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Applying Circular Economy Principles to Urban Housing

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Abstract. This research seeks to develop a step change to the way housing is designed for cities in the UK. Housing demand in cities is predicted to increase. Urban centres are struggling to provide affordable housing. Moreover, cities are wasteful in terms of resource consumption, and waste generation heavily affecting the environment. The circular economy offers new ways to design, make and use houses to address these issues systemically as long as technical innovation is combined with social innovation. To date, the circular economy has mainly focused on technical innovation with limited emphasis on user social practices and behaviours. The combination of technological and social innovations through design has just appeared in emerging research and practice areas of design for sustainability. So, approaches that support the design of integrated solutions for transforming large socio-technical systems like cities are not yet well-established. To contribute to the development of integrated approaches for implementing a circular economy in urban housing, this study reviews a set of existing cases of social innovation for regenerative and restorative urban systems. Through empirical observation, we seek to integrate existing theories and concepts on circular economy and formulate theoretical insights for promoting the development of social-technical innovations.

1. Introduction

More than half of us now live in urban areas, and by 2050, two-thirds of the world's population will live in cities. If current trends in urbanization and income growth continue, by 2025 one-third of urban population (at least 1.6 billion people) will live in cities in substandard housing or financially stretched by housing costs [1]. In the UK, the number of new homes supplied annually has been growing for several years, but it is still lower than the estimated need. However, it is not just the number of houses built, but also the balance of tenures and affordability which need to be considered in both the private and social housing sectors. To reduce the cost of delivering housing by 20 to 50 per cent, new approaches that can coordinate interventions in multiple areas – land at the right location, construction costs reduction, increase of operations and maintenance efficiency; financing costs reduction – are needed [1]. Additionally, community engagement and social value have been shown as being essential for successful affordable housing initiatives [1]. Housing impacts on the environment through increasing carbon emissions, energy and water usage, sewerage loads, and flooding. Because of growing urbanization combined with a linear operating system of "take, make, and dispose of", cities emit between 60-80% of carbon emissions, consume over 75% of natural resources, and produce over 50%

of global waste [2]. The housebuilding sector needs to cope with these ongoing effects and reduce carbon emissions. With the domestic sector accounting for around a quarter of the UK's carbon emissions, it will need to change the way we design, build and use our homes. Thus, meeting housing needs and protecting and sustaining the environment must be pursued together.

The circular economy offers clear potential to improve the sustainability of both existing and future housing. Core urban benefits of a circular economy implementation include the possibility to reduce the need for new construction, improve urban land use, reduce construction and operational costs, and increase resource-efficiency while strengthening the local economy and improving the environment. A circular economy offers principles to rethink and reshape current practices of producing, consuming and living in cities to enable society, the economy and the environment to prosper in new ways. However, systemic changes in a large socio-technical system such as energy, mobility or housing and infrastructure urban systems can only be promoted by approaching the entire socio-technical system [3] and combining technological innovation with social innovation [4]. Until now the notion of a circular economy has mainly referred to technical aspects covering innovation levels from materials to products, business models and industrial systems with a limited emphasis on user practices and behaviours [5]. To implement a circular economy in urban housing, an integrated approach that units technical and social solutions through design are required. The combination of technical and social innovations through design has only recently appeared in the research and practice of design for sustainability, such as in design for system innovation and transition. As an emerging interest, approaches that focus on the development of integrated technological and social innovations for transforming large socio-technical systems [5] are not yet established. This exploration aims to distil theoretical insights based on empirical observations from a broad empirical sampling of contemporary social innovations for regenerative and restorative urban systems. This analysis will integrate existing concepts on circular economy to formulate theoretical propositions for supporting the development of integrated social-technical solutions for a circular economy in urban housing.

2. Circular economy in cities

A circular economy is restorative and regenerative by design. It represents a systemic shift that promotes environmental and societal benefits, generates businesses and economic opportunities, and builds long-term resilience. A circular city seeks to offer residents improved access to housing, goods, and services, as well as increased livability and prosperity while decoupling the creation of value from the consumption of finite resources. Implementing a circular economy in a city implies systemic changes in a large socio-technical system. A city can be considered as a socio-technical system made of (at least) two main interacting systems, a physical system, made up of buildings linked by streets, roads and infrastructure, and a human system made up of people, movement, interaction and activity [6]. Changes in urban systems are systemic (i.e. changes in one element of the system may induce changes in another), and dynamic (the result of feedback loops). A systemic change can only be promoted by approaching the entire socio-technical system and not its elements in isolation [3]. A circular economy in cities focuses on creating opportunities in the following key urban systems: buildings, mobility; goods; food; water; energy; and green infrastructure. Systems will be designed to be durable, adaptable, modular, free-from-waste and easy to maintain, with repurposed components and materials [7].

The study developed by Ellen MacArthur Foundation suggests that four building blocks are the requirements on a systemic level for the circular economy to be implemented [8]: 1) *Circular economy design* - design of solutions that facilitate product reuse, recycling and cascading; 2) *New business models* - introduction of innovative business models; 3) *Reverse cycles* - introduction of mechanisms in order that products, components and materials are looped or cascaded back into industry or the natural environment; 4) *Enablers and favorable system conditions* - introduction of support (such as access to examples, and collaboration) from policymakers, educational institutions, and public opinion leaders. The ReSOLVE framework [9] defines six strategies to promote circular economy opportunities: 1) *Regenerate* - regenerating natural capital by safeguarding and increasing the resilience of ecosystems, or by returning valuable biological nutrients safely to the biosphere; 2) *Share* - maximizing assets

utilization by sharing the use; 3) *Optimize* - optimizing system performance by prolonging asset use periods, reducing waste during production, or optimizing the logistics system through the implementation of reverse logistics; 4) *Loop* - keeping assets in closed loops and priorities inner loops by refurbishing, remanufacturing or recycling; 5) *Virtualize* - displacing utility virtually by delivering virtual services; 6) *Exchange* - selecting resources and technologies wisely by shifting to renewable energy and material sources using alternative material inputs, replacing traditional with advanced technologies or replacing product-centric delivery models with new service-centric ones.

3. Social innovation

Social innovations are new solutions that simultaneously meet social needs (more effectively than existing provision) and lead to improved relationships and capabilities and make better use of assets and resources to create social value. The aim of meeting a social need more effectively than existing solutions is as important as the process of enhancing the society's capacity to act by creating new roles and relationships, developing assets and capabilities and/or better assets and resources use [10]. The notion of social value creation is at the core of social innovation. Social value can be described as the societal, economic or environmental benefits created for society through efforts placed to address social needs and problems [11].

According to [10], social innovations are varied and may include new products, services, processes, markets, organizational forms, and business models. Core elements of social innovations are the novelty, the implementation and application of an idea into a financially sustainable service or initiative, the aim to meet social needs, more effectiveness compared to existing solutions, and the implementation by a process that enhances society's capacity to act. The common features have been identified among social innovations: cross-sectoral; developed 'with' and 'by' users; open, and collaborative; produced by consumers or co-produced; developed from bottom-up; obtained by mutual dependence; using assets and resources better; through new capabilities and assets [10]. Social innovation does not refer to any particular sector of the economy, but to innovation in the creation of social outputs. So, it can take place in all four sectors: 1) non-profit sector; 2) public sector; 3) private sector (social enterprises, social businesses, movements like Fair Trade), and 4) informal sector (informal networks, associations and social movements). Social innovations can involve more than one sector, as well as they can start in one sector and then can be taken up in others except for systemic change, which it will necessarily involve a multiplicity of actors, across sectors [10].

The literature on design for social innovation has emerged only in the past decade. Six stages have been identified in the process of development: 1) Prompts – identifying needs; 2) Proposals – generating ideas; 3) Prototyping – testing the idea in practice; 4) Sustaining – developing a business model; 5) Scaling and diffusion – growing social innovations; 6) Systemic change. Social innovations do not necessarily go through all six stages, and often stages are iterative and overlapping. In some cases, social innovations remain small in scale and locally based, rather than attempting growth and scale, and very few reach the stage of systemic change [12].

Recent researches situate social innovation as a force for sustainable development since it can align individual interest with social and environmental interests. A variety of social innovation initiatives in cities are creatively recombining existing resources (food, energy, water, and fabricated products) and capabilities thanks to the information and communication technology and the technological innovation of production systems to create new functions and achieve social goals in a new way [13].

4. Social innovations for regenerative and restorative urban systems

For this study, research papers, research project deliverables, policy documents, online platforms have been scrutinized with the purpose to identify cases of social innovation initiatives related to urban circularity. Google's Internet search engine has been used in order to identify appropriate cases, based on the combination of the following keywords: 'social innovation'; circular economy; 'sustainable cities'; 'urban sustainability' and 'urban regeneration'. Using the above information sources, and respecting the set criteria, 32 cases of social innovation initiatives for regenerative and restorative urban

systems were detected. These cases are analytically presented in a cross-case matrix form in Table 1. With respect to each detected case of social innovation initiative, data were collected in terms of the two distinct domains: 1) social innovation, looking at types and sectors of innovation (as explained in Section 3), and 2) circular economy implementation, looking at involved urban systems as well as implemented building blocks and strategies (as explained in Section 2). The foremost volume of our data was collected by means of primary research, and predominantly by exploring the websites of each initiative. To analyze the collected data, a cross-case comparative analysis was performed. It is a form of qualitative analysis that allows to first analyze each case individually and afterwards synthetically, to detect patterns, clusters and disparities across the cases.

Table 1. Case studies analysis.

Initiatives		Social innovation											Circular economy implementation															
		types							sector				urban systems							building blocks				strategies					
		Products	Services	Processes	Markets	Platforms	Organizational forms	Business models	Non-profit	Public	Private	Informal	Buildings	Mobility	Goods	Food	Water	Energy	Green infrastructure	Circular design	New business models	Reverse cycles	Enablers & favorable system conditions	Regenerate	Share	Optimize	Loop	Virtualize	Exchange
01	*GEN*					●	●					●	●				●	●		●	●		●	●	●	●			●
02	*Transition Net.*					●	●					●	●		●	●		●		●	●		●	●	●	●			●
03	*Catalytic Action*			●					●				●							●						●			●
04	*596 Acres*					●						●				●			●		●			●				●	
05	*Homeshare Inter.*				●						●		●								●				●				
06	*Liter of Light*	●	●					●	●									●				●					●		
07	*INFORSE*						●					●						●					●						●
08	*WMG*							●	●								●			●				●					
09	*The Ugly Indian*			●								●					●						●	●					
10	*BlaBlaCar*					●					●			●							●					●			
11	*CycleHack*					●						●		●									●		●				
12	*TreePeople*						●					●							●				●	●					
13	*GK Enchanted Farm*							●	●							●					●		●	●					
14	*Food Commons*						●	●			●					●					●					●			
15	*Good Food Community*							●				●				●					●					●			
16	*Growbox/ Mycotech*	●									●				●	●				●		●				●			
17	*Goldfinger Factory*							●	●						●							●				●	●		
18	*Opendesk*					●					●				●						●					●		●	
19	*Morada da Floresta*	●	●						●						●								●			●			
20	*Fab Labs*			●			●					●			●						●		●		●	●			●
21	*Hackerspace*			●			●					●			●						●		●		●	●			●
22	*Learning Lab,*		●								●				●							●	●		●		●		
23	*Library of Things*		●				●					●			●						●				●				
24	*Fat Llama*				●	●					●				●						●				●				
25	*Smarta Kartan*					●				●		●			●						●				●				
26	*Repair Cafés*		●				●		●						●							●	●			●	●		
27	*iFixit*					●	●					●			●							●	●			●	●		
28	*Halle 2*						●				●				●							●	●			●	●		
29	*BIG REuse*						●		●						●							●	●		●	●	●		
30	*UPASOL*						●				●				●							●					●		
31	*BV Rio*						●		●	●	●				●						●	●	●	●		●			●
32	*Austin Material M.*					●					●				●							●				●	●		

01. *Global Ecovillage Network (GEN)* is a network of more than 500 eco-villages and intentional communities across the globe to support people on building regenerative communities and starting community-led initiatives in cities. An ecovillage is a community-led living laboratory designed through locally owned participatory processes in all dimensions of sustainability towards low-impact, high-quality lifestyles [14].
02. *Transition Network* is a network which works to inspire, connect, support and train communities to address current living challenges locally by reclaiming the economy, sparking entrepreneurship, reimagining work, reskilling themselves and weaving webs of connection and support [14].
03. *Catalytic Action* (London) is a not-for-profit organization that works internationally on the development of spatial interventions to empower vulnerable communities. They perform the project development through three interconnected phases: participatory planning, sustainable design and community-engaged construction [15].
04. *596 Acres* (New York) is a citizen-driven pilot project to create an interactive crowdsourced map of vacant space and assist neighbourhood-led campaigns to turn inner-city land into community space, such as gardens, farms, and playgrounds and support social cohesion and effective land use [7].
05. *Homeshare International* is a network that is specialised in facilitating intergenerational home-sharing, providing a solution to the needs of two groups of people – those in need of affordable housing (often younger people), and those in need of support to live independently at home (usually older people) [7].
06. *Liter of Light* (Makati, Philippines) is a no-profit organization that uses inexpensive, readily available materials (discarded plastic bottle and standard kerosene lamp) to provide solar lighting to people with limited or no access to electricity. The organization works with women's collectives, foundations and corporates teaching them to build more clean and affordable lighting and start their manufacturing enterprise [16].
07. *INFORSE* (International Network for Sustainable Energy) is a network of 140 independent NGOs working in about 60 countries to promote sustainable energy and social development. The network provides a large set of experiences on the interaction between sustainable energy and new social economy [14].
08. *Watershed Management Group* (WMG) (Tucson, Arizona) is a non-profit organization working to develops community-based water-harvesting projects to help homeowners to harvest rainwater on their own proprieties at minimal costs. All profit earned from these services is invested in public education programs. They provide people with the knowledge, skills, and resources to retrofit residential and commercial sites [17].
09. *The Ugly Indian* (Bangalore, India) is a movement started by design students in Bangalore that focuses on cleaning up informal latrines, trash-covered sidewalks and illegal rubbish dumps which pollute the water supply. They use the visible result of their initial action to start conversations and people engagement. They effectively combine social skills with systems thinking [17].
10. *BlaBlaCar* is a world's long-distance carpooling platform – a global trusted community of 80 million drivers and passengers in 22 countries. The platform connects people looking to travel long distances with drivers heading the same way, so they can travel together and share the cost. With the integration of a coaching network and a commuter carpooling service, BlaBlaCar aims to become the marketplace for shared road mobility.
11. *CycleHack* is a global movement that empowers people to design, prototype & test new ideas that improve the experience of cycling & get more people on two wheels. It prototypes new products, services and physical spaces from the ground up and tests ideas out in the street [17].
12. *TreePeople* (Los Angeles) is a social organization that supports citizens to come together to plant and care for trees along city streets and in neighbourhoods, harvest the rain, and renew depleted areas [17].
13. *GK Enchanted Farm* (Bulacan, Philippines) is a no-profit organization that promotes urban farming and social entrepreneurs by providing a platform for social business incubation [16].
14. *Food Commons* is an organization that applies a whole system approach to provide a food integrated system that links food-producing land, support infrastructure and support services. It allows the interests of farm communities, local people, land, watersheds and biodiversity are considered together [17].
15. *Good Food Community* (Quezon City, Philippines): it is a partnership model between farmers and consumers to share responsibilities, risks and rewards of farming. The farmers grow organic vegetables and promote biodiversity, polyculture and soil health [16].
16. *Growbox/Mycotech* (Bandung, Indonesia) are businesses that are utilizing fungi to generate value from agriculture. Growbox is edible growing DIY mushroom kit inspiring around 18000 new urban farmers per year to grow their own food anywhere and anytime. Mycotech focuses on mycelium agricultural waste as a natural adhesive to pull organic fibres together and produce panels and tiles for furniture and other interiors [16].
17. *Goldfinger Factory* (London) is a social enterprise that creates furniture and objects from secondary raw materials, provides skills training and assists people in gaining or returning to employment as well as offering a platform to develop and sell bespoke furniture and interiors [19].
18. *Opendesk* is a global furniture platform that connects customers with designers, and local makers/material suppliers. It reduces the number of intermediaries and the length of the supply chain while increasing pay for designers and makers and giving customers access to high-quality furniture at more affordable prices [7].
19. *Morada da Floresta* (São Paulo) is a social enterprise that provides products and services to allow people to move toward more sustainable living such as products that promote a transition from disposable to reusable products (such as reusable nappies). These products mean a lower overall cost for the consumer while reducing the waste to landfill and supporting gender equality [16].

20. *Fab Labs* is a global community of fabricators, artists, scientists, engineers, educators and students located in 1750 Labs that share the aim of providing access to the environment, skills, materials and advanced technology to allow anyone to make things anywhere. The community is a manufacturing network, a distributed technical education campus, and a distributed research laboratory for digital fabrication [14].
21. *Hackerspace* is a network of physical sites like Fab Labs, but these spaces are self-organized by users, and more strongly committed to principles of open source, commons-based, peer-production. There are over 1330 Hackerspaces networked globally, and through events like Makers Fairs [14].
22. *Learning Lab*, IKEA Greenwich (London) is a store's Lab that offers bookable workshops and activities on how to reduce waste, re-use materials and upcycle. It is a creative space in which customers can learn how to upcycle, repair and prolong the life of products through a variety of activities and workshops [19].
23. *Library of Things* (London) is an organization in which kitchen appliances, tools, gardening equipment, electronics, toys, instruments and recreational equipment are loaned out to members in a process similar to traditional libraries. The Library of Things takes responsibility for sourcing, maintaining and repairing 'things' in the library, as well as the development of online and digital services [7].
24. *Fat Llama* is an online borrowing platform that facilitates peer-to-peer lending, with insurance for lenders that is covered by the platform [7].
25. *Smarta Kartan*, is a smart-mapping tool developed by the City of Gothenburg with residents. It shows where residents can find things to hire, borrow, share, and swap. It helps to connect people, change their behaviour, reduce consumption-based carbon emissions, and inspire new services [7].
26. *Repair Cafés* is a no-profit organization that provides support to local groups in the Netherlands and other countries wishing to start their own Repair Café. Repair Cafés are meeting places that focus on repairing things (together). In these places, tools, materials and expert volunteers, with repair skills in all kinds of fields, are available to help people make any repairs on clothes, furniture, appliances, bicycles [20].
27. *iFixit* is an open-source website and global community of repair technicians and fixers that teaches people and businesses how to fix almost anything. To do this, iFixit is building partnerships with manufacturers to help them create repair organisations, both internally and with customers [7].
28. *Halle 2* is a repurposed shoe shop in Munich that has been turned into a multi-purpose hub where residents can purchase second-hand items, access repair services, and take part in events and seminars where they can learn how to repair products themselves [7].
29. *BIG REuse* (New York) is a non-profit organization that takes a multi-faceted approach to materials recovery and reuse. They run two warehouses selling a wide assortment of reclaimed materials, appliances, accessories and furnishings to the public at reasonable prices. They provide a training work site, and net revenue supports local, environmental initiatives [18].
30. *UPASOL* (Vicuña and La Serena, Chile) is a private organization that operates a free collection service for recyclable household goods. The waste is then sold to companies that use the material in their recycling and production processes, generating revenue for financing a rehabilitation centre for disabled children. Everything in the rehabilitation centre is also recovered or put into the on-site Museum of Old Objects for learning [16].
31. *BV Rio* (Rio de Janeiro, Brazil) is an organization that involves private, public and third sectors in promoting sustainable economic development into various sectors: timber production and trade, timber manufacturing; and waste management. Plastic waste recovery and recycling are promoted through credits mechanisms rewarding waste pickers for their role [16].
32. *Austin Material Marketplace* is an online platform allowing businesses and organizations to connect and find reuse and recycling solutions. These activities divert waste from landfills, generate cost savings, energy savings, new jobs and business opportunities [7].

5. Discussion and Conclusions

Through empirical observations from a broad empirical sampling of contemporary social innovations, this study has provided considerations on 1) social innovation for a circular economy, and 2) on the implementation of a circular economy through social innovation.

Firstly, this analysis has observed that most of the selected social innovation initiatives for a circular economy in cities consist of new organizational forms (such as community interest companies or networks) or platforms or new business models (such as social enterprises). These cases have shown that a circular economy is implemented in urban systems by social initiatives mainly promoted by groups of people or aimed at linking people for building groups. This phenomenon is consistent with current literature on social innovation [13] in which it is explained that these initiatives are becoming widespread practice due to the present economic crisis that forces people to reinvent their lives while reducing their consumption and redefining their ideas about well-being (and work) and thanks to two recent phenomena, the information and communication technology and the technological innovation of fabrication systems. Moreover, it has been observed that analyzed initiatives do not refer to any

particular sector of the economy except for the public sector. They come from the third sector as well as the informal and the private sector, while a few examples have been observed in the public sector. This result is consistent with current literature on the role of policymakers in the implementation of a circular economy. Globally, policies that enable a circular economy are growing, such as in Denmark and the European Union. However, the implementation of circular economy policy frameworks has been delayed due to the limited evidence base available, and an ongoing debate about targets. At the city level, municipal policymakers have begun to embed circular economy principles in city strategies and roadmaps, but since the current built environment is characterized by multiple stakeholders operating in silos and lacking incentives to collaborate, it makes difficult to get circular solutions [21].

Secondly, this study has observed that most of the initiatives implement a circular economy focusing on goods while they are less implemented in other urban systems. This result is consistent with the current understanding of the circular economy implementation: actually, a circular economy has been mainly implemented at the product and product-service system level because of tangibility of the goods system in people's daily life, the availability of examples and easiness in implementing a circular economy in this system compared to others like buildings in which products are aggregated and interrelated. Because of the building system complexity, circular economy innovations in the building system are just started to be explored [5]. Their implementation requires understanding and taking into account the interrelationships between several technologies, ecosystems, social and cultural practice as well as city governance in design decisions. Moreover, this analysis has examined that existing theories and concepts on a circular economy do not consider social aspects. Building blocks and strategies focus on a technological approach. The circular economy building blocks do not include any piece related to social innovation, and the ReSOLVE framework does not include any strategies to foster social innovation. Since the circular economy in cities aims to transform socio-technical systems through the development of integrated technological and social innovations, the study has proposed to integrate existing concepts on circular economy with social aspects and formulate theoretical insights for supporting the development of integrated socio-technical solutions. Therefore, criteria that are crucial for social innovation have been included in both sections. These criteria have been identified through the literature review and applied to the selected case studies for checking relevance in all of them. So, an additional urban system – *citizens* – has been suggested to be added the other urban systems considered for the implementation of a circular economy in cities because of the active role of people and community in cities and social innovation [6, 10]. A further requirement – *social value* - has been proposed into the set of circular economy building blocks. It concerns the creation of societal, economic or environmental benefits for people through efforts placed to address social needs [11]. A further lever – *empower* – has been suggested to be included in the ReSOLVE framework. It refers to the social innovation strategy of enhancing people's capacity to act for addressing social needs by creating new roles and relationships, developing assets and capabilities and/or better assets and resources use [10].

This study aims to provide an understanding of the possibilities for applying circular economy principles to urban housing by design. The challenge is not only to design technical solutions following circular economy principles but to integrate these with social ideas that persuade people to adopt circular economy practices. Approaches that focus on the implementation of integrated socio-technical solutions are not yet established; their development has just appeared in emerging research and practice areas of design for sustainability. Through empirical observations from a broad empirical sampling of contemporary social innovations, we argued that selected innovations are creatively recombining existing resources (goods, food, energy, water and buildings) and capabilities through circular economy practices to achieve social needs in new ways. So, social innovation can contribute to aligning individual interest with social and environmental interests by circular economy practices, but current initiatives are mainly promoted by groups of people focusing on goods. The public sector may contribute to foster and support initiatives in other urban systems by the creation of economic incentives such as reductions on circular economy services and assets, the specification of more circular public procurement measures, or the convening of partnerships with private-sector organizations to catalyze collaboration that encourage companies and professional to engage people in new initiatives into the other urban systems.

Moreover through this analysis, we concluded that social innovation is not currently supported by existing theories and concepts on a circular economy. Thus, theoretical insights have been formulated to integrate them.

However, further studies need to be implemented in order to integrate the social side also in the development process of circular solutions. In the next step, a pilot study will be undertaken to investigate the process of developing a socio-technical solution on a small-scale project with and for a housing community in London to enable a better understanding of the development of integrated solutions for implementing a circular economy in urban housing.

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