Circular economy digital market solutions for reuse in the European construction sector

M Sivers¹,²,*, M Fröhlich¹ and C Fivet²

¹ Laboratory of Elementary Architecture and Studies of Types, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
² Structural Xploration Lab, Ecole Polytechnique Fédérale de Lausanne (EPFL), Fribourg, Switzerland

* maria.sivers@epfl.ch; Tel: +41 (0)21 693 44 48

Abstract. Focusing on the cross-matching supply and demand for reused building components and related services, the paper analyses existing Digital Reuse Market Solutions (DRMS) in the European construction sector. A collection of 746 DRMS is built from major online circular economy platforms and custom online search queries. A taxonomy of 9 categories and 28 types is then extracted based on the activities of collected DRMS. Nearly half (46%) of collected DRMS are proper dealers of reused building components. Traditional building component dealers and demolition companies account for another third (32.8%). The rest is made of marketplaces, craftsmanship, and providers of related services and knowledge. Only 13.4% of all collected DRMS allow online payment for goods or services.

Keywords: reuse, market analysis, marketplace, circular economy, buildings.

1. Introduction

Circular economy (CE) solutions, digital technologies, and reuse in the construction sector

In response to global warming and other societal issues, the transition from a linear to a circular economy has become an international goal [1], as demonstrated by the Paris Agreement in 2015 [2]. Although the interpretation of the document's accountability mechanisms remain controversial [3,4], since then, the concept of the circular economy (CE) has been at the centre of strategic thinking among research and business institutions, with numerous practical initiatives being implemented [5,6].

The widely discussed elements of the CE concept are associated with the so-called “R Framework,” actions on how to reduce, reuse, recycle and recover resources, which is at the core of the European Waste Directive 2008/98/EC [7]. Article 3.13. of the document states that reuse is “any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.” The present study considers the reuse of building components, i.e., the process sequence that consists of: deconstructing a component from a donor building; cleaning or refurbishing it with only minor geometric and functional transformations; and transport and reassemble it in a potentially-different receiver building. This process is one of the 9 operations in the 9R system [8].

In line with the Paris Agreement, in 2018, the European Commission has provided the “2050 long-term strategy” and “vision,” which aims to achieve a climate-neutral European economy (with net-zero greenhouse gas emissions) by 2050 [9]. An essential role in this transition in the short term is given to “Digitalisation and automation” as one of the “effective avenues to increase competitiveness, leading both to efficiency gains and to greenhouse gas reductions,” which includes increasing technological innovations in the construction sector [9]. To address the aim in 2021, the European Commission has
adopted "Europe's Digital Decade" and "2030 Digital Compass" to empower all European industries in
digitalisation, technologies, innovations, and data management. The text of the document states that
among all major industrial sectors, the construction industry had “the lowest productivity development”
in the last 20 years [10]. With this, digitalisation is seen as a catalyst for the construction sector's
development improvement [11].

Digitalisation for construction is a technical, economical, and business necessity [12,13]. This is
largely due to the fact that the construction industry is based on the exchange of information between
the involved parties in various interrelated processes, and a large amount of data needs to be managed
and processed daily [14]. Although the sector faces several issues related to implementing new digital
technologies, research data indicate that stakeholders increasingly recognize the need to adopt digital
changes [12–14]. Acceleration of the data exchange reinforces competitive positions and improves
companies' overall productivity and efficiency [18]. Concerning the circular economy, these issues are
especially critical [11,17]. The untimely exchange of information, in addition to economic, technical,
and organisational issues, is one reason why the reuse of building components currently accounts only
for 1-7% [11,18]. The lack of timely information on available components for reuse also leads to an
underdeveloped market for reusable components [19].

Given the preceding factors, this paper explores existing digital market solutions for circular
economy in the construction sector concerning component reuse, taxonomy of such solutions, their
characteristics, and distinguishing features, with the aim of understanding their potential for
improvement. The term “Digital Reuse Market Solutions” (DRMS) is explained in detail in 2.1. and
refers to the internet platforms, web stores, and web applications that trade goods on the reuse market,
are engaged in direct sales to customers, and incorporate digital technologies to facilitate reuse in the
construction sector.

2. Methods and objects of research, organisation of the analysis
This work aims to identify intermediaries as digital solutions operating between supply and demand
related to RBC and associated services such as repair, refurbishing, remanufacturing, and repurposing.
To achieve this, a stepwise approach is applied to specify, evaluate, and create a matrix of DRMS. As a
first step, this paper reviews available online sources that outline handlers dealing with the circular
economy in Europe. In the second step, data on digital reuse solutions are collected by identifying and
inspecting the websites of the handlers engaged in reuse. Based on the collected data, the DRMS
taxonomy is determined. Finally, DRMS accounting transactions are analysed to evaluate the possibility
of online procurement of reuse products and services. The following subsections describe the data
sources and the analysis and classification methods applied.

2.1. Scope of study
Despite the constantly growing number of academic research on the CE framework [20,21], ISO
standard like the international guidance on CE are still not implemented [22]. At the same time, due to
the “top-down” approach to CE policy realisation [20], numerous widespread publications and
discussions on CE topics come from non-academic institutions associated with NGOs, political
organisations, and enterprises [21] that appeal to the benefits of CE for economics and business. It has
led to different approaches to classifying processes and stakeholders associated with the reuse in the
construction sector [23–25]. Some classifications are based on lifecycle assessment stages such as
Extraction – Manufacture – Construction – Use – End-of-Life (ISO 21930:2017), classical or forward
logistics [25]. Other approaches are established on reverse logistics that refer to the processes of bringing
a product back into a supply chain after its use [26,27]. The closed-loop system concept includes all
processes related to the forward and reverse supply chain of building products from the moment of the
raw materials destruction, production, use, reuse into new constructions, and till the waste management
phase [26,28].

In this regard, the current study research scope is built on Supply Chain Management (SCM) in the
reuse market and the basic categories related to the definition of market – supply and demand [29]. In
relation to the reuse of the building components, the category supply is associated with the resource
object – a source of material for reuse, and demand is determined by the destination object, referring to
the new construction cycle. Hence, reuse market solutions are services that help to organise processes
of transferring reusable components from a resource to a destination object. One of the current study aims is to uncover how many types of DRMS exist between reuse supply and reuse demand and which of the DRMS refer to both - donor object and receiver object. Market solutions can have several definitions and forms. We use an arrow definition that includes actions by selling and buying reusable building components, information, and services, associated with reuse market operations, led by reuse market participants. Digital reuse market solutions (DRMS) are associated with the digital online presented services and platforms which allow purchasing or selling a product or service related to reuse building components (RBC) through online or offline payment.

Another important basic economic dimension of market demand and supply and their measurement is time, which directly influences both categories defining the type of needed products and services according to the supply and demand curve versus time. Concerning reuse, it involves different types of markets: classical “old” analogue markets, currently developing online markets, and concept markets that do not function yet but show potential by involving blockchain technologies, and information databanks exchange.

2.2. Data collection and analysis methods

This study is based on a web data collection initiated from the following sources: the main European circular economy initiative “European Circular economy stakeholders platform”, which provides an information map of 733 circular economy solutions and stakeholders across Europe in different industries, including construction; an additional part of it with information about 167 European Circular economy networks and platform; the non-governmental CE European reuse network initiative that includes the biggest listing from 519 designations of reuse building components’ suppliers and stakeholders of reuse services; Opalis proposes a detailed inventory of all handlers and contractors dealing with reusable building components around Belgium, France and Netherlands; The French database of 514 circular solutions Materiauxreemploi was used to verify the developed taxonomy of solutions and supplement it with additional categories important for the final conclusions [Appendix A]. To date, in Europe, these digital information bases are the only systematically established resources for the circular economy network and its stakeholders that provide reuse products or services. The total number of analysed cases amounts to 1933. Among them 746 DRMS in the construction sector were identified for a comprehensive examination. All gathered data results are dated to May 2022.

An additional analysis was conducted through Google, Bing, Swisscows, and Ecosia to cover available DRMS categories. Different search queries that refer to DRMS are applied as a combination of “find (buy, sell) reuse (re-use, used, reclaimed, salvaged, repurposed, second-hand, scrap) building (construction) components (materials, pieces, parts, elements, stone, iron, steel, timber, beams, brick, doors, windows, tiles)”. These queries were translated into various European languages (Czech, Danish, Dutch, English, French, German, Italian, Polish, Portuguese, Romanian, Spanish and Swedish) and looked up using Virtual Private Networks (VPN) located in the related European countries.

The further analysis included the identification of types and patterns among the selected solutions. The summary of the results for the selected websites is given in Figure 1.

2.3. Comparison methods, classification, and production of a taxonomy

The proposed general DRMS taxonomy of the selected solutions aims to embrace the current state of the reuse market as a basis for further identifying the market gaps and obstacles to reuse increase. The taxonomy comprises a total of 9 major DRMS categories. A generalised framework used for the DRMS taxonomy establishment is summarised in Table 1.

Table 1. Template of DRMS generalised framework developed from a review of 1933 organisations.
Based on the data obtained a comparative case study approach was applied [30]. Answering the explorative character of the study, all solutions presented on the mentioned web pages were divided into groups according to the following: type of core activities such as RBC trade, service or data exchange, in order to identify the DRMS category, webpage language to recognise the coverage area, type of the webpage, company localisation, range of RBC products, type of CE scenario, type of reusable materials, and price indication, online payment implementation availability, other payment options by buying or selling operation towards a reuse product or service to specify a digital character of a solution. The next phase involved extracting from all solutions those that are consistent with the definition of DRMS adopted in the paper.

3. Analysis of DRMS in Europe

The present section reveals tendencies from the existing DRMS in Europe. Applying the above-mentioned methodology to 1900 webpages, a collection of 746 reuse solutions is created. All selected solutions support CE and are active in the processes leading to the reuse of the building components from donor buildings to receiver buildings. The next sub-section presents a taxonomy of the collected reuse solutions. The following sub-section analyses their payment method.

![Figure 1. DRMS in European construction sector within 9 categories](image)

3.1. Taxonomy

After analysis based on the framework presented in Table 1, 9 DRMS categories (Figure 1) and 28 DRMS types are identified. Categories and types are presented on Figure 2, by decreasing number of
occurrence, as a percentage of the 746 collected reuse solutions. The following paragraphs review them. Selective sampling of the inspected webpages within the DRMS categories is given in Appendix B.

3.1.1. Reuse building components (RBC) dealers (46.4%). The most represented category within the dataset, consists of regional second-hand dealers, often family businesses for 40-60 years, spread across Europe, that provide reuse components dating from the time of flea markets and antique shops. In addition to declines in purchasing power among those financially marginalised from the major distribution channels, in response to interest in original artefacts and raised attention to environmental issues, such enterprises have experienced rapid growth in the past 20 years [31,32]. RBC dealers are divided into five types. The “antique RBC” dealers propose a broad spectrum of products from architectural and building components to interior elements. In relatively equal proportions, “selective RBC (one material)” dealers (9.4%) distribute RBC made of a single type of material (stone, iron, steel, concrete, wood) and “selective RBC (one element)” dealers (8.0%) distribute each only a specific type of building component (windows, doors, fireplaces, stairs, (roof) tiles or parquet). The “selective RBC” dealers offer used building components without interior items. The “antique luxury” segment, or antiquarians, closes the list. Except for the last type, in most cases, RBC dealers have a monolingual local website with minimum options and descriptions of their products, usually including a photo without selling price, requiring direct contact for more information.

3.1.2. Demolition companies (15.55%). Unlike RBC dealers, these actors acquire RBC directly from receiver buildings instead of from third parties. It comprises 3 types. The first type, “demolition and trade” (12.3%), relates to demolition companies that combine deconstruction-related activities (demolition, deconstruction, asbestos, and chrome 6 remediations, drilling and sawing) and RBC trade (selling, buying). Components for reuse range from structural to non-load-bearing elements and equipment elements such as heating and sanitary. In the solutions reviewed, 93% of the companies

![Figure 2. Identified categories and types of DRMS, and their distribution in the reuse market.](image-url)
indicate the availability of RBC on their main website. Their cost is not specified, and the spectrum of materials is presented either with a few pictures or a short, incomplete list of items with company contacts for information. A visit to a storage site is required before any purchase. Among 7% of the type are companies that have split RBC trade into a separate business as RBC marketplace or use the external multi-trade platform to place the presented RBC for selling. However, there are solutions where a different website does not indicate the RBC price and encloses a catalogue function with the need for offline visits to the material storage location.

The second type, “Demolition for trade” (1.9%) refers to companies that get RBC with a trade target by providing selective or so-called “circular” deconstruction after RBC are carefully identified and assessed for reuse potential. In most cases, the companies deal only with a particular type of RBC and provide a separate website for trade with or without prices.

The third type, “demolition, trade and service” (1.34%), is defined by companies that, in addition to demolition activities and RBC trade, provide services connected to RBC – cleaning and renovation of RBC, their renting, and RBC procurement from the private and business owners.

3.1.3. Building Components Dealer (BC Dealer) (17.16%). The category relates to the classic analogue market representatives, who traditionally sell new building materials and have partly moved online, adding 2-20% reusable components to the assortment. The scope of RBC includes mainly non-structural building components, excluding antique items or second-hand furniture. The first type under the category is large sellers of new building materials “new BC and all RBC”. Sellers of several particular reusable components, “new BC, selective RBC” deal mainly with a combination of wood and stone components, doors, elements of landscape architecture, and greenhouses. The other two types, as in the RBC dealer category, enclose shops that deal with either one type of RBC material or only one type of component. In 70% of cases, these last types offer additional installation services or design recommendations.

3.1.4. Marketplace (5.9%). The rapidly growing category of marketplaces or “electronic marketplaces” and “e-marketplaces” occupies a special place in retail today giving access to more buyers and suppliers, and reducing marginal costs for information exchange [33,34]. Unlike the previous categories, marketplaces are digital platforms which enable value exchange and co-creation between independent market participants [35] and allow them to act as both a seller and a buyer, using Internet technologies to complete transactions and payments. Regarding reuse, four types of the category were distinguished.

The first one, Marketplaces (2.4%), refers to digital platforms based on trade exchange between RBC supply and RBC demand. This type includes several classes and sub-classes consisting of single-vendor solutions where the platform sells all goods solo or uses external multi-trade platforms to distribute goods, and multi-vendors that serve as intermediaries. All classes can operate as B2B (business-to-business), B2C (business-to-customer), and C2C (customer-to-customer) retail business models [36].

Marketplace complete solutions (1.6%), represents a second type. Those are hybrid solutions that offer different services related to RBC in addition to their trade. Dividing into classes, the services include RBC assessment and RBC full maintenance up to the point of application of RBC in the new construction cycle such as RBC assessment, organisation of dismantling, design with RBC, and consulting services for planners that aim to implement reuse components in their projects.

Marketplace multi-businesses (0.8%), are also newly emerged solutions but they separate additional services associated with reuse into an independent business or even several businesses.

Finally, Marketplace multi-trades are large multi-trade marketplaces such as eBay that distribute RBC among goods of all sorts.

In contrast to most other DRMS, these businesses propose the whole spectrum of RBC with supplementary information regarding dimensions, embodied carbon, dismantling options etc.

3.1.5. Local craft (5.63%). This category represents the trade of RBC by local artisans, often family businesses. Related types include: masters who work only with RBC produced from one material such as stone, wood, or metal; those who specialise in one type of RBC; and those who work with several diverse RBC types. Besides the trade, these craft companies propose connected services of renovation,
remanufacturing, and installation of the products. Regarding the reuse of wood, an additional service often includes own design product series.

3.1.6. Network platform (4.56%). A new tendency is the emergence of reuse networks [37,38]. Such unions have an online presence. Types vary according to activities directions: RBC sellers united for trade (contacts, trade), network of reuse stakeholders that provides training (trade, contacts, workshops), and networks whose primary purpose is to provide information on stakeholders and services in the reuse market (trade of contacts).

3.1.7. RBC service (1.88%). The main difference in this category is that it is not driven by the sale of RBC but by the sale of reuse-related services. There are two main types: “trade of knowledge, service”, which is directed by RBC experts that offer pre-demolition RBC assessment, engineering for RBC deconstruction and construction, design with RBC; and “craft, service, trade”, which refers to artisans specialising in the renovation of particular RBC.

3.1.8. RBC knowledge (1.61%). This category is characterised not by trade but by exchange of RBC knowledge, providing information and knowledge about reuse and RBC, for example through reuse and repair centres, RBC learning centres, and research projects that gather, reproduce, and then sell the data and information related to RBC in the form of data and publications.

3.1.9. Data platform (1.34%). Consisting of data-driven solutions, this new category is the most technology-intensive [39]. The category includes three types. “Data trade” refers to databases that provide information on construction-related carbon footprint, used for life cycle assessment (LCA) of RBC. This type also comprises digital twin libraries and BIM-related databases. “Data trade, data service, data knowledge” appeals to solutions connected to data analysis and BIM integration of elements for subsequent exchange of this data with interested recipients [40]. Here included are also new applications bonded to digital innovations in data exchange on RBC based on artificial intelligence, blockchain for data exchange [16], and self-learning systems for data analysis. The last type, “data, service,” is defined by RBC assessment platforms and tools such as online carbon footprint calculation and circularity assessment for buildings.

3.2. Online payment implementation for DRMS, current state

The analysis reveals that only a portion of DRMS implements online payment transactions allowing a direct procurement of reusable building components or some of the RBC-related services such as installation, delivery, certification, quality assurance, guaranty, carbon footprint calculations, BIM. Such solutions consist of the following categories and types: Marketplaces (all types), RBC dealers (selective RC, selective RC (one material)), Demolition (all types), BC dealers (new BC and all RBC; new BC, selective RBC with service); Data platforms (all types), and Network platforms (trade, contacts, workshops).

The Marketplace and Data platform categories present the highest ratios of online payment quantity (OPQ) per number of websites; 0,86% (=38%/44) and 0,8% (=8%/10), respectively, Figure 3. They are followed by Network platforms (0,17%), Demolition companies (0,16%), BC Dealers (0,09%), and RBC Dealers (0,06%). Marketplaces and RBC dealers dominate the total number of DMRS with online payment.
4. Discussion and Conclusion

The proposed study contributes to the identification and analysis of digital reuse market solutions (DRMS) across Europe by proposing a taxonomy of their operations. A collection of 746 DRMS is built from circular economy network platforms or through custom internet queries.

Nearly half (46%) of collected DRMS are actual dealers of reused building components. Traditional building component dealers and demolition companies account for another third (32.8%). The rest comprises marketplaces, craftsmanship, and related services and knowledge providers. Only 13.4% of all collected DRMS allow online payment for goods or services.

Despite the digital transformation of the construction market and the emergence of the need for the RBC market and its solutions, it can be assumed that most currently existing solutions are still transitional, not only in terms of reusable materials but also in terms of newly manufactured ones. Even if sizeable B2B sellers of new building materials provide online catalogues of products, contact with a company is still requested since prices are not given or online payment is not implemented. Also, as of today, reuse building components are mainly available in offline markets, and distributing companies’ websites are mostly landing pages, that is, providing only limited information on RBC, which comprises the fact that components are available, a list of categories offered or a catalogue with photos, without prices or technical data. This may be due to the significant range of materials in the construction market and the consequent difficulties in devoting many resources to maintaining an online marketplace.

Alongside the emergence of new reuse businesses, recent attention to the circular economy probably helped the development of new reuse activities within otherwise traditional businesses. For instance, a number of demolition companies propose so-called “circular deconstruction” and sell reclaimed components, competing with newly developed deconstruction companies. The variety of stakeholders currently active makes it challenging to identify what DRMS will succeed in the long term.

Based on the analysis provided, a considerable opportunity to develop the RBC market lies in improving reuse market solutions that are offline or only superficially online. Further research can investigate key drivers and issues when transferring from offline to online distribution of reused building components and related services.

5. Authors’ Contributions

Conceptualisation: MS, CF, MF; methodology: MS, CF; investigation, data curation, literature review, and original draft writing: MS; writing, review and editing, MS, CF, MF; figures: MS; project administration: MF. All authors have read and agreed to the published version of the manuscript.

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Appendix A

- European Circular Economy Stakeholder Platform (accessed on 30 May 2022):
  https://circulareconomy.europa.eu/platform/good-practices;
European Circular economy networks and platforms (accessed on 30 May 2022): https://circularconomy.europa.eu/platform/en/dialogue/existing-eu-platforms;
- Opalis, “Building and renovating with reclaimed materials Professional dealers, common materials, examples of the reuse: https://opalis.eu (accessed on 30 May 2022);
- Materiauxreemploi, map of the reuse of building materials: https://carte-des-acteurs-du-reemploi.gogocarto.fr (accessed on 30 May 2022).

Appendix B

Webpages are given without http:// prefix, and were all accessed on 10 May 2022.
- RBC Dealer: mercatorenco.nl, bricobidule.fr, nord-antique.com, tuinmaterialenbvba.be, materiauxdantan.fr, sturmendekker.nl, paves-anciens-gedou.fr, marisnatuursteen.be, thekairoscollective.com, legens.com, origines.fr, the-saleroom.com, antiquitesphilippelachaux.fr;
- Demolition: groothuishandel.nl (shop, twenteklinker.nl), tweedehandsmaterialen.nl (shop, snellen.nl), tsloopenensaneren.nl (shop, tncirculair.nl), jensen.com (jensengenbrug.dk), vermeulensloopwerken.nl (shop, gebruiktesloopmaterialen.nl), baukarussell.at (shop, baukarussell.bauteillager.de), anticaftermat.fr, dwendingzeeland.nl, elzenverbruggen.nl, gebroedersweersmuellers.be;
- BC Dealer: pekaar.com, vanharn.nl, vanelsen-wood.com, crijsnbouwmaterialen.nl, ctc.be, europort-bvba.be, harmoniedulogis.com, multimat76.com, mundindataktmaterialen.nl, vanbaal-herveld.nl, occultam33.fr, floorz.nl, 2dehandsbouwmarkt.nl, sydhavengrugscenter.kk.dk;
- Marketplace: batiertre.fr, gadero.nl, gewo-hout-en-bouwmaterialen, materiaalbankleveren.be, cornermat.be, jk-genbrugsj Center.dk, backacia.com, materium.ch, rotordc.com, readyramer.com, concular.de (restdo.de), caprionis.fr (r-place.fr), sumami.ch (useagain.ch), site-cycle-up.fr (cycle-up.fr), enfin-reemploi.fr, bobireemploi.fr, plateaucirculaire.fr, baukarussell.at, baukarussell.bauteillager.de, troc.com, leboncoin.fr, dba.dk, permute.it, subito.it, secondamano.it;
- Local craft: huismus.be (shop, recupmarkt.be), oudhout.be, houtmehistorie.nl, vieux-bois-des-alpes.com, arts-techniques.fr, parquetsbriatte.fr, rikstroms.com, gunterbosmans.be, jvisser.nl, crombe.be, vieuxgranits.com, tailleur-pierre-tarn.com, pesce-tailleurdepierre.fr;
- Network platform: laressourcerieverte.com, syphon.ch, ecrouvis.org, laregatterie.fr, lamiraille.org, graanbuurt.nl, opalis.eu, reemploi-construction.brussels, acciona-construccioon.com, lesateliersduplateau.fr, boma.alsace, matieregrise.org, metabatik.fr, idre-dc.org, lerepair.org;
- RBC service: lambertcyril.fr, tailledepierreres-lieval.fr, r-use.fr, zirkular.ch, citae.fr, bellastock.com;
- RBC knowledge: bamb2020.eu, circular.berlin, rediscoverycentre.ie, nweurope.eu, ellenmacarthurfoundation.org, reuse.brussels;
- Data platform: madaster.com, ecoinvent.org, abstractbim.com, oneclicklca.com, platform.excessmaterialsexchange.com, geofluxus.com.

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