Chapter 14
Circular Business Models for Digital Technologies in the Built Environment

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Abstract Business model innovation enabled by novel digital technologies can accelerate the impact and upscaling of the circular economy in the built environment. Digital technologies not only enable highly impactful new business models but also enable innovation of existing business models. Considering the disruptive power of digital technologies, rethinking business models in the construction sector for the circular economy is vital to manage risks and capture opportunities. This chapter presents 12 real-life cases of emerging business models enabled by digital technologies that successfully narrow, slow, close, or regenerate resource loops in the construction sector. Cases are analysed regarding how they create, deliver, and capture value and how they enable circularity. Findings present different types of business models for digital technologies prevalent for narrowing, closing, slowing, and regenerating resource loops and that enabling capabilities for circularity, such as tracking, monitoring, control, optimisation, design evolution, and information exchange, are at the core of their value propositions. Industry practitioners can use findings to familiarise themselves with emerging business models and innovation opportunities.

Keywords Circular business models · Business model innovation · Digital technologies · Built environment · Building industry

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14.1 Introduction

A business model is a useful management tool to analyse and design a firm's business logic (Casadesus-Masanell and Ricart 2010) and how a company delivers, creates, and captures value (Osterwalder and Pigneur 2010). During this process, it helps managers to focus on the most relevant building blocks for the creation of commercial value (Osterwalder et al. 2005). The business model concept in management literature originates from the time when the Internet proliferated, and companies' blueprints to creating value diversified and became more complex compared with traditional business models (Osterwalder et al. 2005, Amit and Zott 2010). Business models are considered a strong indicator of competitive advantage (Magretta 2002) because changes are harder to replicate than product innovations (Amit and Zott 2010). Thus, in order to stay successful, companies must adapt their business model over time to changing business environments (Demil and Lecocq 2010).

Technological advances since the diffusion of the Internet in the 1990s have enabled new digital business models, which are now transforming industrial-age industries, such as the media, retail, financial services, and logistics sector (Veit et al. 2014). Digital business models can be defined as those that rely on digital technology and leverage the effects of digitalisation (Guggenberger et al. 2020; Bärenfänger and Otto 2015). Veit et al. (2014, p. 48) define a business model as digital "if changes in digital technologies trigger fundamental changes in the way business is carried out, and revenues are generated" of which Uber in the transport sector and AirBnB in the hospitality sector are prominent examples that have caused major disruption of previous business practices.

Even though the adoption of digital technologies in the building sector is slow compared with other sectors (ESCO 2021), an increasing number of digital technologies and business models are proliferating. Business models are paramount for the market introduction and uptake of these technologies. Only if technologies are embedded in business models that create superior customer and business value, the technology-enabled offers can be commercialised and scaled. This is the case, for instance, in platform models, such as those operated by the Norwegian company Loopfront that enables material or second-hand product exchanges (Loopfront 2022). Given the enormous challenges, such as stagnating productivity, high construction costs, resource intensity, and scarcity paired with pending ambitious environmental regulation in national legislation (ESCO 2021; JRC 2019), new digital business models could provide unforeseen solutions to challenges and serve customers in radically superior ways. Digital business models are understood as innovations in business models that transform analogue, physical objects, processes, or content into primarily digital formats (Trischler and Li-Ying 2022).

Digital technologies, such as platforms or building information modelling (BIM), enable a plethora of benefits, such as improved collaboration, easier transactions, and greater control of the value chain. The Internet of Things (IoT) increases data availability and enables data-driven decision-making for more efficient operations.

These developments are fundamentally changing traditional ways companies approach operations, procurement, design, and construction and engage with value chain partners (McKinsey 2020). For example, Boston Consulting Group estimates that 10–17% of total annual spending can be saved in the operation of buildings and 13–21% in the construction phase from full digitalisation (BCG 2016). Considering the disruptive power of digital technologies, rethinking business models and technological capabilities is vital to manage risks and capturing opportunities.

To provide an overview of the developments of digital business models in the circular built environment, this chapter presents 12 real-life cases of emerging business models enabled by digital technologies that successfully narrow, slow, close, or regenerate resource loops in the built environment. Cases are identified through desk research focusing on Europe, particularly the Netherlands, due to the authors' familiarity with this geographical context and proliferation of commercialised circular solutions in the built environment. Cases are analysed regarding how they create, deliver, and capture value, the digital technologies used, and their level of maturity. Also, their enabling capabilities to help narrow, slow, close, and regenerate resource loops in the built environment are presented. Based on the product and service offers of the case studies, several types of digital business models for the circular built environment are identified.

This chapter proceeds with outlining the theoretical background of the circular business model concept (Sect. 14.2), the presentation of the case studies for narrowing, slowing, closing, and regenerating resource loops (Sect. 14.3), and the discussion and conclusion (Sect. 14.4).

14.2 Circular Business Model Innovation

A business model can be described as a conceptual tool that can assist in understanding how a company conducts business to create and capture economic value (Schaltegger et al. 2012). This chapter defines business models by three main elements: value proposition, value creation and delivery, and value capture (Bocken et al. 2014; Richardson 2005).

The value proposition concerns product/service offerings, customer segments, and customer relationships of a company's business model (Boons and Lüdeke-Freund 2013). Value creation and delivery mechanisms are concerned with the activities, resources, partners, and distribution channels of a company's business model. Value capture is about the cost and revenue model, and in the case of a circular or sustainable model, it also concerns the positive value for society and the natural environment.

Business model innovation is considered to be a holistic approach that can function as an enabler to fulfil radical changes in a company's offers and value chains (Wells and Seitz 2005; Bocken et al. 2016; Tunn et al. 2019). Innovating the business model involves either reconfiguring the main elements of the company's existing business model or developing new business models (Zott and Amit 2010).

In the context of circular economy, business models have received substantial attention in literature and industry as an avenue to achieve increased sustainability in organisations across industries. Circular business models aim to create, deliver, and capture value while implementing circular strategies that can close material loops and extend the useful life of products and parts (Nussholz 2018). Adopting circular strategies usually requires radical and holistic alterations to a company's offers and value chains (Bocken and Geradts 2022; Wells and Seitz 2005; Nussholz 2018).

14.3 Digital Business Models to Enable Circularity

Twelve business model cases enabled by digital technologies were selected to exemplify business models that are narrowing, slowing, closing, and regenerating resource loops in the built environment. The following sections describe the companies' offers, how they enable circularity, and the main elements of their business models. It should be noted that all cases are examples of new business models, sometimes operated through daughter companies or spin-offs, and that not necessarily the whole company associated with the example is fully circular.

14.3.1 Digital Business Models for Narrowing Resource Loops

This section discusses the companies Parametric Solutions, Philips Lighting, and EDGE Next as examples of digital business models for narrowing resource loops.

The Swedish company Parametric Solutions offers an analytics app based on a parametric design method for architectural teams to create and compare design options (Parametric Solutions 2022a). Designs are developed based on the client's criteria and downloadable into design tools such as Revit. Optimisation criteria are, for example, space efficiency, energy efficiency, and reduced embodied carbon. As such, the main enabling capabilities of Parametric Solution's business models for narrowing resource flows are optimisation and design evolution. Parametric Solutions, for instance, partnered with the engineering consultant COWI and architect Arkitema to generate options for building volumes for a respective site (Parametric Solutions 2022b). Parametric Solutions creates value through the development of the parametric method and customised app based on the client's design criteria. Value is captured through users' payments for the app licence (Table 14.1).

Philips Lighting, with its headquarters in the Netherlands, offers an interactive IoT and Big Data System for lighting solutions. Sensors in the lighting panels are connected to interactive app-based systems that measure the occupancy, movement, and lighting levels to adjust and distribute energy usage where needed (Philips

Table 14.1 Examples of business models for narrowing resource loops enabled by digital technologies

Company	Parametric solution	Philips lighting	EDGE next
Sector	Building design	Lighting	Smart buildings
Country	Sweden	The Netherlands	The Netherlands
Business model type	Analytics app developer	Light as a service	Service provision platform
Digital technologies	Artificial intelligence	IoT, big data, and analytics	Digital twin, digital platform, IoT, big data analytics
Enabling capabilities	Optimisation, design evolution	Tracking, monitoring, control, optimisation	Tracking, monitoring, control, optimisation
Value proposition	Instant creation and comparison of design options. Design optimisation based on architectural teams' criteria. Optimisation of sustainability criteria, e.g. efficient space use, embodied carbon, energy consumption and efficiency, biodiversity.	Improved lighting quality. Adjustments based on user preferences. Reduction of energy use. Real-time data on operations and activities for facility managers to streamline operations.	Based on sensors, delivering data and insights for corporate real estate, portfolio managers, and human resources to optimise building performance. Optimisation of space utilisation, operational efficiency, employee Well-being, sustainable performance.
Value creation	Developing algorithms, front and back end by a team of architects and coders. Customisation of backend to customers' needs.	Developing lighting panels, sensor systems, big data system and analytics, and user apps. Maintenance of lighting system.	Developing sensor systems, software, platform, and dashboards apps for different optimisation targets.
Value capture	Payments for licence for app	Payment for products of lighting system and services	Payment per package
Company type	Start-up	Multi-national	Scale-up

Lighting 2022). As a result, increased user comfort is achieved and combined with a significant energy reduction for lighting. For example, energy usage decreased by 70% in the office building The Edge Amsterdam (Philips Lighting 2022). The control application provides building managers with real-time data on operations and activities to optimise operational efficiency and provides users with the possibility of adjusting the lighting. The main enabling capabilities of Philips Lighting's business model for narrowing resource loops are tracking, monitoring, control, and optimisation. Value is created by developing lighting panels, sensors, and a software system to monitor and control the lighting. Value is captured through the sale of the lighting system and services, while apps are offered free to users.

EDGE Next is a Netherlands-based real estate developer that also operates a service provider platform based on digital twin, sensor-based solutions, and big data analytics. EDGE Next offers different service and technology packages for various optimisation purposes, such as improved space utilisation, operational efficiency, and indoor comfort (EDGE Next 2022a). EDGE Next's business model's main enabling capabilities for narrowing resource loops are tracking, monitoring, control, and optimisation. For the Swedish power company Vattenfall, EDGE Next developed a 22,000 m^2 office building in Berlin, using their technologies to achieve a significant reduction in energy use (EDGE Next 2022b). Value is created through the development of the sensor systems, platform applications, and user dashboards, with targeted customers being corporate real estate, portfolio managers, and human resources. Value is captured through continuous payments for different service packages.

14.3.2 Digital Business Models for Slowing Resource Loops

This section discusses the companies Madaster, Rehub, and Excess Material Exchange as examples of digital business models for slowing resource loops.

The Netherlands-based Madaster operates as a digital platform offering a registry of all materials and products used in real estate and infrastructure. Madaster bases its registry on material passports developed for the objects. Amsterdam Metropolitan Area has, for instance, been involved in using Madasters's material passport to stimulate the regional circular economy (Madaster 2022). The enabling capability of Madaster's business model is information exchange. Value is created by linking the registry to material databases of partner companies to facilitate data entry and quality. Value is captured through offering a licence for use.

Rehub is a Norwegian start-up offering a material bank platform that connects the supply and demand side for the reuse of construction materials (Rehub 2022). Rehub's business model offers the enabling capabilities of optimisation and information exchange. The value proposition is about the database for reusable materials and warranties, environmental impact analyses, and assistance. Value is created through the development of the platform and data registry of the materials, and value is captured via subscription-based payments for access to the platform.

Excess Material Exchange (EME) is a Dutch start-up operating as a digital marketplace platform focused on allowing clients to find new high-value reuse options for their end-of-use materials and products (Excess Materials Exchange 2022). EME's tools are, for instance, applied in the European carpet industry to ensure that recyclable carpet tiles are matched with the demand side. The carpet tiles are given a product identification to gather all product information and allow for recyclability (Excess Materials Exchange 2019). The business model's enabling capabilities involve optimisation and information exchange. The company's value proposition is about the offering of an online material matching platform focused on selling B2B. Value is created through developing the platform, and value is captured by selling subscriptions to access the platform. Examples are given in Table 14.2.

Table 14.2 Examples of business models for slowing resource loops enabled by digital technologies

Company	Madaster	Rehub	Excess material exchange
Sector	Buildings and infrastructure	Construction materials	Cross-industries
Country	The Netherlands	Norway	The Netherlands
Business model type	Material passport platform provider	Material bank platform provider	Marketplace platform provider
Digital technologies	Digital platform, material passports	Digital platform	Digital platform, blockchain, artificial intelligence
Enabling capabilities	Information exchange	Optimisation, information exchange	Optimisation, information exchange
Value proposition	Registry of information on all materials and products in a building project. Circularity, embodied carbon, or toxicity assessment. Material passport for optimised end-of-use and end-of-life value management for construction materials and products.	Database for reusable material. Warranties on the material. Documenting CO_2 savings.	Online marketplace for all excess material. B2B sale by matching the supply and demand across industries.
Value creation	Acquiring partner companies to facilitate data entry and data quality	Development of digital platform	Development of platform
Value capture	Licence for use	Subscription-based payment for platform access	Subscription-based payment for platform access
Company type	SME	Start-up	Start-up

14.3.3 Digital Business Models for Closing Resource Loops

This section discusses the companies MetroPolder, Circularise, and Loopfront as examples of digital business models for closing resource loops.

The Dutch company MetroPolder (2022a) offers a green roof with a rainwater storage system. Storage and discharge are controlled through a sensor-based software system allowing for controlled discharge of rainwater to prevent flooding and enable reuse, thereby preventing the use of drinking water. This system for control and optimisation helps close resource loops for rainwater. Through its biodiversity and cooling benefits, the green roof also fits the regenerate principle. In Amsterdam, MetroPolder's water storage system is used on the roof park/garden Babylon providing a 1500 m^2 park with a water storing capacity of 50,000 l. Water is used for plant irrigation, for example, for the vegetable and fruit garden, enabling suitable irrigation levels (Metropolder 2022b). MetroPolder's business model creates value

by developing a sensor and software system, green roof technology, an operating system, and a dashboard for users, e.g. facility managers. Value is captured through the sale of the water capture system technology and services such as construction and maintenance.

The company Circularise, based in the Netherlands, offers a blockchain-enabled software platform to help companies track products and materials and allow information exchange to enable closing loops of materials (Circularise 2022a). Circularise partnered with the City of Amsterdam to increase traceability and transparency in their construction procurement process and gather data on environmental impact, enabling information sharing without risking sensitive data. Circularise also partnered with a concrete product company to help trace materials end-to-end throughout the supply chain, and that information can be shared without risking sensitive data (Circularise 2022b). Circularise's business model creates value through the development of blockchain technology and the creation of data, product passports, and other certificates. Value is captured through selling services and payment for licences for software solutions.

Loopfront is a Norwegian company that offers clients working across the built environment access to a reuse platform. The digital platform offers material passports, a material bank, and a survey tool and assists in closing resource loops through its enabling capabilities of optimisation, tracking, monitoring, and control (Loopfront 2022). The value is created through the development of the digital platform and is captured through selling membership packages on four different levels (Starter, Basic, Standard, or Enterprise). Examples are given in Table 14.3.

14.3.4 Digital Business Models for Regenerating Resource Loops

This section discusses the companies WASP, Lo3Energy, and AUAR as examples of digital business models for regenerating resource loops.

WASP is an Italian firm specialised in designing, developing, and selling 3D printers (WASP 2022a). The company has succeeded in 3D printing structures that are entirely developed using reusable and recyclable bio-based materials from local soil. Specialist software allows for two printing arms to be synchronised for the construction, which allows for avoiding collisions and ensuring simultaneous operation. WASP recently created an installation for Dior in which they 3D printed two pop-up stores on Jumeirah beach in Dubai from all-natural materials (WASP 2022b). WASP's business model creates value through the development of advanced 3D printers, whereas value is captured through the sale of 3D printers and 3D printing services.

Lo3Energy is an American company that has developed a front-end blockchain-powered platform called Pando that enables suppliers and clean energy operators to support 24/7 load matching and offers intelligent incentives to drive renewable energy use (LO3Energy 2022). The Pando software solution has, for instance,

Table 14.3 Examples of business models for closing resource loops enabled by digital technologies

Company	MetroPolder	Circularise	Loopfront
Sector	Roofs and water management	Manufacturing and recycling	Platform developer
Country	The Netherlands	The Netherlands	Norway
Business model type	Software system provider	Software platform provider	Digital platform and surveying tool
Digital technologies	IoT	Blockchain technology, digital platform, material passports and databank	Digital platform
Enabling capabilities	Control and optimisation	Tracking and information exchange	Tracking, monitoring, control, optimisation
Value proposition	Sensor-equipped roof system with rainwater storage, e.g. developers or facility managers. Controlled discharge of water to prevent flooding and enable rainwater use. Biodiversity benefits and cooling effects.	Blockchain technology to trace products and materials and verify their origins. Creation of product passport and certificates.	Survey tool. Material cards. Marketplace. Material passports.
Value creation	Developing sensor and software system, green roof technology, operating system and dashboard	Developing software and platform solutions, including back end and dashboards	Developing and piloting material bank and material passport system
Value capture	Sale of roof systems and services, e.g. planning, construction, maintenance	Sale of services and licences for software solutions	Sale of membership to access platform
Company type	SME	Start-up	Pilot project

been installed in a shopping centre in New South Wales, Australia, where it will be used to optimise renewable energy production. The company's business model's main enabling capabilities are monitoring, optimisation, and information exchange, helping to regenerate resource loops. The business model is capturing value through developing a grid-edge accounting service platform that can match the production and consumption of clean energy at defined time intervals. The value is captured through payment by grid operators and energy utilities to promote their offers on the app.

AUAR is a British start-up, which develops dwelling units through robotic manufacturing using bio-based materials with a zero-carbon life cycle (AUAR 2022). It has been used in an installation at The Building Centre in London to show how it can act as a home, office, and co-working station solution (Design Boom 2020). AUAR's business model's enabling capabilities consist of optimisation and design evolution. Value is created through the development of robotically assembled dwelling units, and value is captured through the payment for customised

Table 14.4 Examples of business models for regenerating resource loops enabled by digital technologies

Company	WASP	Lo3Energy (Pando)	AUAR
Sector	3D printed construction	Renewable energy	Automated architecture
Country	Italy	USA	UK
Business model type	3D printer manufacturer	Web platform provider for energy retail	Automation developer
Digital technologies	3D printer manufacturing	Blockchain technology	Additive/robotic manufacturing
Enabling capabilities	Optimisation, design evolution	Optimisation, monitoring, information exchange	Optimisation, design evolution
Value proposition	Optimising construction to be more time and resource-efficient. Use of 100% bio-based materials.	Software platform allowing clients to forecast the availability of cheap and clean energy.	Modular dwelling units with installation that can be developed according to clients' specific needs. Zero-carbon life cycle.
Value creation	Development of 3D printers or building constructions with 100% bio-based materials for reuse and recycling	Development of grid-edge accounting service to match production and consumption of clean energy at specific time intervals	Development of robotically assembled and customised dwelling units
Value capture	Sale of 3D printers and 3D printing services	Payment by grid operators and energy utilities to promote their offers on the app	Payment for dwelling units on demand
Company type	SME	Start-up	Start-up spinout

dwelling units on demand. The prices are dependent on the dwelling unit size and amounts of units needed. Examples are given in Table 14.4.

14.4 Discussion and Conclusions

This chapter has presented 12 cases of business models enabled by digital technologies that help narrow, slow, close, and regenerate resource flows in the built environment. The analysed companies were active in various sectors within the built environment, such as smart buildings, interiors, building design, and construction. Business models were found to use a variety of technologies, often pairing multiple technologies such as digital twins, digital platforms, IoT, and big data analytics. No emerging business models, however, were found based primarily on BIM and Geoinformation Systems (GIS) technologies. A reason could be that these types of software are available through licences of established companies, widely used, but in the case of GIS, also accessible open source. Both technologies however

have the potential to track stocks and locations of components and materials suitable for reuse and recycling (see Chap. 2 for industry use cases of GIS).

Through developing and using digital technologies and thinking of resource efficiency and circularity in their business models, the analysed case companies make significant contributions to enabling circularity in the built environment through their offers. They capitalised on several enabling capabilities of digital technologies to realise circular resource flows. In particular, tracking, monitoring, control, optimisation, and information exchange and optimisation were prominent examples of how digital technologies help enable different strategies for circularity. It should be noted that some of the presented cases explicitly define themselves or their services as circular (e.g. Circularise) while most of them do not (e.g. EDGE Next).

Based on the overview of several case studies, various business model types were identified, summarising commonalities of companies' offers. Types identified were 3D printer manufacturer, platform provider (e.g. material registry, marketplace, service provision, retail), automation developer, product manufacturer, light as a service model, and analytics app developer. Specifically, service offers facilitated through platforms were common even though they had a lot of variation in terms of their use and offerings. For narrowing resource loops, business model types based on software for optimisation were the most common. For slowing and closing resource loops, business model types based on platforms were dominant. For regeneration, manufacturers or providers of automation and 3D printing machinery or services dominated.

Many of the identified cases were in the Netherlands. The Netherlands has a progressive circular economy policy (Ministerie van Infrastructuur en Waterstaat 2021) and ranks high in the Global Innovation Index (GII 2021), which might be an explanation for the proliferation of circular start-ups in this country. However, the fact that the authors of this chapter have better insights into the developments in the Dutch built environment and might have missed cases in other countries, for example, if company websites were not available in English or less emphasis was put on communication outside of the national market, might have contributed to the dominance of Dutch case studies.

Most of the studied cases were start-ups. Some companies are already small to medium-sized enterprises, such as the digital twin and optimisation platform provider EDGE Next or the 3D printing company WASP. Many of the identified start-ups are daughter companies or spin-offs of incumbent multinationals (e.g. PolderRoof by Wavin, Rehub by Ramboll). Certainly, many digital technologies, such as parametric design, BIM, and GIS are also already used by incumbents. This study presented companies with circular business models enabled by digital technologies, offering their benefits to other actors in the sector. Future research is needed to investigate potential pitfalls and uncertainties associated with digital business models for enabling circularity in the built environment that might stem from a higher dependence on critical materials, data and technology, or environmental rebound effects. Despite these pitfalls, these developments in the uptake of digital technologies are critical as wide adoption is a prerequisite to capitalise on the improvement potential of digital technologies for circularity and other sustainability benefits (JRC 2019).

14.5 Key Takeaways

- Considering the disruptive power of digital technologies, rethinking business models in the construction sector for the circular economy is vital for companies to manage risks and capture opportunities.
- Companies considering resource efficiency and circularity in their business models and developing offers based on digital technologies can make significant contributions to enable circularity in the built environment.
- Emerging business model examples for the circular economy include 3D printer manufacturers, platform providers (e.g. material registry, marketplace, service provision, retail), automation developers, product manufacturers, light as a service models, and analytics app developers.
- Different business model types (e.g. digital marketplaces, platforms, etc.) are suitable for enabling different circular principles (i.e. narrowing, slowing, closing, and regenerating resource loops).

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