at every stage and in every type of project.

3.1.3. Identified Success Factors to Help Project Managers Integrate Circularity in Construction Projects

A success factor was defined, in this research, as a factor that needs to be added to the initiation of a project in order to adopt a circular approach and will influence the successful management of a circular project.

The success factors resulting from the literature focus, for instance, on describing ambitions, formulating objectives, cooperation with external parties, selection of market parties, the project team, the sharing of project information and the role of the client. The success factors resulting from the results of this research focus, for instance, on: the role of the project manager in the initial phases, conducting a conversation with the client, defining circular ambitions, formulating project objectives, the selection of market parties, the documentation of project information, including reflection time and budget-related aspects. The most significant success factors that emerged from this study are focussed on ensuring and measuring circular objectives and success factors for the project manager.

The success factors identified in the literature and in this research were re-examined, merged and reduced to a list of 66 success factors that were assessed using the fuzzy Delphi method. The 66 success factors were classified within the main categories "project preparation" or "project management" and are divided into several sub-categories. The 66 success factors with their source are added to Appendix A.

Thirty potential respondents were contacted to rate the success factors with a five-point Likert scale in a carefully designed questionnaire. Twenty-five respondents completed the questionnaire. The respondents can be divided into the following groups: (1) circular advisors, (2) construction project managers and (3) respondents that have knowledge of circularity and construction management.

Given answers of the respondents with the five-point Likert scale were converted to single derived numbers per all respondents, group 1, group 2 and group 3. These single derived numbers were tested against a set threshold of 0.6. These calculated numbers can be requested from the authors. The aim of the assessment was to identify the most successful factors that could make the biggest contribution to realise successful projects when adopting a circular approach. The margin between the highest given value and the lowest given value was limited. This small margin can be explained by the fact that the factors were identified as success factors through different methods and had to be ranked to narrow down the list of success factors. The first threshold was set at 0.6 which resulted in 18 success factors that scored above the threshold if the single derived numbers of all respondents were used. There is a significant difference in the answers given by the various groups on the degree of success per success factor. This means that a success factor might not be taken into account due to the score of all respondents, although it would have been ranked very high by a single group, and this would not do justice to the available data and the respondents involved. Furthermore, it should be noted that a different question was asked to the different respondent groups in the questionnaire. Group 1 was asked to rate the factor in terms of circular successfulness, group 2 rated the factor on integrating the factor successfully in a project, and group 3 considered both. Therefore, a sensitivity analysis was conducted by creating four scenarios in which different respondent groups have more influence than others. All four scenarios were created on the basis of assumptions and can be found in Table 3. The values of the single derived numbers per success factor were also calculated for the four created scenarios and can be requested from the authors.

Table 3. Overview of the four created scenarios [11].

	Scenario 1			**Scenario 2**			**Scenario 3**			**Scenario 4**
Group	***1***	***2***	***3***	***1***	***2***	***3***	***1***	***2***	***3***	***All***
Power	2	1	3	1	2	3	1	3	2	1
Interest	3	1	2	2	3	1	2	1	3	1
Importance value	6	1	6	2	6	3	2	3	6	1
Weight	0.46	0.08	0.46	0.18	0.55	0.27	0.18	0.27	0.55	0.33
Explanation of the scenario	Group 1 and group 3 can col-lectively make the best estimate of what the most successful factors are. The scenario is determined by giving group 1 and 3 the same weight.			It was assumed that group 2 with the project managers would know best which success factors could be applied since all factors that have to be validated were already identified as success factors. Furthermore, group 3 also has more power since it also includes project managers.			It is assumed that group 3 should have the most influence because they can make both considerations and have already performed circular projects in the role of project manager.			It is based on equality between the different groups. It should be noted that this scenario is different compared to the all-respondent values since the numbers of respondents differ per group.

The phenomenon that some groups of respondents rated the factors much higher than others could not be ignored, and therefore, the scenarios were included in the selection of the success factors. The threshold was increased to 0.64 in order to meet the requirements set by the researchers of a maximum of 30 accepted success factors. This second set threshold resulted in 27 success factors, in which eight success factors were associated with project preparation and 19 success factors with project management. These 27 accepted success factors can be found in Table A1 and should be included in the framework as a tool for the project managers to help integrate circularity in construction projects.

3.1.4. Determining the Requirements for the Framework

Within this research, there was not enough time or capacity to fulfil all preferences of the interviewees. Therefore, four design propositions with the CIMO-logic approach were drawn up with the help of the preferences to which the framework must comply [82]. These design propositions include: to help the project manager to integrate circularity into the initiation and definition phases of the project, the framework designed for the project managers can be used:

(1) As a basic model to illustrate the process of a circular approach and the consequences of a circular approach for the project;
(2) To explain to the client why a circular approach is required, how it can be achieved and what a circular approach means for the project;
(3) Interactively by the project manager and by the client to discuss a circular approach for the project;
(4) As a checklist to realise projects according to the circular concept.

3.2. Phase 2—Solution Design

3.2.1. Which Frameworks Do Exist and What Should They Look Like?

The term framework refers to a guide that organises (new) ideas in an overall picture so that it is easy to remember and apply the (new) concept. Currently, a few frameworks, which consist of text, figures or interactive forms, have been developed for implementing circular construction, but these documents consist of more than 25 pages [10,43,83–85]. A document with more than 20 pages will not work in favour of the project managers since the information needs to be transmitted to the clients and this time will be at the expense of the project time [80].

In this study, the researchers set a maximum of four pages to the framework to be able to fulfil the third formulated design proposition of being able to use it as an interactive tool with the customer and to comply with the working method of project managers and

their time constraints. This results in the idea of a placemat or infographic that compactly illustrates the most important information at a glance.

3.2.2. Creating the Framework

The design propositions, the layout requirements and the results of Section 3.1 problem investigation were assumed as the basis for the framework. This resulted in a framework of two sheets of A3 format.

The framework consists of three important steps to approach a circular project successfully. These steps are elaborated on the first page of the framework and entail: "knowledge of circular economy in the construction sector", "integrate circularity into project preparation" and "integrate circularity into project management". The second page includes extra background information with definitions, two important models and the 27 identified success factors in the format of a checklist. The developed framework can be found in Appendix B or requested in PDF format from the authors.

3.3. Phase 3—Solution Validation

Validating the Framework

The validation of the framework is crucial to design science research (DSR) and requires rigorously demonstrating the utility, quality and efficacy of a design artefact using well-executed evaluation methods [30,86]. In addition, the validation also examined whether the knowledge of the artefact contributes to the knowledge base [86]. An ex ante evaluation was performed in order to estimate and evaluate the impact of future situations and to test if the artefact would work in a real situation. One evaluation period was used to validate the framework. Expert interviews were conducted to validate the designed framework and to weed out bad designs early. During the validation interviews, the design propositions were explained, the validation questions were shared, the framework was explained, and finally, the validation questions were asked.

The experts described the framework as an excellent tool that can be used primarily for the initial discussion with the client and as a guide for the project manager, which would certainly be useful for a project manager in practise [87]. Furthermore, the framework is straightforward and has a clear structure and a pleasant colour scheme [88]. It reflects the different steps that need to be followed and considered during the initial stages, shows the common thread for a circular approach, could be used to convince the client and reflects the consequences of a circular approach [87–90]. The framework meets all design propositions. One expert indicated that more substantive knowledge is needed in a project, but this can also be obtained by including a circular advisor [87]. Another expert indicated that it is a very informative framework that represents the information in a compressed form but finds it difficult to apply the framework in a project since circularity remains a specific matter that requires impactful decisions in the project, and more examples would help [89].

Three out of four experts would like to implement the framework in their working method since the framework matches the market demand that exists today: how to approach a circular project. There will probably be challenges to implementing the framework, but these are not yet known [90]. Information regarding the needed investment for a circular approach, the remaining value, and the choice for a particular strategy is not available in this research and will be recommendations for future research [87,90]. The designed artefact was validated as functional, complete, consistent, performance-oriented, usable and fit with the questions of practical experience. The questions of the validation focused only on functionality, performance and usability.

4. Discussion

Design science research combines and is closely related to the scientific and practical relevance of the research topic. This is due to the fact that design science research is interlinked with the environment by the relevance cycle and the knowledge base by the rigor cycle [91,92]. The exchanged information and the three cycles are visualised in

Figure 7. The design cycle was used to implement design science research into this study and made it possible to design a framework for the project managers and to validate the framework by experts. The rigor cycle provides the research with grounding theories, methods and expertise concerning the research topic from the knowledge base. These are: the lack of understanding of how to address circularity in the initial phases of a construction project, the lack of a framework that addresses circularity and the theory that a circular building process is different compared to a traditional process. This research created knowledge and contributed to the body of knowledge by creating a framework that could be used as an instrument for the transition to a circular economy and by identifying an approach to adopt circularity in the initial phases of construction projects. The relevance cycle provided the research with requirements from the contextual environment, which are project managers involved in the initial phases of construction projects. Nevertheless, the framework could also be used by other people involved in construction projects and interested in an approach to implementing a circular economy in the initial phases of the project. The environment has project managers, who have a lack of capabilities and knowledge to execute circular construction projects according to the concept of circular economy. This research contributes a framework to the contextual environment, which is ready to be implemented and concerns insights into the crucial task of project managers to support the client in adopting a circular project approach. Additionally, the validation of the framework revealed that the framework is eagerly desired by the project managers as three out of four wanted to use the framework immediately.

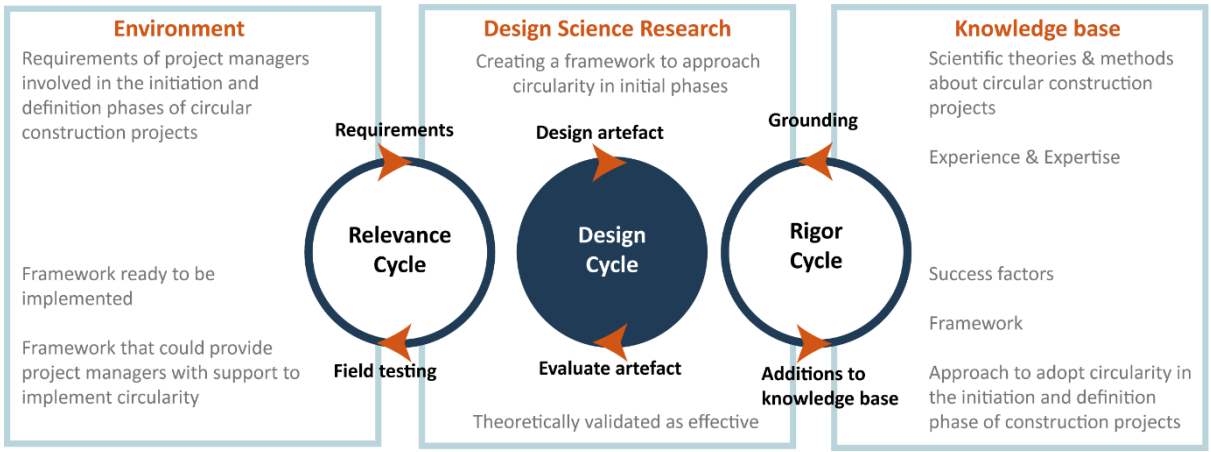

Figure 7. Research contributions to the contextual environment and the knowledge base [11].

Although the framework was validated as effective, it can be concluded that the transition to a circular economy is still in progress. For this reason, the framework satisfies the needs at the moment but has to be updated in the future with new developments and additional information. The design cycle that made it possible to develop the framework can be seen as an iterative process; however, this cycle was only completed once in this study due to time constraints. Additionally, the identified approach in the framework is simplified compared to the complex reality. Indirectly, all the choices that have to be made and which are now presented in a chronological sequence are linked to each other, and it is, in reality, an interactive process in which trade-offs have to be made. For example, a circular strategy has consequences for the circular objectives, and the formulated objectives might require specific management aspects such as extra investments. Although this limitation is present, the work of a project manager consists of making choices within the constraints set by the client, and the developed framework can support the reasoning process to make the trade-offs.

Although the developed framework contributed to the contextual environment and the knowledge base, there were some limitations to this research that could be improved in subsequent research. The cases used in the case analyses and the information obtained by

the circular advisors cannot be validated since there is no accepted universal measuring method to indicate circularity. Secondly, the research used design propositions as requirements for the framework but did not specify other design propositions which could lead to an alternative framework. Thirdly, the framework is mainly focussed on the initiation and definition phases of a construction project and can be elaborated with knowledge, additional tasks, other consequences for the management aspects and the role of the project manager when the excluded phases, namely the design, realisation and maintenance phase of a project, are taken into account. Furthermore, within this research, the analysed cases were focussed on utility projects, while other types of projects such as housing (complexes) would be interesting to investigate as well. Furthermore, this research focussed on circularity and neglected the relation between circularity and the other sustainability aspects which could be combined in one framework. Some construction project managers also indicated the amount of different sustainable approaches, and thus one does not know what to focus on. An expert who validated the framework indicated that more research is needed regarding the necessary investment into a circular approach and the remaining value at the end of a building's lifetime. The amount of residual value is of importance to weigh the additional investment needed for a circular approach. Finally, the choice of a particular circular strategy appears to be important when defining ambitions but did not yet deserve the necessary attention in this research.

5. Conclusions

This research improves the capabilities and knowledge of project managers to integrate circularity in the initial phases of construction projects by providing the developed framework to the knowledge base and tries to contribute to the (fully) circular economy targets set by the Dutch government. Design science research was used, and we divided the research into three steps: investigating the problem, designing the framework and validating the framework. Three interviews and a case analysis obtained knowledge for the framework. The fuzzy Delphi method was used to identify the 27 most important success factors to enhance circular projects. The developed framework consists of three important steps to approach a circular project successfully. These steps are elaborated on the first page of the framework and entail: (1) knowledge of circular economy in the construction sector, (2) integrate circularity into project preparation and (3) integrate circularity into project management. Step one involves information such as circular definitions, models and strategies to create awareness and support for a circular approach. This is needed for step two in order to define ambitions and to formulate, ensure and measure circular project objectives. These circular project objectives have consequences for the project management aspects time, money, information, organisation, procurement and risks which are discussed in step three. The second page contains extra background information on definitions, two important models and the 27 identified success factors in the format of a checklist. The framework was validated by experts in the field of construction project management and was validated as effective, ready to implement and useful for the current challenges, demands and questions of the market.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. List of 66 Success Factors

Table A1. The 66 success factors found in literature or by research results and the outcome of the FDM (Többen, 2021).

No. SF	Main Category	Sub-Category	Success Factor	Literature	Research Result	Result	Rank
1	Project preparation	Ambition	There is a circular ambition and vision from the client		X	accepted	1
2	Project preparation	Ambition	An ambition document has been drawn up for the project		X	accepted	12
3	Project preparation	Ambition	Circular ambitions are inventoried, formulated and translated into project objectives as soon as possible	[21,22,93,94]	X	accepted	3
4	Project preparation	Ambition	The client is made aware of their possible (circular) ambitions and the new developments in the market		X	rejected	35
5	Project preparation	Objectives	Circularity is an additional objective within the project		X	rejected	63
6	Project preparation	Objectives	Circular objectives are formulated in a way that is achievable and measurable	[93]	X	rejected	28
7	Project preparation	Approach project preparation	The concept of circularity is defined and documented in the project		X	rejected	51
8	Project preparation	Approach project preparation	Circular project requirements are formulated by the entire project team	[21]	X	rejected	32
9	Project preparation	Approach project preparation	Circular project requirements will be drawn up		X	accepted	6
10	Project preparation	Approach project preparation	Support for a circular approach from the client ensures a circular outcome at project level	[3]	X	accepted	17
11	Project preparation	Approach project preparation	Additional time will be reserved for setting ambitions, drawing up an ambition document and formulating objectives		X	accepted	14
12	Project preparation	Role project manager	The project manager should initiate a conversation with the client about the circular ambitions and the possibility of integrating circularity in their projects		X	rejected	40
13	Project preparation	Role project manager	The project manager should question the client whether the project can be connected to (other) existing circular/sustainability ambitions of the company	[95]	X	accepted	19
14	Project preparation	Role project manager	The project manager should be able to explain to the client what the consequences of a circular approach are in relation to the project		X	accepted	20

Table A1. *Cont.*

No. SF	Main Category	Sub-Category	Success Factor	Literature	Research Result	Result	Rank
15	Project preparation	Role project manager	The project manager has to create awareness and support from the client for a circular approach towards the project	[3]	X	rejected	33
16	Project management	Approach project management	The circular objective is outlined on the horizon and divided into small steps. After every step, it is evaluated, and follow-up steps are considered		X	rejected	37
17	Project management	Approach project management	All phases in which the building is involved are included in the project; both the construction phases from initiation to realisation and the subsequent maintenance and disassembly phases		X	accepted	21
18	Project management	Approach project management	A circular approach also includes a circular service; come up with a solution from the beginning, provide a solution and remain involved during the life cycle so that solutions remain as optimal as possible		X	rejected	38
19	Project management	Approach project management	The project collects pre- and post-information on design and demolition process	[96]	X	rejected	58
20	Project management	Approach project management	Opportunity cards will be made about circular ideas and opportunities in the area that can be linked to the project		X	rejected	43
21	Project management	Approach project management	Sustainability/circularity is managed		X	rejected	30
22	Project management	Approach project management	A market consultation will be held to test the circular requirements and ambitions		X	rejected	62
23	Project management	Approach project management	Attention is paid to ensure that an interactive process can be created in the design and realisation phase		X	rejected	53
24	Project management	Approach project management	In a project, the focus is on what is close to the scope and within reach of the project	[93]	X	rejected	44
25	Project management	Approach project management	Client must be challenged to innovate; this is not only the task for market parties/stakeholders in a circular approach		X	rejected	54
26	Project management	Procurement	In the project, agreements are made (with new contract forms) so that materials do not end up as waste	[21]		accepted	15
27	Project management	Management	Project information is shared efficiently and transparently so that information does not get lost and the idea does not have to be reinvented	[3,21,93]		accepted	18
28	Project management	Management	The project/project team is flexible to review requirements in subsequent phases		X	rejected	47

Table A1. *Cont.*

No. SF	Main Category	Sub-Category	Success Factor	Literature	Research Result	Result	Rank
29	Project management	Management	Clients take more risks to stimulate innovation and creativity	[21]	X	rejected	61
30	Project management	Management	Stakeholders abandon their standard approaches and routines and take more risks	[94]	X	rejected	56
31	Project management	Management	Examples of other circular projects are used to inspire and to show that circularity can also be accessible and that not everything has to be applied at once		X	accepted	5
32	Project management	Management	There is knowledge of the existing legislation, and regulations in the field of circularity and circular solutions are examined within these boundaries	[94]	X	rejected	55
33	Project management	Management	Time for reflection is included in the process to evaluate the project, reflect on the team members, inspire each other and challenge each other on whether the ideas can be made even more sustainable and efficient		X	accepted	27
34	Project management	Management	Projects are digitized by means of BIM, a digital twin or a material passport	[97]	X	accepted	23
35	Project management	Project team	The project team uses non-hierarchical organisational structures	[21]		rejected	66
36	Project management	Project team	The project team includes people who can think outside the box		X	accepted	11
37	Project management	Project team	Conditions to collaborate in a project are facilitated	[3]	X	accepted	26
38	Project management	Project team	The project team has knowledge of the concept of circularity		X	accepted	7
39	Project management	Project team	The project team understands each other, and the members share the same circular goals, vision and philosophy	[21]	X	accepted	13
40	Project management	Project team	Trust is the basic principle between the client and the contracted party, but a contract remains necessary		X	rejected	60
41	Project management	Project team	All the interests of all parties are shared, and there is an understanding of certain choices and points of view			rejected	48
42	Project management	Project team	All stakeholders involved in the project are motivated, both at company and personal level, to organise the project in a circular way	[93]	X	accepted	22

Table A1. *Cont.*

No. SF	Main Category	Sub-Category	Success Factor	Literature	Research Result	Result	Rank
43	Project management	Project team	An external party joins the project team that has knowledge of circularity, can ensure the knowledge and can tell what is currently the highest achievable point in the market		X	rejected	34
44	Project management	Project team	Increasing cooperation with new, multidisciplinary and international teams		X	rejected	64
45	Project management	Project team	There is a transparent cooperation with involved parties in order to promote the development of new concepts and sustainable collaborations	[3,93]	X	rejected	42
46	Project management	Project team	There is confidence in the market and opportunity for innovation in the process		X	rejected	45
47	Project management	Project team	In addition to the scope of the building, the project team also investigates possibilities for connecting the project to circular ideas of the area		X	rejected	39
48	Project management	Project team	Client participates in the project team		X	rejected	49
49	Project management	Budget	On top of a traditional budget estimation, 10-15% is added for a circular approach		X	rejected	36
50	Project management	Budget	An inventory is made of additional financial resources at the client's organisation for sustainable/circular alternatives (such as tuition fees, sustainability budget)		X	accepted	24
51	Project management	Budget	The budget of the project is managed in a transparent way	[21]		rejected	59
52	Project management	Budget	The residual value of materials/the building is included in the budget if it can be deducted from the investment		X	rejected	31
53	Project management	Procurement	The market is involved in the process during initiation and/or definition phase	[22]	X	rejected	41
54	Project management	Procurement	A construction team will be integrated into the early phases of the project, based on trust, intended cooperation and suggested approach rather than money and quality	[94]	X	rejected	29
55	Project management	Procurement	Circularity must be clearly formulated in invitations to tender	[94,98]	X	accepted	8
56	Project management	Procurement	Tendering for market parties early in the project ((end of) definition phase)	[21]	X	rejected	57
57	Project management	Procurement	Select stakeholders with the entire project team	[21]		rejected	65

Table A1. *Cont.*

No. SF	Main Category	Sub-Category	Success Factor	Literature	Research Result	Result	Rank
58	Project management	Procurement	The concept of circularity is included in selection criteria	[94]	X	accepted	9
59	Project management	Procurement	Selecting market parties on the basis of a competitive dialogue and assessing the proposed approach to them	[22]	X	rejected	50
60	Project management	Role project manager	Project manager has basic knowledge of the concept of circularity, understands the concept of a circular economy, is able to involve an advisor when necessary and can translate the knowledge into their own projects		X	accepted	4
61	Project management	Role project manager	Project manager knows that circularity can be a challenge for the client	[3]	X	accepted	25
62	Project management	Role project manager	Project manager has the courage to change, is curious about the concept of circularity, wants to try out new techniques and sees the urgency of a transition to a circular economy		X	accepted	10
63	Project management	Role project manager	Circularity is always an ambition of the project manager within the established requirements of the client		X	rejected	46
64	Project management	Role project manager	The project manager is critical towards the client, discusses the established requirements of the project and asks why these requirements exist		X	accepted	16
65	Project management	Role project manager	The project manager has intrinsic motivation and creates enthusiasm which convinces the client about a circular approach		X	accepted	2
66	Project management	Role project manager	The project manager starts defining a process model for the project instead of drawing up a programme of requirements	[22]		rejected	52

Appendix B. The Developed Framework

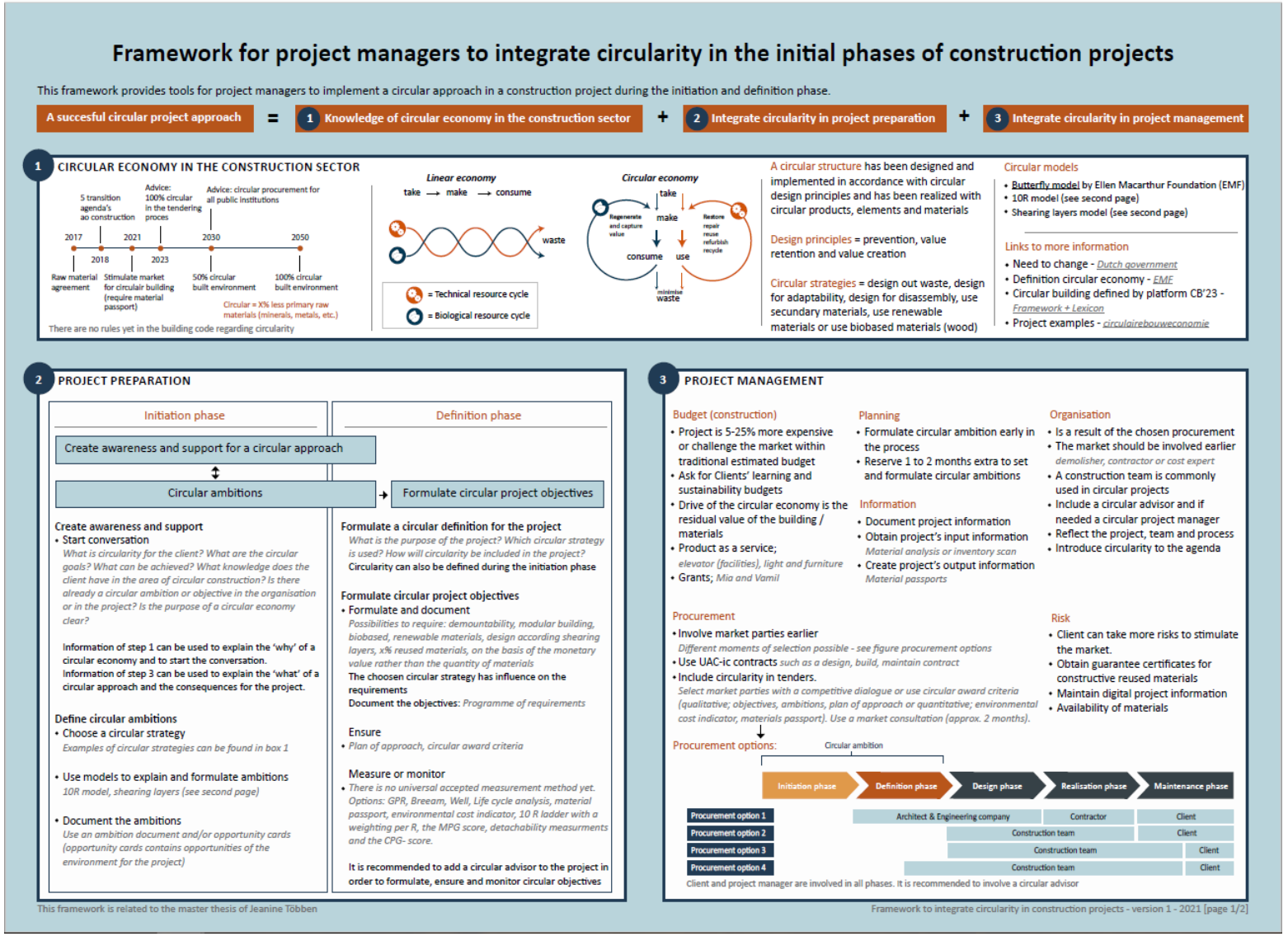

Figure A1. *Cont.*

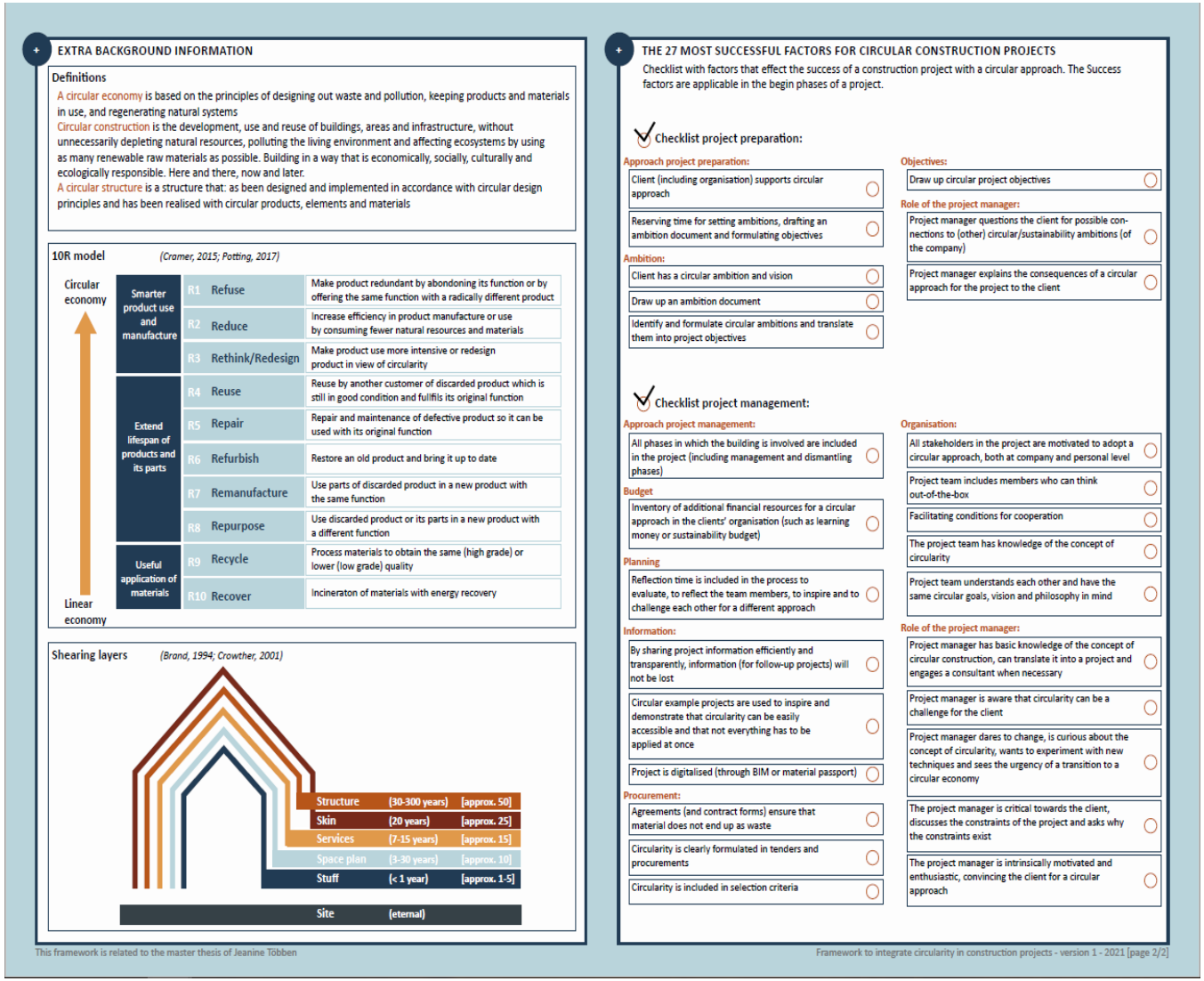

Figure A1. Framework for project managers to integrate circularity in the initial phases of construction projects.

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