Journal of Cleaner Production 337 (2022) 130494

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Barriers, success factors, and perspectives for the reuse of construction products in Norway

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ARTICLE INFO

Handling Editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Reuse
Construction material
Building industry
Circular economy

ABSTRACT

Reuse of construction materials and products has great potential to reduce the environmental footprint of a building. However, the way buildings are designed and constructed rarely considers closed loop materials systems and the implementation of reuse in building projects is associated with many hurdles. Various professionals might experience different challenges or might be affected to different degrees. The objective of this paper is to provide an insight into experiences and perspectives of professional actors involved in projects with a focus on reuse in Norway. A series of interviews with manufacturers, architects, contractors, environmental consultants, and public institutions was conducted to (i) identify barriers and success factors for reuse in pilot projects, (ii) capture the issues that seem most pressing for different actors, (iii) identify which actors in the value chain need to be more included into reuse processes, and (iv) define and prioritise necessary actions to advance reuse in Norway. The results suggest that reuse in Norway could be greatly advanced by more communication and cooperation between different actors in the value chain. Especially manufacturers can play an important role and need to be more involved in reuse processes. Planning for and practical execution of reuse will benefit from well-functioning research infrastructure. However, legislation needs to be adjusted in favour of reuse. Currently being one of the greatest barriers as experienced by most actors, it has the potential to become the greatest enabler for the reuse of materials and products in the Norwegian building sector.

1. Introduction

The Norwegian building and construction industry is responsible for approximately 26% of the total national waste stream (Statistics Norway, 2021). From 2018 to 2019, the amount of waste from construction, rehabilitation, and demolition further increased by 5.6%. Less than half of this waste was recycled (Statistics Norway, 2021), which is below national and EU requirements of 70% reuse, recycling and recovery of non-hazardous materials (European Commission, 2018). The vast majority of construction waste in Norway consists of non-contaminated and inert materials and could be reused without any health or environmental risks (Statistics Norway, 2021).

Reuse is a key principle in the waste hierarchies. It improves material efficiency across all economic sectors and represents the second-best choice after waste prevention to decrease resource consumption and carbon emissions, and divert demolition waste from landfills (Akinade et al., 2017; Rakhshan et al., 2020). A Nordic study states that reuse of construction products has the potential to reduce resource consumption by 20% in the Nordic construction sector resulting in greenhouse gas emission (GHG) savings of approximately 900 000 tons CO_2equivalents (Høibye and Sand, 2018). At the same time, it can create social and financial benefits for private companies equating to 1.7% of the annual growth rate (Høibye and Sand, 2018).

The concept of design for deconstruction (DfD) has been introduced decades ago (Akinade et al., 2017), however, traditional methods of end-of-life building disposal are dominating since modern society rarely designs with material recovery in mind (Guy and Shell, 2002). Construction materials hold the potential of lowering overall embodied impacts of buildings from the early stages (Rahla et al., 2021) and designers, contractors and other construction actors must act together to define ambitions for material loops.

Key drivers for reuse in the Norwegian building sector are the reduction of GHG emissions and enhanced company image by fulfilling criteria of sustainability schemes. The latter often combine sustainability and circular economy concepts (Rahla et al., 2021). BREEAM-NOR (Grønn Byggallianse, 2020) and the Norwegian FutureBuilt criteria for

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https://doi.org/10.1016/j.jclepro.2022.130494
Received 14 July 2021; Received in revised form 17 December 2021; Accepted 10 January 2022
Available online 13 January 2022

circular buildings (FutureBuilt, 2020) include both reuse and circular economy principles. In addition, national initiatives such as the "National Strategy on Circular Economy" (Ministry of Climate and Environment, 2021), requirements for the assessment of reuse of construction products (Direktoratet for byggkvalitet, 2021), and the establishment of digital reuse platforms (Loopfront, 2021; Rehub, 2021) demonstrate the growing interest in circular practices.

Reuse is still in its early stage in Norway. Only few pilot projects are currently testing reuse solutions and processes. The first FutureBuilt projects testing the feasibility of reuse in construction projects have recently been completed (Entra, 2021). The lessons learned from these pilot projects will play a major role in the development and implementation of measures to advance the reuse of construction products and materials.

In the framework of the research project "REBUS – Reuse of building materials - a user perspective ", a series of interviews with different groups of actors from the Norwegian construction industry was conducted to identify barriers and success factors for reuse as experienced by different experts and professions.

Several studies have identified a range of sectoral, financial, regulatory, and cultural factors affecting material reuse in the building sector (Camacho-Otero et al., 2018; Debacker and Manshoven, 2016; Dunant et al., 2017; Hart et al., 2019; Nordby, 2019) showing that addressing reuse obstacles requires a holistic approach (Rakhshan et al., 2020). While barriers and success factors identified from the interview data coincide to a great extent with findings from other studies (Rakhshan et al., 2020), the analysis of perceptions and viewpoints of different actors add a new level to studying the adoption of reuse in the Norwegian building sector. The groups of actors participating in the interviews were chosen based on their first-hand experience in pilot projects or other direct professional experience with reuse of building materials.

The principal objective of the article is to provide an insight into experiences and perceptions of different groups of actors concerning practical challenges, barriers, and success factors related to the reuse of construction products. Secondary objectives are to (i) isolate differences between different groups of actors and identify specific needs and requirements in terms of successful implementation of reuse, (ii) capture the issues that seem most pressing for different actors, (iii) identify, which actors in the value chain need to be more included into reuse processes and (iv) define and prioritise necessary actions to advance reuse in Norway.

Section 1 introduces the topic with a theoretical background, study goal and scope. Section 2 describes the interview methodology, interviewee profile, and data analysis (section 2). Next, the results of the thematic analysis are presented discussing and investigating barriers and success factors with a focus on different groups of actors (section 3) and in a Norwegian context (section 4). The article closes with a short conclusion (section 5).

2. Methodology

2.1. Interview format and procedure

Semi-structured interviews were conducted between November 2020 and February 2021 in Oslo, Norway. Due to Covid 19 restrictions, all interviews were conducted online via Microsoft Teams. Twelve interviews were conducted with a total of 21 actors participating. Two participants unable to take part in the online interviews due to time constraints answered the questions in written form.

All interviews followed a standardized set of questions (appendix A) that was sent to all participants prior to the interviews. The following main themes were covered:

(i) *General project information*: Background information of the pilot project that interviewees were involved in and their role in the project. Participants that did not take part in a relevant pilot project, were encouraged to provide experiences on reuse initiatives and approaches in their workplace.
(ii) *Reuse potential*: Detailed questions concerning reuse potential, material sources and experiences concerning the reuse of various materials.
(iii) *Mapping and evaluation*: Questions focusing on product selection criteria, evaluation methods, and practical challenges for reuse.
(iv) *General comments and opinions*: Personal views and reflections on success factors for the reuse of building products.

Actors participating in the same pilot project were interviewed in groups, where different actors could answer the questions they considered relevant for their role in the project. Interviewees were free to go into detail when giving their answers and follow-up questions were asked to allow participants to elaborate on matters specifically relevant for the research objectives. Between one to four persons participated in each interview session, which lasted between 60 and 90 min.

All participants signed an agreement prior to the interviews consenting to the recording of the interviews and the use of information in research activities and publications. Data collection was conducted in the form of recordings and notes, and interviews were transcribed. Transcripts of the interviews were sent to interviewees for comments and verification. Due to data protection requirements, only profession and role of the interviewees in pilot projects may be revealed in the article.

2.2. Interviewees' profile and pilot projects

All interviewees are involved in projects that have a focus on reuse and/or have a professional interest in reuse of building material. Participants from four different pilot projects (Table 2) were part of the interviews. The aim was to cover a range of different professions and functions within the value chain. Interview participants have various backgrounds and hold different roles in pilot projects. This approach was taken to find out whether perceptions, experiences, and mindset towards reuse of building material differs depending on a person's background, role, and responsibilities.

Interviewees were chosen from five groups of actors typically participating in construction or rehabilitation projects:

(i) *manufacturers:* Participant P4 represents a company selling used products and is directly involved in the reuse business. Participants P20 and P21 represent a manufacturer that is following a linear business model but has started to investigate recycling and recovery of raw materials from their products.
(ii) *architects:* Participants P5, P10, P12 and P15 were part of pilot projects (Table 2). Their main task was to design and develop reuse solutions.
(iii) *building owners/contractors:* Participants P6, P7, P9 and P16 were part of pilot projects (Table 2).
(iv) *environmental/reuse consultants:* Participants P1, P2, P8, P11, P13, P14, and P18 took part in the pilot projects. Participants P2 and P8 are reuse experts currently developing tools for reuse of building materials.
(v) *Public institutions:* Participant P3 represents a programme for climate friendly urban development funded by several municipalities supporting pilot projects to achieve sustainability criteria including reuse. Participant P17 represents a public building owner for social housing and participant P19 functioned as project leader for developing reuse infrastructure for a Norwegian municipality.

Table 1 summarises interviewee profiles.

A limited amount of suitable pilot projects and hence potential participants were available for this study. Table 2 presents background information on the pilot projects included in this study.

Table 1
Interviewee profiles.

Interview #	Participant #	Manufacturers	Architects	Building owners/contractors	Reuse/environmental consultants	Public institutions
1	P1				x	
2	P2				x	
3	P3					x
4	P4	x				
5	P5		x			
	P6			x		
	P7			x		
6	P8				x	
	P9			x		
	P10		x			
	P11				x	
7	P12		x			
	P13				x	
8	P14				x	
	P15		x			
	P16			x		
9	P17					x
10	P18				x	
11	P19					x
12	P20	x				
	P21	x				
# of participants/group		**3**	**4**	**4**	**7**	**3**

Table 2
Background information for pilot projects.

	Pilot project 1	Pilot project 2	Pilot project 3	Pilot project 4
Location	Oslo, Norway	Oslo, Norway	Oslo, Norway	Fornebu, Norway
Project period	2018–2020	2020–2022	2016–2021	2017–2026
Type of project	Rehabilitation, extension	Rehabilitation	New building/extension	Urban development
Type of building	Office building	Office building	Public school	Housing area
Total floor area (m^2)	4300	8736	10286	59206
Reuse goal	>60% reuse	Min. 50% reuse	Circular principles	Focus on reuse in one pilot area

2.3. Data analysis

The qualitative data collected in the interviews was analysed using a thematic coding and categorization scheme. Interviews were coded using NVivo qualitative data analysis software (QSR International Pty Ltd., 2020).

2.3.1. Thematic analysis

A thematic analysis approach (Braun and Clarke, 2006) was applied for an overall categorization of all data. The first step of the analysis consisted in the coding of extracts in the interview transcripts following a preselected set of themes based on the research objectives. Data extracts demonstrating individual themes were collated together within the relevant codes. New themes and sub-themes were created based on patterns, concepts, and new revelations which emerged while coding the data. The full data corpus was coded for all themes.

Interviews were individually coded by two researchers, both of which were present during the interviews. Analysis results were jointly refined, and categorisations finalised to ensure a common agreement on overarching key themes and sub-themes.

2.3.2. Visualising distribution and relative importance for different groups of actors

Following the thematic analysis, the identified barriers and success factors were allocated to five groups of actors. Every actor mentioning one of the barriers or success factors was counted and an overview was created showing the distribution and relative importance of the key themes for different groups of actors. Group size varied (see Table 1) due to limited reuse experience, few pilot projects focusing on reuse and availability of experienced actors in Norway. The number of responses was converted into a colour-coded chart based on the percentage of group members mentioning a certain barrier or success factor.

2.4. Definition

During the interviews, no exact definition was offered by the interviewers or interviewees when referring to "reuse of construction products and materials". The term "reuse" may therefore refer to one of the following options: (i) Reusing old products or materials for the same purpose with or without processing, (ii) repurposing products or materials with or without processing for an alternative function/use, (iii) repurposing damaged new products or materials for an alternative area of use, and (iv) preserving and lifetime extension of existing components and other structural or non-structural features in rehabilitation projects.

3. Barriers and success factors for different groups of actors

The following section summarises the findings from the interviews categorised under four main themes with a focus on different groups of actors and their perception, viewpoints, and experiences. Distribution and relative importance of barriers and success factors for individual actors is discussed on the background of conditions in Norwegian pilot projects, regulations and in the context of the existing literature.

3.1. Key themes

The thematic analysis of all 12 interviews resulted in four overarching key themes – each comprising a set of identified barriers and success factors concerning reuse of construction materials: (i) mindset and knowledge, (ii) reuse infrastructure, (iii) business framework and (iv) legal framework. The resulting thematic map representing main themes is presented in Fig. 1.

Different actors tended to express the same factor in different ways, which made it sometimes difficult to clearly separate barriers from success factors. Some actors expressed an issue in form of a barrier,

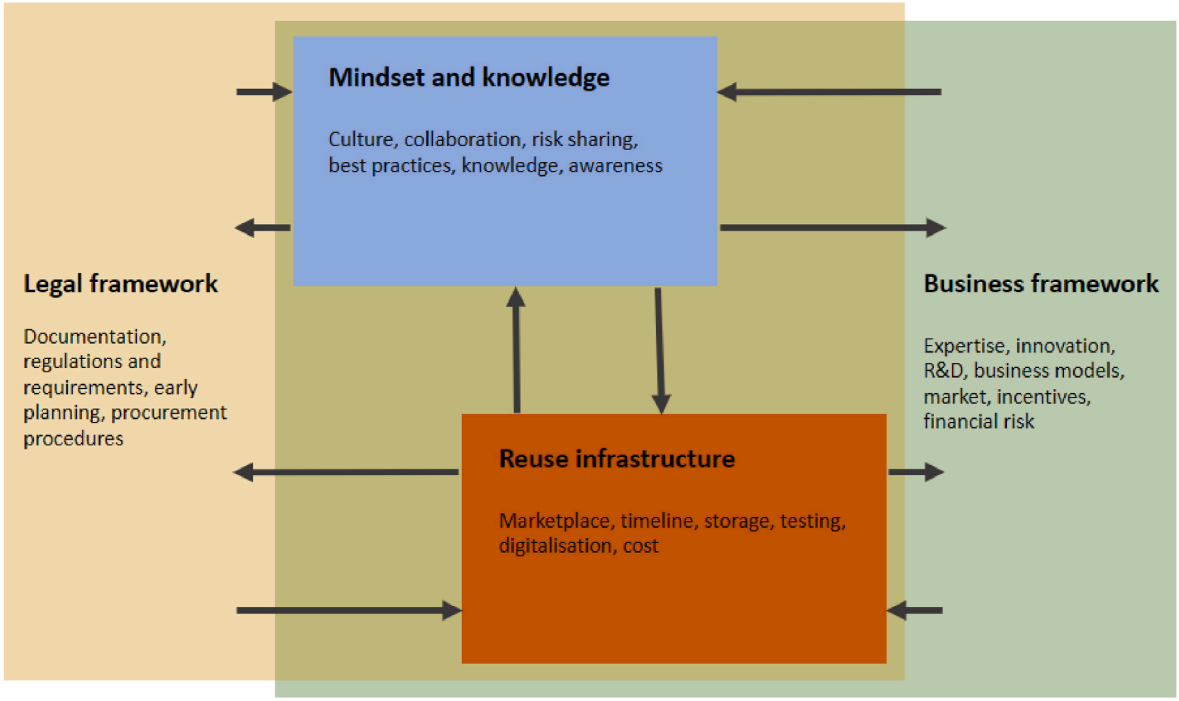

Fig. 1. Conceptualisation of the data pattern and relationships/interactions between main themes.

while others described it as a success factor for more reuse in construction projects. The four main themes are interconnected and influence each other in various ways. For example, the current legal framework often influences attitudes towards reuse in a negative way, making it seem complicated or even impossible. Based on our analysis, two themes (legal and business framework) form the backbone of the other two themes (knowledge and infrastructure). Legal and business framework both influence each other, while simultaneously having the potential to enhance or inhibit knowledge and the development of a well-functioning reuse infrastructure.

Group of actors \ Barrier	Mindset and knowledge				
	Conservative way of thinking	Lack of collaboration	Reluctant to take/share risk	Lack of best practices	Lack of knowledge
Manufacturers					
Architects					
Building owners/contractors					
Environmental/reuse consultants					
Public institutions					

Group of actors \ Success factor	Mindset and knowledge				
	Awareness and change of culture	Cooperation and communication	Risk sharing	Pilot projects	Knowledge
Manufacturers					
Architects					
Building owners/contractors					
Environmental/reuse consultants					
Public institutions					

Colour code	0%	1-25%	26-50%	51-75%	76-100%

Fig. 2. Distribution and relative importance of barriers and success factors under the key theme "Mindset and knowledge" for different groups of actors. The colour coding is based on the percentage of participants for each group. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.2. Mindset and knowledge

The first key theme identified from the interview data concerns mindset and knowledge. Findings from the interviews suggest that these two aspects are strongly interlinked, and that education and information can lead to a change in culture and mindset. This led to the decision of a shared main theme with barriers and success factors presented in Fig. 2.

Lack of knowledge was mentioned as an important barrier by all actors; architects, consultants and public institutions seem especially concerned. Accordingly, pilot projects and knowledge are regarded as success factors by almost all groups of actors. Reuse of building materials is not an established practice in modern times and pilot projects allow all actors in the building industry to get more experienced with practices and processes around reuse. Lack of knowledge was also mentioned as part of the reason why reuse is often met with scepticism; especially consultants and public institutions experience that a conservative way of thinking is still prevalent in the Norwegian building industry. Reuse practices are often strongly influenced by a conventional way of thinking and socio-cultural factors such as perceptions, status, customs and behaviours (Kozminska, 2019). Prior negative associations were also noted, such as connecting reuse with lower quality, inferior aesthetics, and reduced functionality. One of the reuse consultants (P13) stated: *"We need knowledge, to make people understand that you can get very modern and functional buildings with reused materials … that it's not like a flea market or it doesn't have to have a bad architectural design"*.

Manufacturers, architects, consultants, and public institutions stressed the importance of introducing awareness raising campaigns, as well as showcasing more examples and best-practice case studies, which may help to change the negative attitude towards reused building materials and help advance the learning process. This was also stated in another study investigating the awareness of circularity in the building sector (Adams et al., 2017). On the product and material level, reuse is hindered by a lack of knowledge about possible methods of remanufacture, especially if the product is to be reused for an alternative purpose. Reuse consultants explained that reuse in Norway is often based on a "trial and error" process, due to a limited number of pilot projects and lack of experience, turning reuse into a more time-consuming and costly solution. Architects and designers are not formally trained in the circular design process (Kozminska, 2019), and few manufacturers are involved in the reuse of materials. This emphasizes the need for more expertise on circular building design, material reuse, and experience with adapting building materials for alternative areas of use. Knowledge needs to be developed throughout the value chain, and contractors and building owners need to be involved in this endeavour. Practical challenges might often not be as obvious for this group of actors as it is consultants and architects that are responsible for finding practical solutions.

Another aspect considered important by almost all groups of actors is cooperation and communication in the value chain. One reuse expert (P17) reported on a positive experience including contractors in the procurement process: *"Reuse needs interaction and cooperation … it was open for contractors to suggest solutions. We had a dialogue with them to see who comes with the best solutions, and this has been part of our selection criteria for who got the project"*. The involvement of various actors early in the project can raise the acceptance of reuse and alleviate scepticism in individuals not yet used to this concept. In addition, it can also prepare the ground for more efficient reuse and innovative solutions. Lack of collaboration and communication can also negatively influence progress in construction projects, which was pointed out by an environmental consultant (P13): *"We need to rethink the way we collaborate and work in different project phases – as the current practise leads us to postpone decisions that the system (focusing on reuse) would require us to take in an early stage … "*. Manufacturers would also appreciate more communication. It was mentioned by participants P20 and P21 that manufacturers depend on feedback from other actors in the value chain to adapt their products and business models to trends in the market.

Another barrier addressed by the informants was the reluctance to take risks or the lack of risk sharing. One municipality representative (P3) pointed out that: "*Willingness to take the risk for all uncertainties might take long, since the market is not very fond of risks*". Reusing building materials is still associated with greater risks, both financially and in terms of documentation issues, availability, and material sourcing. All user groups, except for architects, found this to be a major barrier for reuse.

3.3. Reuse infrastructure

Barriers and success factors identified under the key theme "Reuse infrastructure" are presented in Fig. 3.

Reuse infrastructure comprises, in the context of this article, all digital and physical infrastructure, but also technology that may facilitate processes related to the reuse of building materials – such as material sourcing, mapping, storage, logistics and testing.

Lack of a functioning market and availability of reuse products were mainly mentioned by those directly involved with material sourcing, such as architects, consultants and public institutions: *"Availability right now is one of the biggest challenges. … you never know what is going to be available, even if you design for reuse. At the end of the day, maybe you end up using new materials because they are not available."* (P13). A clear need for designated reuse infrastructure, both digital and physical, where materials can be viewed and ordered, was expressed by all groups of actors participating in pilot projects. Mechanisms to match supply and demand need to be put in place to connect those with surplus materials and reusable products to those who might need them. This could be achieved through the establishment of stockholding facilities and reuse platforms that will make the process of reuse easier for contractors. This would reduce uncertainties not only for sourcing materials – the possibility to pre-order used products that will become available at a certain time would contribute to making reuse more predictable and allow for planning and designing with reused products from an early stage. Increased efficiency, availability of products, and reliability would also help to reduce the extra costs that are associated with reuse, enabling more competitive pricing of reclaimed materials.

Timing, logistics and storage are important barriers that were pointed out. Especially architects, reuse consultants and contractors find that timing is a decisive factor. Many times, demolition of buildings or disassembly of products from a donor building may not coincide with the time products are needed in a new building. Difficulties arising from extended scheduling of works due to length of deconstruction, lack of storage space, disparity between location of stocks of reclaimed items, and added costs due to transport and storage, often seem too hard to overcome. An architect participating in one of the pilot projects (P5) experienced this first-hand: *" … when to find the material that can be reused, where is it going to be stored? The timeline is quite important because sometimes it doesn't suit with your project."*.

Architects and consultants see digitalisation as one of the success factors in the reuse business. Database management systems for existing and new buildings will help create an inventory of materials that are in circulation. Using buildings as material banks and developing material passports as suggested in the EU Horizon 2020 project "Buildings as material Banks (BAMB, 2020) will be a major driver for a successful transition to a more circular building industry. One of the reuse experts stated: *"Year of construction, date of demolition, …create predictability which materials will enter the market and prepare architects for which type of materials they need to find solutions for in five years from now. Big data. This is a success criterion."* (P17). The existing built environment will have a major impact on resource flows for many years to come. Stocktaking and cataloguing on a city, regional or national level will connect different actors in the building industry and preserve the value of building materials.

Other barriers mentioned concern test methods and infrastructure, as well as current demolition practices. Like other more practical issues, mainly architects and consultants seem to be confronted with these

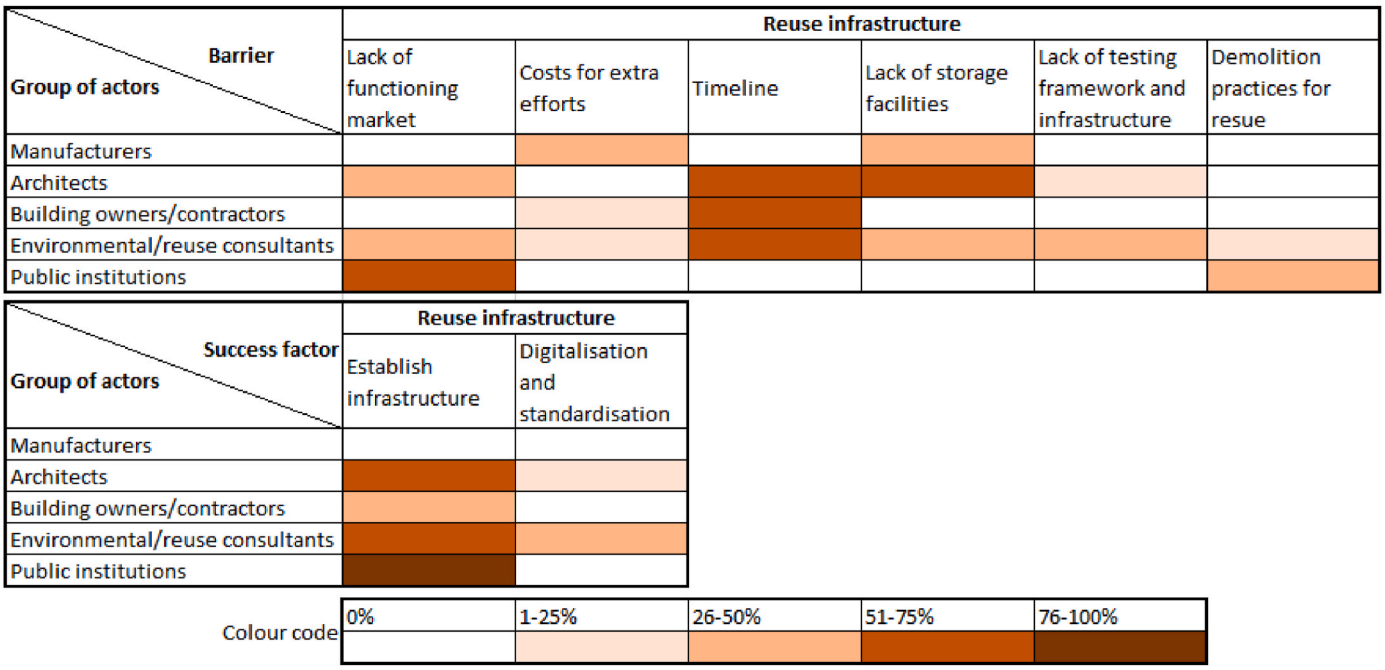

Fig. 3. Distribution and relative importance of barriers under the key theme "Reuse infrastructure" for different groups of actors. The colour coding is based on the percentage of participants in each group. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

challenges. The existing building stock has not been designed for reuse (Guy and Shell, 2002). Current demolition practices and disassembly procedures need to be adapted and innovative technical solutions are needed to ensure increased circularity of materials at their highest possible value (Adams et al., 2017). Future building design should allow for flexibility and consider gentle deconstruction procedures.

3.4. Business framework

The third key theme identified from the interview data is business framework. Fig. 4 summarises barriers and success factors associated with this category.

Lack of expertise was frequently pointed out as an important barrier during the interviews. Pilot projects that employed a person dedicated to the reuse of building materials gave positive feedback on the usefulness of such experts: *"I think we will have a reuse advisor in all of our projects … if we have an expert that can go and pick the specific products that could be reclaimed … someone with more knowledge would be very helpful in the projects."* (P1). It was also mentioned that manufacturers could positively contribute to this new expertise given their detailed knowledge on

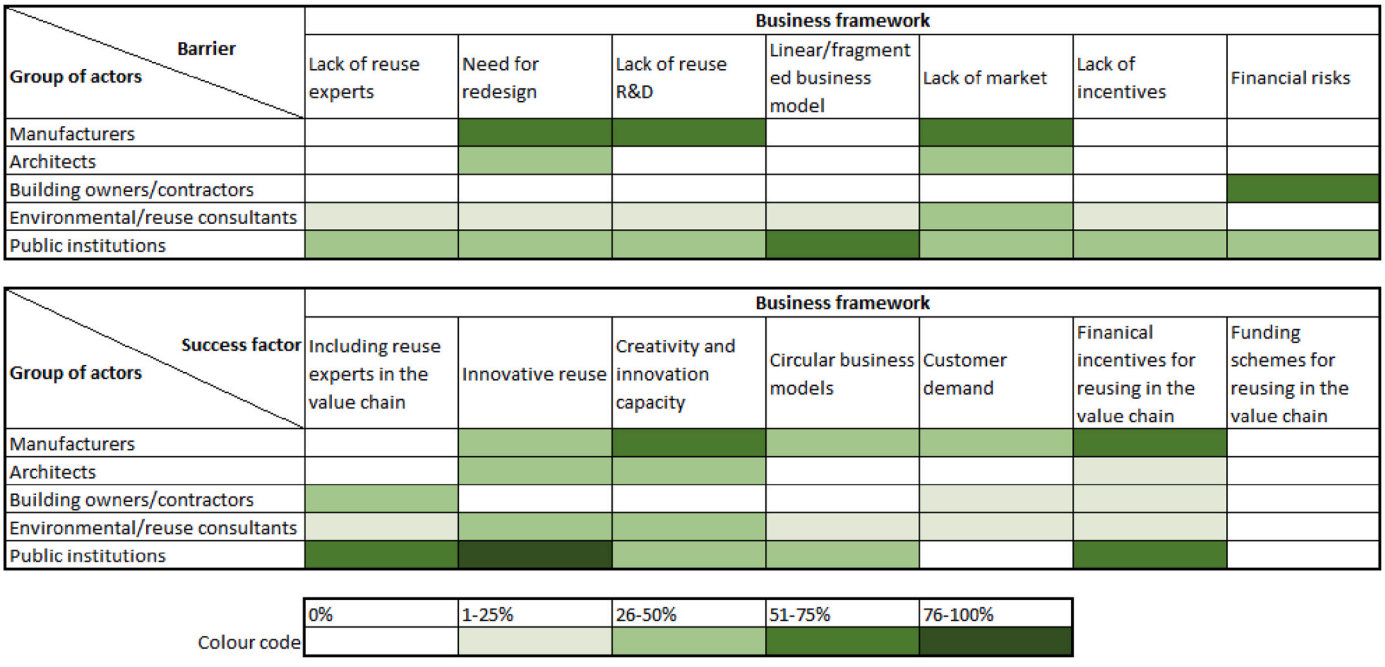

Fig. 4. Distribution and relative importance of barriers under the key theme "Business framework" for different groups of actors. The colour coding is based on the percentage of participants in each group. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

material qualities and composition of their products: *"We need more specialists on reuse and on demounting and upcycling. I've been in contact with some manufacturers that want to do this themselves, which would be ideal, since they know their materials best."* (P17).

Current market structures mean that companies have few incentives to reuse or recycle products. Virgin raw materials are not only often cheaper, but are also considered easier to implement, because their quality is more consistent (Guldmann and Huulgaard, 2020). Especially manufacturers and public institutions regard financial incentives and funding schemes for the development of circular business models as an important driver to motivate circular transformation: *" … we need some incentives to make it happen. It doesn't happen by itself, rather we need to be pushed in some way."* (P20). Adapting a product to circular principles often requires changes to the existing production infrastructure. This can be very costly, and manufacturers are often not willing to take the risk alone.

At the same time, one manufacturer (P20) reported that their company experienced growing interest from architects and other customers in reclaimed products and take-back systems: *"A lot of our customers are now asking for solutions for reuse of our products or whether we have a system to take them down and use them for new things. There is very much focus on that, which is very good, but also difficult."* (P20). The interviewee acknowledged that companies should respond to this trend, also with regards to future employees and the importance of creating attractive workplaces for the younger generation.

Innovative reuse or innovation in reuse was identified as a success factor under the business framework theme. Participants in the Norwegian pilot projects reported that building materials were often reused for different purposes, and that this process could be very time consuming. It also often required changes in the initial design. One reuse consultant (P2) expressed the need for guidelines and the creation of a portfolio for repurposing and reuse of materials, but also new technologies and ways to rework different materials. These could be collected in a sort of catalogue available to architects and designers. Educational institutions also need to broaden their curriculum to circular practices in building construction.

3.5. Legal framework

The fourth main theme resulting from the analysis of the interview data concerns the legal framework and procurement process. Fig. 5 shows barriers and success factors allocated to this category.

Currently, many aspects of Norwegian legislation and national regulation hinder the reuse of construction materials, which is one of the main concerns stressed by most groups of actors. One reuse expert (P1) mentioned that the attempt to reuse is often hindered by regulations: "*Right now, even though you want to reuse, you have to find ways to work around the regulations to make it work. So, it is more up to the government, which I feel is the big drawback that's slowing down the process.*". Legislation and regulations can be important drivers for the economy, and proper regulatory support is crucial for a wider implementation of reuse in the building industry (Rakhshan et al., 2020). Architects, contractors, consultants, and public institutions would appreciate it if authorities set stricter requirements for reuse in construction projects: *"I think requirements need to be forced from the government for it (reuse) to happen on a large scale."* (P13). Manufacturers focusing on new products are not affected but agree that regulations supporting reuse would facilitate a wider adoption and possibly force manufacturers to adjust.

Lack of documentation and reluctance to use products without certification of tested performance are often reasons to choose new products, as highlighted by consultants, manufacturers, contractors, and public institutions. A reuse expert (P18) stated that valid documentation is one of the main criteria for reuse of construction products in their projects. A feasibility study was conducted in one project to identify all relevant products and materials suitable for reuse based on visual inspection. When confronted with the documentation requirements, most materials no longer qualified for reuse in the project: *"It was therefore impossible to fulfil requirements for documentation according to both TEK (the Norwegian building code) and DOK (Regulations on documentation of construction products) for several building materials that had been considered suitable for reuse in the feasibility study."* (P2). Putting in place suitable assessment systems providing reliable and standardized product information on material composition, durability, health and safety, and

Barrier / Group of actors	Legal framework			
	Lack of supporting regulations	Lack of technical documentation	Lack of early planning	Rigid contract/procurement process
Manufacturers				
Architects				
Building owners/contractors				
Environmental/reuse consultants				
Public institutions				

Success factor / Group of actors	Legal framework			
	Reuse-friendly regulations and stricter requirements for reuse	Responsability for documentation; certification agencies	Setting ambitious and achievable goals in early planning phase	Reuse focused collaborative procurement process
Manufacturers				
Architects				
Building owners/contractors				
Environmental/reuse consultants				
Public institutions				

Colour code	0%	1-25%	26-50%	51-75%	76-100%

Fig. 5. Distribution and relative importance of barriers under the key theme "Legal framework" for different groups of actors. The colour coding is based on the percentage of participants in each group. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

alternative applications will reduce uncertainties and make reuse more predictable (Nußholz et al., 2019).

Another barrier extracted from the interview data concerns procurement procedures. Turnkey contracts are widely used in the Norwegian building industry and were described as " … *the wrong type of contract when you want to reuse building materials*" (P16). Apart from manufacturers, all groups of actors agreed that a reuse focused collaborative procurement process allowing for some degree of flexibility could facilitate reuse. Reuse experts and consultants specializing on reclaimed materials procurement could help reduce the risk of disruption or delay (Gorgolewski et al., 2008).

Few pilot projects and a lack of experience and infrastructure require collaboration in the value chain to find good solutions; in addition, a flexible and more holistic approach to regulations and codes could greatly advance the transformation process towards more circularity (Kozminska, 2019). Often, the public sector has additional regulations that may further limit the possibilities for reuse. Participant P1 explained that "*Right now, we (municipalities) are not allowed to reuse products from other building owners …. There are many restrictions and leading documents that we are required to follow* ". Green public procurement requirements have been found to be an important enabler by designers, researchers, and consultants (Adams et al., 2017), and could function as role models for private actors in Norway.

4. Addressing reuse barriers in Norway

Several barriers have been identified in the interview data that need to be addressed to facilitate a wider adoption of reuse in the Norwegian construction industry. The barriers mentioned by the interview participants coincide well with those reported in the literature (Bohne and Wærner, 2014; Hart et al., 2019; Hobbs and Adams, 2017; Nordby, 2019; Rakhshan et al., 2020). Our data shows that some issues are more pressing and apparent for certain groups of actors, signalling the need for more communication and cooperation in the value chain.

4.1. Establishing reuse infrastructure and knowledge base

Architects and consultants mainly point out barriers connected to the realisation of reuse in practice. This group of actors can give valuable input concerning tools and reuse infrastructure that supports their efforts. They constitute the main user group for reuse infrastructure and can guide the development of functional digital and physical solutions. The same actors also depend on knowledge and guidelines for the reuse of different materials. Trial-and-error and finding solutions on-the-go, as practised in several of the pilot projects presented in this study, is not practicable in the everyday construction project. Findings from these projects need to be fed into databases and turned into guidelines to make reuse in Norway efficient and affordable.

The process of integrating reused materials and products in pilot projects is described as time-consuming and costly. The lack of availability and accessibility of reused construction products is identified as a main contributor to these issues. Mapping existing buildings and establishing material inventories would help to identify reuse potential and manage future material sources. The need for a digital platform was stressed by all participants, but physical marketplaces are also considered essential. When it comes to marketplaces for reusable construction products and materials, several Norwegian companies such as Loopfront (2021), Rehub (2021) and Resirqel (2021) have created digital platforms and tools for mapping and/or registering materials. These platforms are expected to create a marketplace for reuse and increase collaboration between actors in the value chain. Madaster, originally developed in the Netherlands (Madaster Holding BV, 2021), has launched a Norwegian version of their platform aimed at providing a material passport for construction products. With the expansion of the platform to Germany, Switzerland and Belgium, there is great potential for uniform procedures within Europe, which can foster advances in reuse. European collaboration and exchange of knowledge can boost the potential for reuse in countries that have not yet been able to make progress in this field.

Most of the challenges related to reuse are connected to the absence of data. Information on material properties, reuse potential, sourcing and product preparation, costs and environmental performance can be collected and stored in reuse databases (Rakhshan et al., 2020). Individual initiatives need to team up to form a European platform that can offer solutions to enable a wider implementation of reuse. The on-going collaboration and network platform in the REBUS project is a good example where actors in the value chain are gathered to raise awareness and disseminate knowledge and experience on reuse of construction products. Sharing the knowledge and experience from REBUS and other national initiatives with Nordic, European, and international networks will help to create synergies between initiatives.

4.2. Getting manufacturers on board

Manufacturers play an important part in the reuse process. However, linear business models are prevailing, and many manufacturers are not aware of the challenges related to the reuse of their products. However, detailed knowledge of material composition, durability and other product characteristics put them in a unique position when it comes to material knowledge. The capability of suppliers to issue quality certificates and guarantees for second-hand materials could help the growth of a reuse market (Rakhshan et al., 2020). Connecting manufacturers with actors involved in the actual reuse processes in construction projects will foster a better understanding of material and product potential and can spark innovation. Circular business models comprise both the development of new products fit for reuse (DfD), as well as reuse of existing products. The latter may include take-back schemes, leasing options, and repair services.

In recent years, a growing number of companies selling used products have emerged in Norway. They mainly specialise on single products such as bricks or furniture. The latter does not require any testing or recertification and is therefore easy to realise.

Norway's new "National Strategy for a Circular Economy" promises to promote product design that enables repair, upgrade, and reuse. The government also wants to strengthen the concept of "Extended Producer Responsibility" to motivate the development of circular products (Ministry of Climate and Environment, 2021).

However, adopting strategies for reuse of building materials may require radical changes in a company's production infrastructure, value chain, and product and service offers (Nußholz, 2018). Various materials may require different types of business models, which are determined by life cycle, supply risk and value retention potential (Wang et al., 2017). More incentives, funding, and government subsidies that encourage and support the development of circular business models are necessary to make these types of investments more attractive. Companies are more likely to invest and venture out of established and profitable set-ups when risks can be shared (Guldmann and Huulgaard, 2020).

4.3. Enabling reuse through regulations and increased reputation

The current Norwegian regulations hinder reuse and are considered by all groups of actors as one of the main barriers. Unlike with new construction products, there is also a lack of harmonised standards, European assessment documents (EAD), and other technical specifications that could provide guidance for the reuse of construction products (Fufa et al., 2021; Rakhshan et al., 2020). The national strategy on circular economy (Ministry of Climate and Environment, 2021) and on-going work on developing a guidance document for reuse (Direktoratet for byggkvalitet, 2021) are first steps towards a circular building industry in Norway. However, immediate consequent governmental action is needed, such as national policies for waste and resource management making it more attractive to conserve landfill space

(Gorgolewski et al., 2008) and propelling the adoption of reuse for construction materials.

Voluntary sustainability schemes are potential drivers for reuse of construction products. The FutureBuilt criteria (FutureBuilt, 2020), representing the only scheme for circular buildings in Norway, promote the preservation of existing structures and define requirements for reuse in projects that commit to the programme. The first large-scale circular pilot project in Norway complying with FutureBuilt criteria, an office building in the centre of Oslo, has recently been completed (Entra AS, 2021). "Trailblazing" results for the reuse of building materials and circular solutions were the main goal of the project owners that were willing to take on risks and additional financial burdens to position themselves as environmental leaders in the industry (Skanche, 2020; Steni, 2021). Commitment to greener and more sustainable practices can strengthen a company's reputation and attract new contracts. The FutureBuilt label further attracts attention in the Norwegian building sector showcasing actors that are willing to take the extra step.

5. Conclusions

This article presented the findings from a set of interviews conducted in the framework of the research project REBUS. Participants from five groups of actors - manufacturers, architects, contractors, consultants, and public institutions - were chosen for the interviews to get an insight into the viewpoints and experiences of various professionals typically involved in construction projects in Norway. The identified barriers and success factors were categorised into four key themes and allocated to different actors to map differences and prevalence for the different professions.

One major issue that crystallised from the analysis of the interview data is the need for collaboration and exchange of information in the value chain, especially towards production and manufacturing industries. Manufacturers, with their in-depth knowledge on material characteristics for their own products, can play a key role in a circular building industry. Effective communication of needs between different actors in the value chain can lead to new opportunities, including greater environmental benefits, new markets, and enhanced societal values. When different groups of actors work together on innovative solutions it can foster a culture of teamwork and continuous improvement.

This study only covers part of the Norwegian building sector with a limited number of pilot projects and actors. Reuse in Norway can still be described as immature and experimental and needs to evolve from a trial-and-error approach to more standardized solutions.

More pilot projects and coordinated large-scale reuse will help establish the necessary processes and infrastructure for successful reuse and resource valorisation on a national scale. Emphasis should be put on data collection and distribution of knowledge to make reuse accessible and practicable for the construction sector and all involved actors.

But most importantly, the authorities need to commit to the concept of reuse. Immediate support is needed in form of regulations favouring reuse, financial incentives for manufacturers willing to adopt reuse as part of their business strategy, and generous R&D funding.

CRediT authorship contribution statement

Katrin Knoth: Writing – original draft, Visualization, Investigation, Formal analysis. **Selamawit Mamo Fufa:** Funding acquisition, Project administration, Conceptualization, Investigation, Writing – original draft. **Erlend Seilskjær:** Resources, Investigation.

Declaration of competing interest

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

Acknowledgements

This research was supported by The Research Council of Norway through the research project "REBUS - Reuse of building materials - a user perspective", under the grant no. 302754. The authors would like to thank the project partners and others involved in revising interview guides and/or participating in the survey.

Appendix A. Interview guide

Part 1: General information

1.1 Which project were you part of?
1.2 What is/was your role in the project?
1.3 What is/was the ambition of the project or the main motivation/driver related to reuse of construction products?
1.4 Who are/were the main actors involved in the project to realise ambitions related to the reuse of construction products?
1.5 What type of contract was used in the project you are/were involved in?
1.6 Were there any requirements for reuse of construction products formulated in the contract? If yes, please specify.

Part 2: Reuse potential

2.1 What construction products have you reused already? What was the reason for choosing those products?
2.2 Which construction products are easiest/have the biggest potential for reuse, and which are most difficult to reuse? Why?
2.3 What is/was your source for reused construction products?
- Do you have knowledge of a digital marketplace for the reuse of construction products? If yes, please specify.
- Do you have knowledge of a digital database for product information (materials passports)? If yes, please specify.

2.4 What type of building is most suitable for reuse (public, private, specific use of building etc.)?
2.5 Did you reuse the products for their intended purpose/function or for a different purpose? Please specify.
2.6 What type of solutions were considered to increase reuse of construction products in different phases of the project?

Part 3: Mapping and evaluation

3.1 How do you map/select potential products that can be reused in the project? What are the selection criteria?
3.2 Was there any evaluation of a potentially negative environmental impact? If yes, please specify the method used and main findings.
3.3 Was there any economic analysis performed in the project? If yes, please specify the method used and main findings.
3.4 What are/were the main barriers or practical challenges related to the reuse of construction products? Please specify.

Part 4: General comments or opinions

4.1 In your opinion, what are success factors for increased utilization of reusable construction products?
4.2 In your opinion, what are the main challenges with reuse of construction products today?
4.3 Do you think it is possible to solve current major challenges and increase utilization of reusable construction products in the near future (<5 years period?)
4.4 In your opinion, what measures should be considered to increase utilization of reusable construction products?
4.5 Do you have any other comments or suggestions related to reuse of construction products?

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