Barriers for data management as an enabler of circular economy: an exploratory study of the Norwegian AEC-industry

To cite this article: A Bellini and S Bang 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1122** 012047

Barriers for data management as an enabler of circular economy: an exploratory study of the Norwegian AEC-industry

A Bellini and S Bang

Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology, 7491 Trondheim, Norway

Email: alessia.bellini@ntnu.no

Abstract. Effective data management can enable the utilisation of new tools and technologies and, ultimately the creation of circular business models in the building industry. To accomplish this, a targeted mapping and collection of data must take place. However, several challenges hinder the exchange of information in a seamless digital flow through the value chain and building life cycle. This exploratory study contributes to bridging the gap in the research, providing an overview of existing barriers related to mapping, collecting, and storing data about materials and products in existing buildings. The findings are obtained through 18 semi-structured interviews with experts working with circular economy and digitalisation in the Norwegian AEC-industry. Some of the identified barriers, such as the lack of data availability and interoperability, lack of competencies and unwillingness to share data, are strongly interrelated; a collaborative approach will be essential across the value chain. The research sets the basis for developing a framework for data management that can facilitate the reuse of materials and products from a building at the end of life to new construction or refurbishment projects. Ultimately, effective data management opens for developing and implementing innovative circular business models, enhancing strategic data-based asset management.

1. Introduction

The construction industry is responsible for consuming almost 40% of the natural resources and generating circa 40% of the total waste in Europe [1,2]. Therefore, a transition to a circular economy is considered essential to sustainable development in the built environment by reducing resource consumption and carbon emissions and moving away from the so-called linear economic model [2,3,4]. Reusing existing materials and products is an example of circular economy practices that can significantly decrease resources consumption and carbon emissions but requires adopting a systemic approach and value chain integration on a large scale [4,5,6].

Like other industries, the construction industry has seen a surge in digitalisation over the last years, despite remaining one of the least digitally advanced industries [7]. The sector has already been positively affected by some technologies, enhancing efficiency in processes and communication [8], but the rapid advancement in digital technologies, such as Building Information Modelling (BIM), digital twins, blockchain, Internet of Things (IoT), and Artificial Intelligence (AI), is an essential means to achieve the potential of a more sustainable and circular industry [9,10,11].

Digitally enabled solutions can support the implementation of circular economy strategies, like the reuse of building materials and products, by helping to map, trace, and provide information about the availability, location, condition, and durability of a product [12]. A standardized information exchange is one of the means for a more circular and sustainable sector [5] and implementing a seamless data flow can facilitate sharing information about reusable materials, from an existing building to a potential new construction or refurbishment project. However, the lack of information and data about the existing built environment is often one of the main challenges for material reuse [5,9,12]. Greater knowledge of existing buildings and materials, greater visibility and transparency of data, and improved construction products information management across the value chain are essential to enable business model opportunities and accelerate the circular transition [12,13,14].

Although several studies, like Knoth et al. [6], Nordby [15], Sandberg and Kvellheim [16], investigates the barriers for materials reuse in the AEC-industry, the research on digitalization connected with circular economy is relatively limited and it often fails to address the topic from a systemic point of view [11, 17,18]. Kovacic et al. [9] underlined that a framework for information management that supports a continuous and standardized data flow for a circular economy is still lacking.

The research conducted by Çetin et al. [10] is one of the few contributions that investigates which digital technologies can potentially enable circular economy in the built environment, also presenting some of the challenges connected with these specific technologies. Similarly, Chan et al. [19] addresses the question of the digital potential in advancing circular economy in the construction industry. The results show how digital technologies (digital twins, BIM, material passport, and digital platforms), can help to create a viable digital marketplace for circular products and services. More specifically, Debacker [20] looks at the challenges for the implementation of *material passports*, underlying the need for a digital and centralized management of building and material information. A material passport can be defined as a tool that helps to document and track circular materials and products, providing accurate information for recovery and re-use [5].

Others research looks at the connection between digital technologies and circular economy but are not exclusively limited to the AEC-industry. De Felice and Petrillo [17] recognizes the lack of interoperable solutions and communication protocols as the main factor hindering innovation and circularity. The authors suggest an integrated approach, that combines technology, legislation, and cooperation among the value chain. Similarly, the research from Mulhall et al. [21] underlines that a standardized data format for storing product information is necessary for circular economy, both in the construction, textile, and batteries sector. Moreover, the newly published report by Ellen Mac Arthur Foundation underlines that data on materials and products are essential to promote circular business models and identifies the barriers that hinder data sharing, across different sectors [22].

When it comes to specifically investigate the barriers for circular economy and reuse of materials in the AEC-industry, several studies have been conducted which do not necessarily focus on the digitalization perspective. Kirchherr and Piscicelli [23] and Munaro and Tavares [24] look at the cultural barriers, such as lack of awareness and holistic thinking, and they underline that the lack of information and the fragmentation of the value chain can hinder the introduction of circular practices and understanding of circular thinking. Norby [15] analysed the technical, legislative, environmental, and market barriers to reusing materials in Norway. Similarly, Sandberg and Kvellheim [16] conclude that the lack of economic incentives and requirements limits the reuse of materials on a bigger scale. Knoth and Fufa [6] analyse perceived challenges, barriers, and opportunities for material reuse from different stakeholders. Finally, it is worth mentioning how Moscati and Engström [25] and Redwood and Thelning [26] look at the barriers for digitalization in the AEC-industry in a general context and they underline how the most significant barriers lie in the organisational aspects rather than technical ones.

The effective and sustainable utilisation of new digital technologies and tools requires effective data management, and this study contributes to bridging the current gap in the research, by providing a comprehensive overview of the existing barriers, related to mapping, collecting, and storing of data on materials and products in existing buildings. The results are obtained through a review of the existing literature and 18 semi-structured interviews with experts in circular economy and digitalisation in the

Norwegian AEC-industry. Specifically, the study will be answering the following research question: *What are the existing barriers for digitalization of data management as an enabler of circular economy in the Norwegian AEC-industry?*

The remainder of this paper is organised as follows; first, the research method adopted in this study is described. Then, findings are presented and discussed. Finally, the last section summarises and concludes based on the previous results, providing an overview and recommendations for practitioners and researchers who wish to explore the topic further.

2. Research method

The research design for this study is exploratory because the topic of digitalization and data management in the context of circular economy is relatively unexplored, and the intention is to clarify the understanding of the problem and seek for new insights [27]. The research started with an initial literature search in three chosen databases (Scopus, Web of Science, Science Direct). This revealed that a research gap exists in the nexus between the topic of data collection and management, and circular economy, as stated in the introduction.

To support the search of the literature and to fully answer the research question, semi-structured interviews were identified as the preferred research method, following the recommendation by Bell and Bryman [27]. This method was seen to provide more broad and contextual results, as compared to more quantitively oriented methods such as questionnaire and surveys. The semi-structured approach allows the respondents to elaborate beyond pre-defined questions, contributing to a comprehensive understanding of the industry and its dynamics in relation to the topic [28].

The interview guide was sent to the interviewees in advance to ensure the alignment of expectations and topics between interviewers and interviewees and it included a series of open-ended questions such as: *'what is the role of data management for facilitating the implementation of circular economy?'*; *'how can the circular data flow for the reuse of materials be structured through the value chain and throughout the life cycle?'* and *'what are the main barriers that hinder the digitalization of the materials data flow?'*.

In total, 18 semi-structured in-depth interviews were conducted, over the course of two interview cycles. The interviewees in the first cycle (12 interviews) were selected based on their experience and involvement in relevant projects and initiatives. Inclusion criteria included experience working with digitalization, digital technologies, and processes in the AEC industry in Norway, as well as the participation in pilot projects, workshops, and networks connected with circular economy and materials reuse. All the interviewees have more than five years of experience working within the AEC industry in major and well-known organizations in Norway, as well as software developers working with circular platforms and solutions. To ensure valid and relevant results, a broad sample of stakeholders, representing the different roles across the value chain was involved.

The interviewees in the second cycle (6 interviews) were selected based on the specific recommendations from the first group of interviewees and from other practitioners and academics. The authors evaluated the suggestions to ensure that the respondents fit the inclusion criteria defined for the first cycle. The final selection of respondents and their role in the value chain is illustrated in Table 1.

Table 1. Number of respondents by role in the value chain.

Role	Number of respondents
Manufacturer	1
Project owner (public & private)	3
Architect	1
Research institute and university	2
Not-for-profit organisation and network	2
Software provider	3
Engineering & sustainability consultant	4
Contractor	2

Each interview lasted for approximately one hour and was conducted as a video call over Microsoft Teams due to the current Covid-19 regulations in Norway. Both authors were attending during the interviews to ensure a higher degree of understanding and reliability in the subsequent coding of the results. The interviews were recorded, and the transcriptions were sent to the interviewees for quality assurance before analysing the data. The interviews were conducted in Norwegian and subsequently translated to English to ensure accuracy and avoid misinterpretation of the information.

The coding process was done iteratively in parallel with the interviews, as recommended by Bell and Bryman [27]. Although interviewees used different terminology when asked to define existing barriers, emerging themes were identified and categorised. This was done through the utilisation of industry-specific knowledge as well as common understanding and asking follow-up questions where necessary. The process resulted in the classification of six main barriers that represent the findings of this research. Both authors took part in coding and analysis, first individually and then comparing and discussing the results, to ensure increased validity and understanding of the findings. As the coding was conducted, it became evident that the interviewees' answers and views on certain aspects of the topic seemed to be converging; this could suggest a higher degree of relevance of the findings.

3. Findings

Six themes emerged from the interviews, resulting in six (6) explicitly defined barriers for data management as an enabler of a circular economy. The barriers are described in the following chapters and summarised in Table 2.

Table 2. Identified barriers for each interviewee's role

	Interviewees roles							
	Manufacturer	Project Owner	Architect	Research	Org. / network	Software	Consultant	Contractor
Lack of data availability	1/1	3/3	1/1	1/2	2/2	2/3	3/4	2/2
Lack of data interoperability	1/1	3/3	1/1	1/2	2/2	2/3	3/4	1/2
Lack of competences	1/1	2/3	1/1	2/2	1/2	3/3	2/4	1/2
Unwillingness to share data	1/1		1/1			2/3	2/4	1/2
Lack of financial incentives	1/1	2/3		2/2	1/2	3/3	2/4	2/2
Lack of harmonisation		2/3		1/2	1/2	2/3	1/4	1/2

3.1. Lack of data availability

As several interviewees underlined, it will not be possible to enable circular economy and reuse of building materials unless the data is available or accessible. One of the main challenges today is that the data about building materials and products are often missing, not complete, not accessible, or not digitised. An interviewee highlighted: *'if one looks ten years back, for example, there is very little documentation available [about buildings and materials]. And when available, it is often buried in archives at the manufacturers' or project owners' offices'.* Another interviewee underlined that: '*to decide to reuse a [building] product, you need certain information about that product'*. It is necessary to collect information about the quantity, properties, characteristics, physical location in the building, quality and current maintenance state, how they can be reused, repaired, or disassembled, which certifications are required, etc. The interviewees recommend this information to be dynamic, possibly connected in a digital model or a material passport. The material passport is a digital register that follows

the building and products through all the life cycle, describing defined characteristics of materials – ultimately providing value for recovery and reuse [5]. Collecting and making information available and accessible increases the possibility to reuse existing materials on a larger scale: *'to achieve a sort of industrialisation for materials reuse, then one needs enough information to evaluate if a product could be suitable for the [new] use'.*

3.2. Lack of data interoperability

Lack of technical interoperability can, according to interviewees, impede effective data management and consequently slow down the practices of materials reuse in the construction industry. As an interviewee stated: '*it is impossible to achieve a circular economy in the building industry without a robust digital infrastructure'*. Data are often stored in different repositories, in different formats, with varying levels of ownership and accessibility. This hinders the exchange of information between the stakeholders through the value chain, so, ideally: *'one should get a seamless data flow that can be triggered automatically because there are a lot of information and products in a building or construction project'.*

The integration with digital tools, such as Building Information Modelling (BIM) or material passports, can simplify this process, given that this platform can exchange information in an open format: *'there are several digital solutions that can simplify data management, for example, only in Norway there are about 30 different software that are designed for the operation & maintenance phase, but none of them is [currently] communicating and none of them is connected with software for circular material reuse either'.* The openness of data is considered essential for enabling interoperability, and some concerns emerged during the interviews: *'what is an open solution [for data collection and sharing], actually? What does it mean to handle the data openly? We need a discussion about this concept'.*

Some interviewees expect governmental initiatives that could promote the adoption of a public database to ensure data openness and transparency on a higher level: *'the access to information is a problem today. Establishing a central system, like a central database or marketplace, where you can gather and collect all the information would be great. Right now, everybody is developing a marketplace of their own, and everyone has their systems. A centralisation of the information is incredibly important'.* One of the interviewees suggested that the requirements for data openness should be regulated at the European or global level to avoid the data being limited in proprietary systems: *'we need guidelines about the requirements for [data] openness and this should be regulated with an EU Directive at least, or a global requirement'.*

Another vital aspect to improving data interoperability is to collect and store data and information about the products and materials in a standardised way: '*when [one] has mapped the existing building materials then these data are updated in a [digital] system. But for this information to be exchanged with another stakeholder [that uses another digital system], they must be in the same format and mapped with the same purpose'.* According to some interviewees, standards that regulate how circular properties for materials and products should be classified and described are still missing. It is challenging to coordinate data management to reuse materials without common standards; as one interviewee mentioned, '*data will have little value if different actors do not use a common language when describing products and materials.* With the support of digital technologies and tools, this data can be shared and connected between the different stakeholders in an open, transparent, and standardised way.

3.3. Lack of competences

Another barrier for data management as an enabler of circular economy in the AEC-industry is the lack of competencies among the different stakeholders. The interviewees refer to this as the competencies on collecting, handling, sharing, and managing the data about the building materials and a broader understanding of the value of this information to accommodate circular principles. As one interviewee mentioned: '*what is missing is the common understanding of the value of data and information (…) in a life-cycle perspective'.* According to some of the interviewees, data management competencies will

be acquired over time by gaining experience from projects and initiatives based on circular principles and thinking: '*while we go through more mappings of building materials, we get a bigger understanding of which [data] is necessary (…)'*.

3.4. Unwillingness to share data

Unwillingness to share data among the parties in the value chain is a barrier for data management and, consequently, hinder materials reuse in the AEC-industry. As one interviewee mentioned, the challenge is that *'there are too few [actors] in the industry that are willing to share the information'*. According to some of the interviewees, the unwillingness of stakeholders to share available data and information ultimately means that other barriers, such as the lack of interoperability, cannot be solved. This aspect impacts the collaboration between the stakeholders, who are unwilling to work together to enable the circular economy in the AEC-industry.

3.5. Lack of financial incentives

Collecting, digitising, and managing data from existing buildings and materials can be quite resource intensive. The interviewees underlined that the lack of financial incentives represents a significant barrier for enabling effective data management. A sustainable circular economy and effective reuse of building materials will require managing a large amount of data. Without financial incentives, originating from the market or the authorities, it is difficult to establish a business model for reuse of building materials on a larger scale, as one of the interviewees mentioned: '*if we manage to collect more data for material reuse, then the market will be much bigger and so the volume of materials and products [available] for reuse'*. Several interviewees claimed that stricter requirements from project owners and authorities could potentially contribute to solving this barrier and make the process financially viable.

3.6. Lack of harmonisation across the value chain

It emerges from the interviews that harmonized procedures and processes for data management across the value chain in a circular economy context are still missing. This represents a barrier to practical implementation because the lack of organizational processes and standardized data management procedures hinder the exchange of information between the different stakeholders, making it difficult to achieve circular economy and materials reuse. According to the interviewees, it is therefore relevant to structure the processes for data exchange and management, by connecting the value chain and defining the roles of the different stakeholders. Combined with the lack of data interoperability, as another barrier for data management (as underlined in Section 3.2), it is even more important to make data available through the life cycle and create mechanism to match the supply and demand of reusable existing products and materials, as one interviewee underlined: *'in a reuse-project (…) you need actors and businesses that can collect information about existing products, re-test the materials etc. All the value chain should be connected'*

4. Discussion

Creating a functional framework for information management, to support a continuous and standardised data flow for circular economy, will be essential to enable the implementation of big-scale circular principles. A comprehensive understanding of the barriers that hinder data management in the circular economy context is consequently a significant step for the definition of this framework.

Previously conducted studies discover the barriers related to digitalisation in the construction industry [25,26] or to circular economy and reuse of materials [6,15,16], but not many studies address the intersection between these two, specifically digitalisation of data collection and management as an enabler of a circular model. Thus, this research contributes to empirical validation of the perceived barriers to this process of digitalisation in connection with circular economy in the AEC-industry.

To enhance the reuse of materials and products from end-of-life buildings to new buildings or refurbishment projects and, in turn develop circular business models, it is decisive to exchange data and information about the reusable materials in a seamless and digital data flow through the entire value

chain and building life cycle; this perception was shared by most interviewees. Collaboration and sharing of data between the stakeholders during the building life cycle is perceived as a critical factor for enabling circular economy and it is also recognized in the literature, despite in connection with different contexts [10,22]. This seems to hold true for the process of digitalisation of data management in the same context, as seen in the identification of unwillingness to share data as one of the critical barriers to this.

The findings show that the lack of interoperability, intended as the ability of different digital systems to coordinate and communicate with one another, still hinders effective data management as an enabler for the circular economy. To overcome this barrier, interviewees suggest that information about building materials could be collected through mapping, stored in a database, and available and accessible through the entire life cycle of the asset; this is in line with findings of studies exploring the barriers of more analogue circular concepts and principles [7,5,14]. The same can be said about the perceived opportunity for increased openness to enable interoperability [19,21,22].

According to interviewees, most material mapping today takes place at the end-of-life phase before a building must be deconstructed or rehabilitated. The findings suggest that the prospect for a circular AEC industry depends on the availability of data and the adoption of material passports or digital inventories, both for new and existing buildings. This is in line with the literature that specifically investigate the implementation of materials passports in the AEC-industry [5,19,20]. As several interviewees emphasised, to make the process of reusing materials viable, the data should be accessible, preferably in an open public database, that could be centrally governed. Precise requirements for data openness and transparency should be regulated at the European level, to avoid data loss through the building life cycle, across borders and industries. In March 2022, the European Commission published the proposal for a revised Construction Products Regulation (CPR) which, among other aspects also suggest the adoption of a centralized database for product information management.

The barriers identified in this study appear to be strongly interrelated. For example, the understanding and definition of the barrier *lack of interoperability* to some extent overlaps with the concept of data openness and standardisation. Some of the identified barriers, such as the *lack of data availability* and *interoperability* involve both technical and organisational connotations. While some barriers could be addressed by implementing new technologies and tools, organisational and managerial efforts are ultimately required to establish a seamless data flow across the value chain. This is particularly true for the barrier *lack of harmonization*, which entails the adoption of processes and procedures for data management to facilitate the exchange of information across the value chain. The idea is that harmonized and standardised processes for data management could be adopted in different projects, helping to achieve materials reuse and circular economy on a larger scale. In addition, competencies, collaboration, and willingness to share data are identified as crucial factors for the industry to move forward and overcome the barriers.

The purpose of this study was to empirically validate and provide a comprehensive overview of the barriers for digitalisation of data management, as an enabler of circular economy in the AEC industry. The insights collected through the interviews acquire both technical and practical connotations, seemingly coinciding with the findings of other studies investigating the link between digitalization and circular economy, focusing on specific aspects or technologies [10,12,13,19]. Ultimately, this study provides also an organisational and procedural perspective to the barriers to data management; it represents a point of reference and perspective of what it entails to digitalize the information required to enable circular economy and material reuse. The interview-based research design was an essential tool to increase understanding of the problem. The findings illustrate how the topic is still in an emerging phase and it requires great engagement both from the industry and the academia.

5. Conclusion and recommendations

This study is, to the best of the authors' knowledge, the first empirical validation of previously theoretically based hypotheses related to the barriers to data collection and data management in a circular economy context. This exploratory study contributes to bridging the gap in the research by concretizing

existing barriers for digitalisation of data management as an enable for circular economy. Coding and evaluation of the emerging concepts identified the following barriers:

1. Lack of data availability
2. Lack of data interoperability
3. Lack of competences
4. Unwillingness to share data
5. Lack of financial incentives
6. Lack of harmonisation across the value chain

Some of these barriers, such as lack of availability and interoperability, are deeply interrelated. A collaborative approach is required to achieve effective data management and ultimately enable a circular economy in the AEC industry. According to the findings, measures that could contribute to overcoming these barriers, include the adoption of a public database to ensure openness and transparency of the data. Regulations should set specific requirements for how data related to the circular properties of products and materials is stored and exchanged across the value chain. In addition, a sustainable circular economy requires effective management of a large amount of data, and this could not be achieved without standardised and harmonized procedures and processes for data management, and without a financially viable model. Finally, to overcome the barriers to data management, it is essential to strengthening collaboration and trust among the stakeholders.

5.1. Limitations of the study

To overcome the limitation of this study, a broader sample of interviewees could be involved, including respondents from several roles and positions across the value chain. The findings show that there is a general agreement among the practitioners in Norway regarding the challenges of data management in the context of a circular economy, and the research opens for further implementation and analysis on the topic.

This study was conducted within a Norwegian context, providing insights from practitioners with expertise and experience from the Norwegian AEC industry. The local context in which the research developed could potentially influence the results, therefore it has been important to analyse the findings also with regards with the international literature that explore adjacent topics such as digitalisation or circular principles in general. This suggest that the findings can be applicable also outside the empirical context and will find a valid application in other countries, considering regional trends and opportunities for the circular economy. To empirically validate this, similar studies of the AEC industry in other countries should be undertaken.

5.2. Future research

In terms of research methodology and in order to validate the applicability of the results, it might be relevant to conduct a similar analysis in other contexts and countries. In addition, future studies could include a larger sample of respondents for each of the roles in the value chain, especially include several manufacturers, contractors, and architects.

In terms of thematic, several potentials lie within this topic. This study identified the existing barriers for digitalisation of data management; future research could analyse each of these barriers, identifying how those can be overcome and concretizing prospects and plans.

An organizational framework supporting a continuous and standardized data flow is still missing in the AEC context; this could be a central topic for future studies. The qualitative and empirical identification of perceived barriers for effective information management could and should be used as a foundation in the development of such a framework. Future research should analyse necessary data and information for the reuse of building materials, and how digital solutions can support the exchange of this information across the value chain. Effective data management can open for the creation of innovative circular business models, and it could enhance strategic data-driven asset management.

References

[1] European Commission 2020 *Circular economy action plan: for a cleaner and more competitive Europe*
[2] MacArthur E 2013 Towards the circular economy *J. Ind. Eco.* **2** 23-44
[3] Cheshire D 2019 *Building revolutions: applying the circular economy to the built environment* Riba publishing
[4] Pomponi F and Moncaster 2017 A Circular economy for the built environment: a research framework J. Clean. Prod. 147 710-8
[5] Munaro M R and Tavares S F 2021 Materials passport's review: challenges ad opportunities towards a circular economy building sector *Buil. Env. Proj. and Ass. Mana.* **11**(4) 767-782
[6] Knoth K, Fufa S M and Seilskjær E 2022 Barriers, success factors, and perspectives for the reuse of construction products in Norway *J. of Clea. Prod.* **337** 130494
[7] Sezer A A, Thunberg M, Wernicke B 2021 Digitalization index: developing a model for assessing the degree of digitalization of construction projects *J. Const. Eng. Manag.* **147**(10) 04021119
[8] Parusheva S and Aleksandrova Y 2021 Technologies, tools, and resources-driving forces in construction sector digitalization *Int. Conf. on Inte. Comp. and Info. Syst.* 219-23
[9] Kovacic I, Honic M and Sreckovic M 2020 Digital platform for circular economy in AEC industry *Eng. Proj. Organ. J.* **9**
[10] Çetin S, De Wolf C and Bocken N 2021 Circular digital built environment: an emerging framework *Sust.* **13**(11) 6348
[11] Chiaroni D, Orlandi M and Urbinati A 2021 *The role of digital technologies in business model transition towards circular economy in the building industry* Springer
[12] Honic M, Kovacic I, Sibenik G and Rechberger H 2019 Data and stakeholder management framework for the implementation of BIM-based material passport *J. of Buil. Eng.* **23** 341-50
[13] Mêda P, Sousa H and Hjelseth E 2020 *Data templates – product information management across project life cycle* Springer 117-33
[14] buildingSMART International 2021 *Digitizing construction for better product exchange, identification and transparency*
[15] Nordby A S 2019 Barriers and opportunities to reuse of building materials in the Norwegian construction sector *IOP Conf. Series* **225** 012061
[16] Sandberg E and Kvellheim A K 2021 *Ombruk av byggematerialer – marked, drivere og barrierer*
[17] De Felice F and Petrillo A 2021 Green transition: the frontier of the Digicircular economy. Evidenced from a systematic literature reviee *Sustainability* **13** (19) 11068
[18] Antikainen M, Uusitalo T and Kivikytö-Reponen P 2018 Digitalisation as an enabler of circular economy *Procedia CIRP* **73** 45-9
[19] Chan P et al. 2020 The digital potential in creating a circular construction economy *Technische Universitetit Delft, The Netherlands*
[20] Debacker W et al. 2017 Circular economy and design for change within the built environment: preparing the transition *International HISER conference on advances in recycling and management of construction and demolition waste* 114-117
[21] Mulhall D et al. 2022 The product circularity data sheet: a standardized digital fingerprint for circular economy data about products *Energies* **15** 9-3397
[22] MacArthur E 2022 *Looping on data*
[23] Kirchherr J, Piscicelli L, Bour R, Kostense-Smit E, Muller J, Huibrechtse-Truijens A et al. 2018 Barriers to the circular economy: evidence from the European Union *Ecol. Econ.* **150** 264-72
[24] Munaro M R, Tavares S F and Bragança L 2020 Towards circular and more sustainable buildings: a systematic literature review on the circular economy in the built environment *J. of Clea. Prod.* **260** 121134
[25] Moscati A and Engström S 2019 *Digitalisation and industrialisation: exploration of the current and future challenges in the Swedish built environment sector*
[26] Redwood J, Thelning S, Elmualim A and Pullen S 2017 The proliferation of ICT and digital

technology systems and their influence on the dynamic capabilities of construction firms *Procedia Eng.* **180** 804-11
[27] Bell E and Bryman A 2015 *Business research methods* Oxford University Place (Oxford)
[28] Ryen A 2002 *Det kvalitative intervjuet: fra vitenskapsteori til feltarbeid* Fagbokforlaget