Original Research Article

Circular Economy Principles in Architectural Design, Construction, and Cities

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ABSTRACT

Circular economy, as a new approach to economic development, seeks to reduce pollution and manage resources more efficiently. The purpose of this article is estimate of Circular Economy Principles in Architectural Design, Construction and Real Estate. Circular economy is an economic system in which products, materials and resources are continuously recycled, resulting in no or minimal waste. It is based on three fundamental principles: design to eliminate waste and pollution; keep materials and products in the cycle of use; and restore natural systems. The world population is expected to reach 9 billion by 2050, with 55% of them living in cities. This population growth will put more pressure on natural resources and demand new infrastructure, services and housing. Currently, cities account for approximately two-thirds of global energy demand and are responsible for 80% of greenhouse gas emissions as well as 50% of global waste, with estimates indicating that urban waste levels will double by 2050. The construction industry's approach to the life cycle of materials and buildings is evolving. For a long time, this cycle has followed the simple formula of "plan, design, build and finally demolish", but over time, new concepts such as recycling, dismantling, reuse and circular demolition have emerged in the industry and form part of the gradual transformation towards a circular economy in construction. This approach not only extends the lifecycle of building components, but also fosters a symbiotic relationship between the built environment and the natural world. Circular design emphasizes several key principles: designing for longevity, adaptability, and disassembling components; using sustainable materials; and ensuring that products can be easily repaired, reused, or recycled at the end of their life cycle. The transformation in the construction industry's approach is bringing the stages of use of buildings and their life cycle closer to reality.

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Introduction

The construction industry's approach to the life cycle of materials and buildings is evolving. For a long time, this cycle has followed the simple formula of "plan, design [1], build, and finally demolish", but over time, new concepts such as recycling, disassembly and materials, reuse and circular demolition have emerged in the industry and form part of the gradual transformation towards a circular economy in construction [2].

The transformation in the construction industry's approach brings the stages of use of buildings and their life cycle closer to reality. The truth is that after demolition, the life cycle of materials continues, and this transition from demolition to methods focused on recycling and reuse could fundamentally change the way we approach construction processes, buildings, and the market by 2030 (Figure1) [3].

The circular economy in construction is a transformative approach that seeks to redefine the traditional linear "take, make" model, and exposure." Rather than following this one-way path, the circular economy emphasizes sustainability, resource efficiency, and the importance of minimizing waste throughout a building's entire life cycle. In this model, materials are not simply consumed. They are viewed as valuable assets that can be reused, recycled, or repurposed. At its core, the circular economy promotes the idea of designing buildings and infrastructure in a way that facilitates the continued use of materials. This means carefully selecting resources that can be easily separated, reused, or recycled at the end of their life cycle. For example, instead of using materials destined for landfill, building projects can use sustainable options such as granite sinks that are not only durable and aesthetically appealing, but can also be recovered and repurposed in future projects. By adopting circular principles, the construction industry can significantly reduce its environmental impact. This not only involves rethinking the materials used, but rather considering the entire supply chain, from sourcing raw materials to how buildings are dismantled and their components disposed of. In a circular economy, waste becomes an opportunity – an opportunity to innovate, save costs and reduce the environmental footprint. In brief, embracing a circular economy in construction means prioritizing sustainability, minimizing waste and maximizing the life of materials.

By incorporating practices that support a circular model, such as using granite sinks that can be recycled or reused, the construction industry can contribute to a healthier planet while also meeting the demands of environmentally conscious consumers [4].

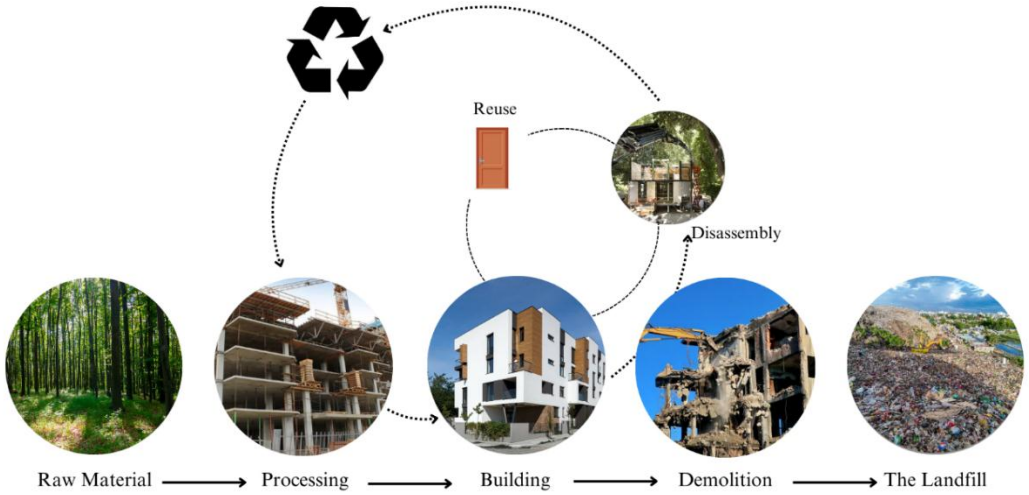

Figure 1: Circular economy principles in architectural design, construction and cities.

Studies show that the transition from a linear economic system to a circular model could potentially generate $4.5 trillion in economic growth by 2030 and help save $700 billion in global consumer spending. As a new business and economic model, the circular economy seeks to create added value by designing products with longer lifespans, increasing the recyclability and reuse of raw materials [4]. The circular economy not only contributes to improving the resource situation and sustainable development of societies, but also provides more job opportunities in related activities such as repair, maintenance, upgrading, renovation, reuse and recycling than in extraction and production processes in a linear economy [5]. In addition, it leads to increased collaboration between organizations and communities to achieve common goals. One of the principles of the circular economy is to focus on reducing waste generation and, by designing products to be reused or recycled, prevents waste from accumulating in landfills. By reducing dependence on primary resources and increasing the use of recycled materials, pressure on natural resources is reduced, which is a great help in preserving ecosystems and biodiversity [6].

Principles of standard architectural design

The principles of standard architectural design include various stages, each of which in some way affects the success of the project. In the following, we will mention the most important of these principles:

Compliance with national regulations and international standards

In any construction project, compliance with national regulations, including the National Building Regulations of Iran, is essential. These regulations include issues such as building safety against earthquakes, fires, and floods, which must be considered in the design of the structure [7].

Application of sustainable design principles

In sustainable architecture, the optimal use of natural resources and energy is of great importance. Designing green buildings that use renewable resources such as solar and wind energy not only reduces energy costs, but also helps protect the environment [8].

Attention to aesthetic principles

Every architectural project must pay attention to aesthetic aspects. Proportions, color, lighting, and harmony of forms are among the issues that must be considered in architectural design. These things help increase visual appeal and create a sense of peace for users [9].

Compliance with ergonomic and comfort principles

Standard architectural design should pay attention to the comfort of users. In the design of interior spaces such as kitchens, bathrooms and living rooms, compliance with ergonomic principles is of great importance, so that users can use the spaces with high comfort and efficiency [10].

Safety in architectural design

Safety is one of the main issues that must be observed in architectural design. The use of fire-resistant materials, fire alarm and extinguishing systems, and the design of emergency exit spaces are among the issues that must be considered in building design [11].

Steps in designing a standard architectural design

To design a standard architectural design, several steps must be taken, some of the most important of which we will mention below:

Analysis of project needs and objectives

The initial step in architectural design is a detailed analysis of the client's needs and determining the project objectives. This step includes examining the surrounding

environment, functional needs and the project budget [12].

Initial mapping and preparation of plans

After analyzing the needs, the initial mapping is done. These plans include architectural plans, structural plans, and utility plans. Special attention should be paid to the spatial distribution and use of spaces.

Facade and volume design of the building

The facade and volume of the building should be designed according to the climate, culture, and user needs. Using appropriate materials and paying attention to natural lighting and ventilation are also important at this stage [13].

Structural calculations and material selection

In this stage, accurate structural calculations are performed so that the building can withstand incoming forces such as live and dead loads, earthquakes, and wind. The selection of resistant and suitable materials for the project climate should also be done carefully [14].

Interior design and material selection

In the final stage, interior design is done. In this stage, choosing the right materials for flooring, wall coverings, and ceilings is very important. Likewise, the design of kitchen, bathroom, and bedroom spaces is done according to the use and needs of the users.

OECD programme to promote the circular economy in cities

Cities and urban areas play a key role in promoting, facilitating and enabling the circular economy. The OECD Programme helps cities identify challenges and opportunities and supports them in implementing and managing this economic model. The Programme's studies examine how cities are defined and how they are performing across a range of policies that affect urban development and the well-being of their residents, from housing, transport and land use to innovation and technology [15]. The Programme's thematic reports provide cross-sectional data and policy recommendations on key issues in urban development, such as ageing, migration, climate change, the circular economy, and investing in smart cities. The OECD's scoring system helps governments assess the enabling conditions for the circular economy, identify challenges, and set priorities. This program provides opportunities for peer learning through multi-stakeholder dialogues and key indicators for decision-making and evaluation of circular economy strategies appropriate for each city. Cities and urban areas can move towards a sustainable future by creating appropriate policies and programs, and to achieve this goal, cooperation between different sectors of society, including government, businesses and citizens, is needed (Table 1).

Successful experiences in different cities demonstrate their ability to create positive changes by focusing on cooperation and innovation, and continuing these efforts requires international cooperation, government support and active citizen participation. The following are some successful urban examples in this regard (Figure 2) [16].

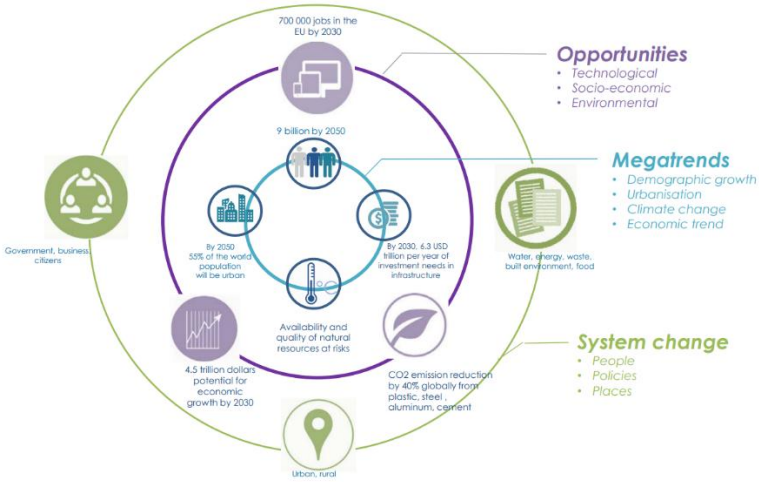

Figure2: the analytical framework of OECD (Source: OECD (2018) The Economics and governance of circular economy in cities a project proposal).

Table 1: Example of sectors including in circular economy initiatives in cities and regions (Source: OECD (2019), The circular Economy in cities and regions, Synthesis report, OECD Publishing, Paris)

City/Region	Initiative	Waste	Construction and Demolition	Land Use and Spatial Planning	Food and Beverage	Manufacturing Industry	Water and Sanitation	Energy	Biomass
Amsterdam (Netherlands)	Amsterdam Circular 2020-25	✓	✓	✓	✓	✓	✓		✓
Barcelona Metropolitan Area (Spain)	Circular Economy Promotion Programme AMB Circular (2019)	✓	✓	✓	✓		✓	✓	✓
Flanders (Belgium)	Circular Flanders (2016)	✓	✓	✓	✓	✓	✓		
Greater Porto Area (Portugal)	LIPOR's commitment to circular economy principles (2018)	✓	✓	✓	✓			✓	
Nantes (France)	Circular Economy Roadmap	✓	✓	✓	✓			✓	✓
North	CIRCWAS	✓	✓	✓	✓	✓	✓	✓	✓

Karelia (Finland)	TE – Towards Circular Economy in North Karelia								
Paris (France)	Circular Economy Plan of Paris 2017-20	✓	✓	✓				✓	✓
Rotterdam (Netherlands)	Rotterdam Circularity Programme 2019-23	✓	✓	✓	✓	✓	✓		✓
Scotland (United Kingdom)	Circular Glasgow	✓	✓		✓	✓	✓	✓	
Tilburg (Netherlands)	Tilburg Circular Agenda 2019	✓	✓	✓	✓	✓	✓	✓	
Valladolid (Spain)	Valladolid Circular Economy Roadmap (2017-18)		✓	✓	✓	✓	✓		✓

Circular economy in Umeå, Sweden

As a growing city with a young population, the city of Umeå in northern Sweden is pursuing initiatives to conserve natural resources and reduce waste. Umeå's population has doubled in the last 50 years, making it one of the fastest growing cities in Europe in the sparsely populated northern region of Sweden [17]. The city is expected to reach 200,000 by 2050, which will have implications for housing, natural resource use, and waste generation. With the city's population growing and the need to manage natural resources, the local government presented a strategic plan for 2016-2028 in 2016 to create sustainable economic models in agriculture, transport, and energy consumption using innovative strategies, integrating environmental, social, and economic aspects into a coordinated approach. Umeå's urban initiatives can be divided into three parts: setting up social networks for resource sharing between citizens, increasing participation in urban agriculture and communal gardening, and supporting local businesses with an emphasis on the use of recycled resources (Table 2). The strategic plan 2011-2028 is in line with the Swedish government's goal of strengthening society's transition to an efficient bioresource-based economy [18].

Circular economy in Glasgow, UK

The transition to a circular economy in Glasgow is part of the city's wider goal of transforming from one of the world's largest industrial centers in the 19th century to a zero-carbon city by 2030. Glasgow's Circular Economy Roadmap seeks to create a system where people have access to local jobs and green businesses help achieve zero-carbon targets. The journey towards a zero-carbon city, led largely by the Glasgow Chamber of

Commerce and Glasgow City Council, can only be achieved by implementing circular economy policies. The city has a range of programmes to support green businesses and encourage sustainable behaviour, and is working to help the local economy recover from the Covid-19 pandemic, which has hit the local economy hard. To achieve the stated goals, Glasgow has created several training centers to teach entrepreneurs the principles of the circular economy, strengthened partnerships between the private and public sectors to implement green projects, and promoted sustainable transportation and the use of public transport [19].

Circular economy in Groningen, The Netherlands

Groningen City is the largest urban center with the youngest population in a large, mostly rural area of the Netherlands. The presence of renowned universities, a high number of students and the rapid growth of start-ups, along with an active business and innovation environment, have made Groningen a knowledge hub for the region. The city council decided in 2018 to prioritize the circular economy, identifying three broad areas as key priorities: public procurement, waste management, education, and research. Since the Dutch national cabinet decided to phase out natural gas production by 2022, Groningen has been playing a leading role in its region by transitioning to renewable energy. The Netherlands has a vision of becoming energy-neutral by 2035, when all energy demand will be met entirely by renewable energy. Groningen City Council has since sought to increase cooperation with businesses and educational institutions to raise public awareness and steer consumer behavior towards more sustainable practices. The city's actions include organizing seminars and workshops, collaborating with local institutions to develop new recycling technologies, and increasing the use of recycled materials in construction projects [20].

Circular economy in Granada, Spain

While the COVID-19 crisis has halted many economic activities, especially tourism, in Granada, the city has been moving towards more sustainable production and consumption

Table 2: Circular economy in Umeå, Sweden (Source: OECD Survey on the Circular Economy in Cities and Regions and the interviews held during the two OECD missions to Umeå, Sweden (18 - 21 March 2019 and 23 October 2019)

Sector	Name of the project ar	Description	Dates
Bio-economy	Bioendev – Biocoal through torrefaction	Developer and supplier of high-tech systems for cost-efficient pre-treatment of biomass for use in heat and power generation, conversion to liquid fuels and production of green chemicals.	..
	BioHubPromoter	BioHub is a business centre that accelerates innovative business models in the biorefining industry to foster the transition to bio-economy in the BotniaAtlantica area. Botnia-Atlantica is a cross-border Interreg programme financing projects between Sweden (Gävleborg County, Västerbotten County, and Västernorrland County), Finland (Central Ostrobothnia, Ostrobothnia and South Ostrobothnia) and Norway (Nordland).	2016
	Bio4Energy – Biorefinery Research Environment	The project aims to create highly efficient and environmentally sound biorefinery processes – including methods and tools for making products such as biofuels, "green" chemicals and new bio-based materials – which draw on biomass sourced from forests or organic waste as a raw material.	2016-20
	Sweden's regional communication	The platform led by Västerbotten Region encourages co-operation between regions to promote the development	2016

	platform for bioeconomic development	of the bio-economy. It supports local firms and developa common position regarding potential regulation changes at the national and European levels.	
Capacity Building	SEE – Sustainability week	The Social, Economic, Ecological (SEE) week is a platform to share sustainability projects organised by Västerbotten County, the Regional Council of Västerbotten, Umeå University and the municipalities of Skellefteå and Umeå. In 2018, 134 activities were carried out in Västerbotten with an important focus on sustainable production and consumption, and the circular economy in particular (e.g. Cradle to Cradle initiatives).	2009-ongoi
	Seeing is Believing – Local study visits on the circular economy in Umeå	Promoted by the Municipality of Umeå and the consultancy firm Esam AB, this knowledge-building initiative consists of the organisation of study visits of ongoing examples of circular and sustainable practices. A group of business leaders, developers and decision-makers have participated in two field trips (to GE Healthcare facilities and IKEA's branch in Umeå).	2017- Ongo
	+Project Umeå School of Business	The business school collaborated within +Project to advance an innovation development programme for small- and medium-sized companies in northern Sweden. It targeted small businesses in the construction industry with a focus on sustainability, new business models and digital manufacturing technology. The programme included five half-day meetings on different topics (e.g. digitalisation, circular economy and sustainable building).	2017
Construction	+Project – 3D printing with woodbased material	Researchers from a number of different institutions are developing techniques to address sustainability in future residential buildings, with the aim of using advanced, additive manufacturing technology combined with cellulose-based materials.	2015-18
Resource efficiency	Green Technology and Environmental Economics	Green Technology and Environmental Economics is a research and collaboration platform integrating different disciplines at Umeå University and stakeholders from the water-waste and energy utility companies owned by the municipality. The general objective of this initiative is to build knowledge to improve resource efficiency and urban sustainability in the circular economy.	..
Reuse	Miljötekniskt Center, MTC (Environmental Technology Centre)	MTC owns and manages a large testbed facility for demonstration of new and innovative environmental technology to develop new treatment technologies and find new uses for waste materials.	..
	Returbutiken (second-hand shop)	Internet of Things (IoT) recognition in repairing and reselling used merchandise from recycling centres.	1998-ongoi
	Reuse houses for second-hand products at recycling centres	Vakin has built reuse "houses" that enable the collection of clothes, products, furniture and more for reuse, repair and upcycling. Reuse houses are placed at the entrance of normal recycling centres to encourage citizens to leave useful things there first, instead of at the material-recycling station. The staff employed in these houses are part of VIVA Resurs.	
	VIVA Resurs	A labour market programme which strengthens	1998-ongoi

		individuals' opportunities by employing vulnerable people in rehabilitation programmes. It contributes to a greener city through reuse/recycling by repairing a number of products and goods.	

The pandemic has increased the need for new urban paradigms and awareness of the potential of the circular economy to join the zero-carbon cities, while creating new jobs and improving people's lives and social well-being [21]. One of Granada's initiatives is the conversion of a wastewater treatment plant into a bio-factory, which has helped increase water reuse and the production of new materials from waste. Other initiatives include the establishment of local stores selling recycled and local products, the organization of awareness campaigns about the benefits of the circular economy, and the engagement of local associations to create comprehensive waste management plans. These programs demonstrated that Granada could play a role as a facilitator for the Spanish economy, although this would require a collective and coordinated approach among all stakeholders and levels of government [22].

Circular economy in Athens, Greece

Athens has also adopted a circular economy model, seeking to reduce waste and increase resource efficiency. The city has implemented several programs to improve its recycling and waste management infrastructure, including collaborating with universities and research institutes to develop new technologies, raising public awareness of environmental and economic issues, and establishing smart waste management systems [23].

Denmark's pioneering circular social housing

Denmark and its capital, Copenhagen, have been at the top of environmental and smart city rankings, thanks to initiatives such as becoming the first carbon-neutral city by 2025 and the creation of a Solutions Lab where smart strategies are designed for the entire city. Herning is another Danish City with similar initiatives, having launched an Internet of Things (IoT)-based smart waste collection system, which aims to remove most garbage trucks from the city's streets. Another such innovative initiative is the construction of circular housing in Copenhagen [24].

Copenhagen's circular house project

The Circular House Project is a group project designed by four architecture studios, and its creation follows the Danish principles of public housing with a focus on social responsibility. Specifically, the project aims to have 90% of the building materials reused, without reducing their construction value. The project is located in a residential area on the outskirts of Aarhus and is designed as a scalable demonstration project to apply new knowledge about circularity in the construction and architecture sector. In 2020, a pilot unit of the project was built, which included an exhibition space to present the project to construction professionals and the general public, to educate visitors on the principles of the circular economy and to provide them with a catalogue of circular solutions available for the industry [25]. The project site is a sloping terrain and two types of buildings will be built on it. Two- and three-storey terraced houses and five-storey blocks that are located in the upper part of the site, so that their shadow does not overshadow the buildings below. All terraced houses have northeast-facing entrances and southwest-facing gardens. The presence of a green and recreational common space increases the building density in this area to between 65 and 80 percent (Figure 3)

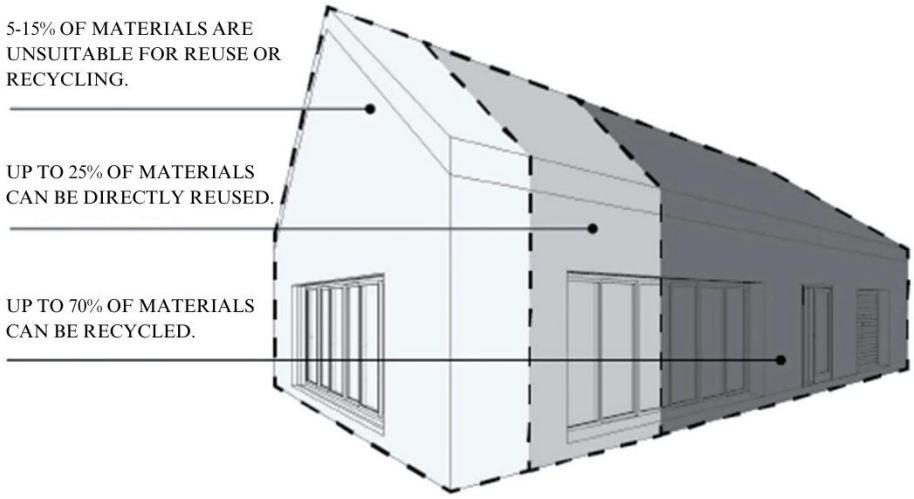

Figure 3: Assessment of material reusability and recyclability in building deconstruction.

Basic principles of circular design

The principles of design in the circular house are applied in three aspects, such as construction elements, material selection, and multidisciplinary collaboration.

Building elements

The circular house consists of a set of building elements that can be disassembled, reassembled, and reused without compromising their integrity. Accordingly, a minimum amount of elements is used for facades, beams, and ceilings. The superstructure of these buildings consists of prefabricated concrete elements produced, mechanical connections and lime mortar proposed by the project's industrial partners, and prefabricated concrete structures are used, including the foundation. The facade of the buildings is further installed using a base, to allow for quick assembly and possible disassembly [26].

Choice of materials

Some of the materials chosen for the circular house are reclaimed tiles made from household plastic waste in a range of natural colors that allow for various designs, pine wood used as a base for attaching the cladding to the walls. This type of wood has natural protection against rot and mould, ensuring long durability.

Another material is recycled acoustic panels with a lifespan of at least 75 years, and thanks to the smart installation system, a single panel can be used in multiple cycles [27].

Collaboration of danish companies

The project has brought together more than 30 companies in the construction sector, each of which offers its own knowledge and expertise. This example of collaboration in the construction sector is very important for realizing the principles of the circular economy, and also enables companies to add new models and technologies to their business and progress towards the application of the circular economy in the construction industry.

Sustainable features of the circular house

In addition to the above, the circular house incorporates more sustainable practices into the project. For example, digital traceability for materials and elements used in the building, known as a material identity card. The use of concrete in the structure of these houses has been minimized. In the prototype built, cork and old newspapers were used for the facade of the building, algae for insulation and used tires for the floor. Research shows that using a circular approach to construction could reduce greenhouse gas emissions from building materials by nearly 38 percent by 2050.

Discussion

One of the key trends in the circular economy and construction is the use of sustainable building materials. The industry is moving towards using materials that have a lower environmental impact, such as recycled steel and concrete. There is also a growing trend towards using sustainable woods such as bamboo, which grows quickly and is easily harvested. In addition, new materials such as mycelium-based composites are gaining traction due to their potential to grow from agricultural waste [28]. Another trend is the adoption of digital technology to reduce waste and increase efficiency. Digital modeling and simulation can help construction professionals design and build structures with minimal waste. Building Information Modeling (BIM) can be used to simulate and optimize building performance, reducing the need for on-site testing and trial and error. The Circular economy also places a strong emphasis on the reuse and recycling of materials. The industry is exploring ways to incorporate recycled materials into new structures. For example, recycled steel can be used to reinforce concrete, reducing the need for virgin steel [29].

In addition, waste materials such as plastic and glass can be used as aggregate in concrete, reducing the need for raw materials. The use of prefabrication and modular construction is another trend in the circular economy and construction. Prefabricated buildings are built off-site, which reduces waste and construction time on site. Modular construction allows for easy disassembly and reuse of building components, promoting the circular flow of materials. However, there are also challenges to adopting a circular economy in construction. One of the main challenges is the cost of sustainable materials and technologies. These materials and technologies are often more expensive than traditional materials and require specialized knowledge and equipment to use effectively. In addition, the lack of a standard definition of sustainable materials can make it difficult for construction professionals to identify and select the right materials. Another challenge is the lack of standardization of sustainable materials [30].

While there are certifications such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Environmental Assessment Method), these standards can be confusing and difficult to navigate. The lack of a standard definition of sustainable materials can make it difficult for construction professionals to identify and select the right materials. Furthermore, there is often a lack of demand for sustainable buildings. Many people are still unaware of the benefits of sustainable buildings and may not be willing to pay the extra cost for them. Furthermore, some people may not be willing to compromise on aesthetics or desired functionality to make a building more sustainable [31].

Circular economy and construction are inextricably linked, and adopting circular principles in construction can help reduce waste and promote sustainability. The industry is moving towards the use of sustainable materials, digital technology and modular construction to promote a circular flow of materials. While there are many benefits to adopting a circular economy in construction, there are also several challenges that need to be overcome.

These challenges include the cost of sustainable materials and technologies, lack of standardization, lack of demand for sustainable buildings and resistance from traditional players in the construction industry (Figure 4). Overcoming these challenges requires innovation, collaboration, and a willingness to experiment with new ideas and technologies [32].

Circular economy waste management, European green capital

The Estonian capital has opened a circular economy center called Lielekola, providing an opportunity to separate waste and repair and reuse items. Tallinn, the capital of Estonia, is listed as a UNESCO World Heritage Site for its preserved medieval architecture and geographical location. Beyond its historical charm, the city is committed to the principles of environmental sustainability, which earned it the title of European Green Capital 2023.

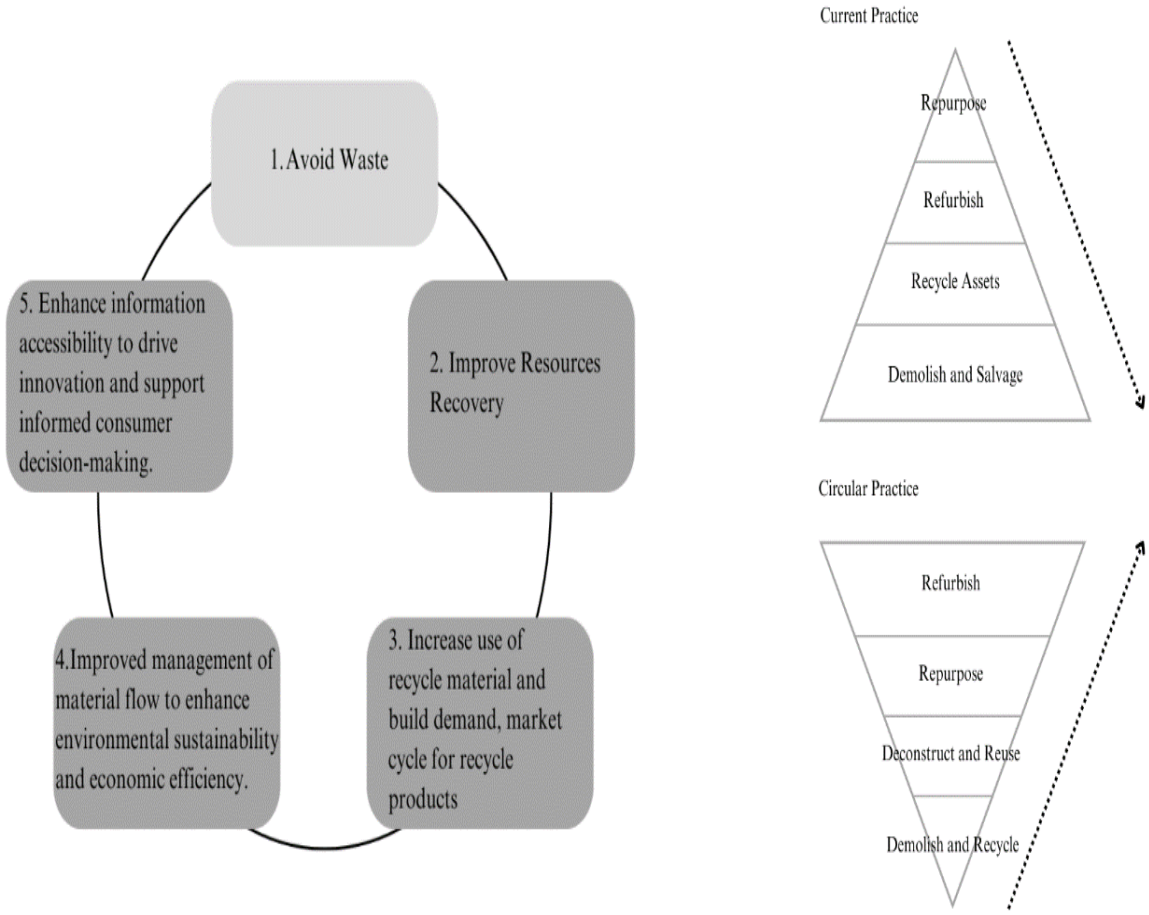

Figure 4: Circular strategies for waste reduction and resource optimization.

Tallinn was awarded the title for its ambitious initiatives to achieve climate neutrality with a strong focus on sustainable transport and the promotion of a circular economy [33]. One of Tallinn's latest initiatives is the development of a circular economy through sustainable waste management, which emphasizes the recycling and reuse of products to reduce the consumption of raw materials. The aim of this approach is to foster a more holistic development model in which environmental impacts are minimized and can create added value.

Achieving climate neutrality

Through the Tallinn Development Strategy 2035, the city has implemented a comprehensive plan to reduce carbon emissions and achieve various aspects of sustainability, including climate adaptation, innovation, health, transport, biodiversity, circular economy, as well as energy and food production. Tallinn's environmental goals are to reduce its total net greenhouse gas emissions to eight million tons and achieve a 30% material reuse rate by 2035. To support its carbon reduction goals, Tallinn has been offering free public transport to all residents since 2013, with the aim of reducing the carbon footprint of its public transport system to zero by 2035. To achieve this goal, it has promoted the use of electric trains and electric buses and expanded its network of bicycle lanes [34]. These measures are part of the overall goal of achieving climate neutrality by 2050. Over the past decade, Tallinn has significantly improved its sustainable waste management, reducing landfill by 80% and strengthening its separate waste collection. The city aims to promote a

circular economy in society by maximizing the use of materials through recycling and upcycling, ultimately reducing the need for raw materials.

Circular economy and zero landfill

The circular economy is an economic model that seeks to maximize the use of resources and minimize the production of waste and waste. In a circular economy, products are designed to be reused, repaired, recycled or renewed, reducing the need for raw materials. The main goal of the circular economy is to move away from the traditional linear model of "extract, produce, dispose" and towards a sustainable cycle. Compared to a linear economy, the circular economy seeks to preserve the value of products and materials, with the aim of moving towards a more sustainable society that causes less harm to the environment [35]. As part of its circular economy strategy to become a green city, Tallinn is implementing the Waste Management Plan 2022-2026, which emphasizes the transition from traditional waste management methods to a focus on reuse and repair, and has launched campaigns aimed at reducing waste production. One of the measures the city is taking to achieve its goal is to establish a network of recycling and repair centers. According to a report by the International Organization for Economic Cooperation and Development, Tallinn has already taken significant steps towards sustainable waste management. For example, it has increased its efforts to collect separated waste and plans to open circular economy centers with facilities such as recycling rooms and repair workshops at waste collection facilities. These initiatives are in line with the circular economy's goals of reducing consumption and keeping products in the cycle of use. The city has already opened a circular economy center where waste is sorted separately and encourages residents to reuse and repair products [36].

Lielekola

Lielekola is Tallinn's first circular economy center, replacing traditional waste management with dedicated recycling and repair rooms, so that products enter a new cycle of consumption. Located in the Christiania district, the center is designed as a modern, environmentally friendly facility, featuring a waste collection area, an office building and a circular economy center, which includes a dedicated room for reusable items, a training classroom and repair workshops. The Lillekola center is surrounded by a garden and has an acoustic barrier installed to minimize noise pollution. The design and implementation of the project, which was commissioned by the city's Circular Economy Center, was completed at a total cost of €2.3 million [37]. The center's outstanding feature is that it provides the city's residents with an easy and convenient way to sort their waste. A smart access system has been implemented in the center, allowing users to book an appointment online for waste collection, select the type and amount of waste, enter the details of the vehicle they will be transporting the waste with, and pay for the selected service if necessary. The entrance opens automatically for the vehicle whose details have been registered, so that there is quick and convenient access to the center. The center is illuminated with LED lights, making it visible even at night, facilitating proper waste sorting and management. The center has a free recycling room where people can drop off items in good condition, such as clothing or sports equipment that they no longer need, so that they can be passed on to others. In addition, there is a clothing repair workshop in the center, where anyone can learn sewing skills and repair their own clothes. The workshop is equipped with essential tools and machinery, including sewing machines, irons, scissors, tape measures and needles [38]. Visitors can also benefit from the guidance of a professional tailor to redesign and extend the life of their clothes. In addition, Lillekula offers a furniture repair workshop equipped with all the necessary tools, including sewing machines, foam cutters, nail guns and compressors, and users can repair their damaged furniture with the help of a skilled expert. The center is also equipped with a free bicycle repair station and has an eco-friendly toilet. Tallinn has plans to open similar centers in Lasnamäe and Habersti,

and to convert traditional landfills in Paljasare, Paskulle, Rahamäe, and Parnamäe into circular economy centers in the near future [39].

Embracing circular design: The role of granite sinks in sustainable construction

As the world increasingly shifts towards sustainable practices, the concept of circular design is emerging as a transformative approach in the construction industry. This innovative model emphasizes the importance of resource efficiency and waste reduction, paving the way for products that are not only functional, but also environmentally friendly. One notable example of this trend is the use of granite sinks, which combine elegance with sustainability. Made from natural and durable materials, granite sinks offer lasting beauty while also extending their lifespan and minimizing waste in the long run. In this blog post, we will explore how granite sinks fit into circular design principles, their environmental benefits, and how they can enhance the beauty and sustainability of your home or construction project. Join us as we explore the intersection of style and environmental awareness and discover why granite sinks have become a preferred choice for architects and homeowners committed to building a greener future [40].

Conclusion

In an era where environmental sustainability is at the forefront of architectural innovation, circular design principles are emerging as a transformative approach. Unlike traditional linear design, which follows a "take, build, throw away" model, circular design advocates a regenerative system that prioritizes resource efficiency, waste reduction, and the longevity of materials. This approach not only extends the lifecycle of building components, but also fosters a symbiotic relationship between the built environment and the natural world. Circular design emphasizes several key principles: designing for longevity, adaptability, and disassembling components; using sustainable materials; and ensuring that products can be easily repaired, reused, or recycled at the end of their life cycle. By integrating these principles, architects and builders can create spaces that minimize environmental impact while maximizing functionality and aesthetic appeal. Granite sinks, in particular, exemplify the nature of circular design. Known for their durability and timeless beauty, granite sinks are more than just a functional element in the kitchen and bathroom. They embody the sustainability ethos that circular design promotes. Their natural stone composition means they originate from the earth and can be reclaimed or repurposed when they reach the end of their functional life. By choosing granite sinks, homeowners and builders can make an informed decision to invest in a product that aligns with circular design principles, ultimately contributing to a more sustainable future in construction.

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