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PRINCIPLES OF CIRCULAR ECONOMY FOR BUILDING SECTOR: A SYSTEMATIC REVIEW

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ABSTRACT

Globally, the building sector accounts for almost 40% of resource use and waste production and nearly 33% of greenhouse gas emissions. The Circular Economy (CE) and the adoption of its principles are currently recognised as one of the options to address these unsustainable issues. Despite, these principles are represented differently within three main domains: (1) collections of R-imperatives or R-framework, (2) CE loops, and (3) the ReSOLVE model, makes it a challenge for embracing CE principles in the building sector. A systematic literature review was carried out to respond to the research question "What are the R-imperatives that are applicable for the building sector as CE principles?", using Preferred Reporting Items for Systematic Reviews (PRISMA). It yielded a total of 23 papers to analyse. This review confirms that although alternative domains exist, the most practical CE principles seem to be confined to R-imperatives. The study provides 17 R-imperatives in the descending order of their circularity, along with their definitions. Finally, these R-imperatives are logically linked with principles of other two CE domains. This would provide a clear understanding of CE principles and thereby enable CE applications in the building sector.

Keywords: *Building Sector; Circular Economy (CE); Literature Review; Principles; Preferred Reporting Items for Systematic Reviews (PRISMA).*

1. INTRODUCTION

The building lifecycle yet based a linear economic model with high natural resource consumption and little resource recovery (Guerra & Leite, 2021; Anastasiades *et al.*, 2020). Buildings account for almost 40% of energy use and solid waste production, 30% of raw material use and nearly 33% of greenhouse gas emissions globally (Eberhardt *et al*., 2019; Bolier, 2018). The concept of circular economy (CE) is a set of principles that collect a large variety of practices under the same objective of cutting the production of waste and consumption of resources by retaining the value of resources as long as possible while improving efficiency of material and energy, using renewable energy and using environmentally low-impact and toxic-free materials (Joensuu, *et al.*, 2020). Lindgreen *et al.* (2020) emphasised that CE must address the linear economy challenges, and it has grown in significance as a practical alternative for the shift to sustainable development

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(Kuzma *et al.*, 2022). This circular way of using materials can also reduce waste, the quantity of new materials used, and carbon emissions (Minunno, *et al.*, 2018). Accordingly, this concept should be used in buildings and building materials to keep materials sustainable and lower their embodied energy and carbon (Akhimien, *et al.*, 2022). It is important and desirable to put CE principles into practice to reduce adverse effects on the environment (Eberhardt *et al.*, 2019). Further, adopting CE principles has the potential to generate a net economic benefit while simultaneously benefiting the environment and society at large (Mhatre *et al.*, 2020). Principles of CE is crucial in the building sector to address the unsustainable effect of the industry and to achieve a resource-efficient society (Benachio, *et al.*, 2020; Osobajo, *et al.*, 2020). Cimen (2021) highlighted that this industry has been struggling to embrace CE principles.

However, CE has been viewed differently in different fields and from different perspectives, based on the representation of its principles. Amongst, primarily, R-framework or R-imperatives can be noted. The roots of CE lie in many schools of thoughts and scientific concepts such as industrial ecology, industrial symbiosis, performance economy, R-framework, blue economy, biomimicry, cradle-to-cradle, that have the closed-loop approach (Lieder & Rashid, 2016). However, the implementation of CE is being pursued through the use of the R-imperatives (or framework), which vary in quantity, and order and also have changed over time (Reike *et al.*, 2018). Amongst, 3R principles (OR framework), Reduce, Reuse, and Recycle are considered as the basis of CE and it summarises CE's primary methodology (De Pascale *et al.*, 2020; Aarikka-Stenroos, 2021). Similarly, Barreiro-Gen and Lozano (2020) indicated that CE encompasses four Rs: Reduce, Repair, Remanufacture, and Recycle. Although there exists several other R-imperatives such as 5Rs, 6Rs, etc, from a broader perspective, Reike *et al.* (2018) and Potting *et al.* (2017) concluded that there are 10Rs value retention options that can be implemented by consumers and enterprises along the whole value chain of a product while Sarfraz *et al.* (2021) highlighted a framework with 11 CE principles for improving the level of compatibility and organisational performance. Moving from the above general perspectives, in a subsequent instance, Cimen (2021) proposed 11Rs, particularly for the built environment by adding the new R principle of “Replace” to the existing 10 “R” principles of Potting *et al.* (2017).

The Ellen MacArthur Foundation's ReSOLVE Model is another domain representing CE where it incorporates six principles (Regenerate, Share, Optimise, Loop, Virtualise, and Exchange) that guide the transition to circular business paradigm (EMF et al., 2015). In addition, it is recognised as the most comprehensive and well-succeeded CE principles or frameworks for businesses (Williams, 2019). There were instances where ReSOLVE model was used as CE principles. For example, Kouhizadeh *et al.* (2019) examined the likely use of blockchain technology to transform and advance CE realisation. Similarly, Williams (2021) and Prendeville *et al.* (2018) explored the ways to adapt ReSOLVE to urban environments.

Apart from R-frameworks and ReSOLVE model, CE loops is another popular domain to represent the principles of CE. There were three different types of loops: closing, narrowing, and slowing loops (Akhimien, 2020; Gallego-Schmid *et al.*, 2020). Later, a regenerative loop was identified as the 4th loop (Cetin *et al.*, 2021). Few studies which used loops as the CE principles include Bocken *et al.* (2016) who developed a framework of strategies to guide designers and business strategists in the move from a linear to a CE, while Gallego-Schmid *et al.* (2020) demonstrated the links between CE and climate change mitigation by increasing resource efficiency through slowing, closing, and narrowing CE loops for material and energy. As foregoing review evidenced, although CE principles are applied and investigated in different fields from the perspective of different domains, a gap exists in applicable CE principles to building sector. To this end, this study aims to explore the CE principles applicable to building sector, and the relationship between the main three domains of CE principles.

The remainder of the paper is organised as follows. Section 2 discusses the study methodology adopted for the study while section 3 presents the literature findings, analysis, and the summed-up principles of CE for the building sector. Finally, section 4 presents the conclusions of this study.

2. RESEARCH METHODOLOGY

To achieve the aim of this study, a systematic literature review was carried out as it enables map, evaluate, and put together different pieces of literature to learn more about a field (Tranfield *et al.*, 2003). Initially, the research question was formulated as "What are the R-imperatives are available for the building sector as CE principles?". Then, appropriate search terms were identified and the final search string was developed as; *(builing?sector OR building? OR construction? OR "building design?" OR "building operation*" OR "building maintenance" OR "facilit* management" OR "building life?cycle" OR sustainability OR "sustainable development?" OR "sustainable building?" OR "adaptable design?" OR "architectural design?" OR "construction and demolition waste" OR whole?life?cycle) AND ("circular economy" OR circularity OR "circular concept") AND (principle?)*

Only peer-reviewed articles pertaining to the principles of CE and the building sector, published in English, between 2010 and 2022 were considered as filters. The said year of publications were considered due to the contemporary nature of the research, the diffusion of research on subject area. The TITLE-ABS-KEY was used as the search field. For the literature search, the Web of Science, Scopus, and Science Direct databases were chosen as they contain academic papers with high rankings and indexes. Google Scholar was also looked at to see if there were any other papers that might have been around and answered the study's research question. The PRISMA statement served as the guide for the systematic review (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Accordingly, Figure 1 depicts the PRISMA flow diagram used in the study.

Figure 1 shows that a total of 265 records were found, including 118 Web of Science, 141 Scopus, and 6 Science Direct records. Out of them, 187 records were selected for the title and abstract screening process after 78 duplicate records were eliminated. 134 of them were found to be unrelated to the research question of the study during the preliminary screening, which resulted in 53 records. The full-text review of 36 records was continued after 17 records were unable to extract the entire article, and finally, 21 research contributions were selected for in-depth analysis. Another couple of records were manually added using Google Scholar Search, bringing the total number of records examined in this study to 23.

Following the systematic review, a further review into available literature was carried out to identify the definitions for particular CE principles which were not defined in the selected studies and to establish the link between main CE domains.

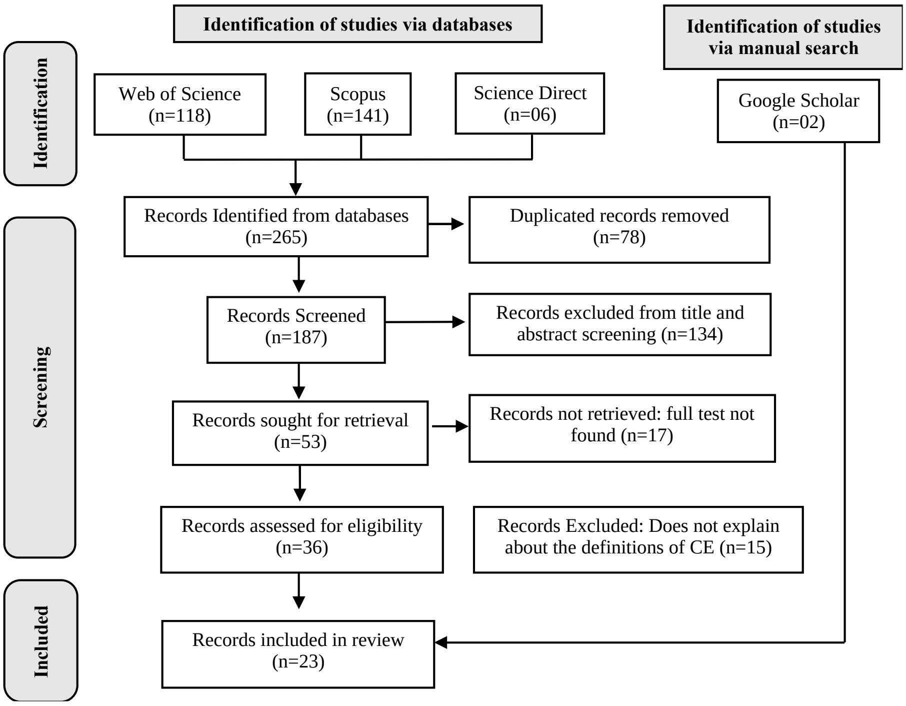

Figure 1: PRISMA flow diagram

3. RESULTS AND DISCUSSION

The results of this research are presented in two parts: (1) a descriptive analysis of the selected articles and (2) an analysis of the content of the articles in relation to CE principles applicable to building sector.

3.1 DESCRIPTIVE ANALYSIS

The number of publications found during the period considered for search is shown in Figure 2. With a steep increase from 2019 to 2020, the number of articles related to subject area published has been on upward trend, indicating the uptake of CE applications. Then, the selected articles were further scrutinised to identify the main domains of CE principles and building lifestyle stages covered in the previous scholarly works. In terms of main domains, most of the studies (17 out of 23) have considered the CE principles in R-frameworks while only few articles covered CE loops and the CE ReSOLVE model. This indicates that R-imperatives have received significant focus in terms of CE principles applicable to building sector. Figure 3 presents the number of articles that discussed the different CE domains.

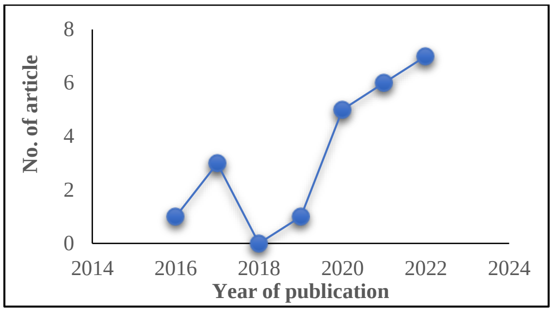

Figure 2: Number of publications

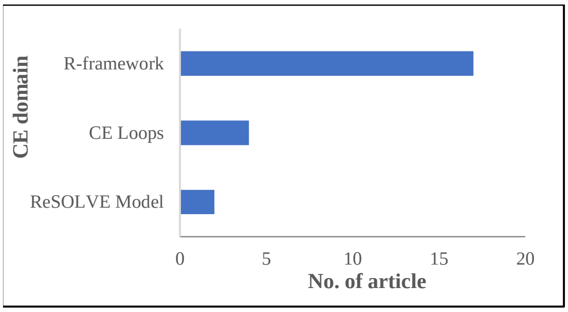

Figure 3: Articles distribution in different CE domains

Figure 4 displays the distribution of building lifecycle stages considered in the selected articles. As seen from Figure 4, generally, studies have considered CE principles applicable to all stages of the life cycle, commencing from design, construction, operation, and end of life. 4 out of 23 studies considered the whole life cycle stages of the building, and 3 out of 23 studies discussed the design stage and end-of-life stage. While 5 out of 23 studies do not specify any building lifecycle stages, they are discussing the CE indicators, stakeholder perspectives, and management of CE application.

Following the above descriptive analysis, Figure 5 displays the distribution of focus of the articles in terms of different building types considered. Mostly, 11 out of 23 articles have not focused specifically on whether existing or new buildings while 2 articles focused on both existing and new buildings. Another 6 and 4 articles considered CE applications in the new buildings and existing buildings, respectively. Accordingly, both new as well as existing buildings are considered almost equally in terms of CE applications. Further, Figure 5 depicts the stages of existing buildings discussed in the articles. Accordingly, the operational stage and the end-of-life stage are covered in most of the studies considered, and there was only one study that focused on both the operational and end-of-life stages.

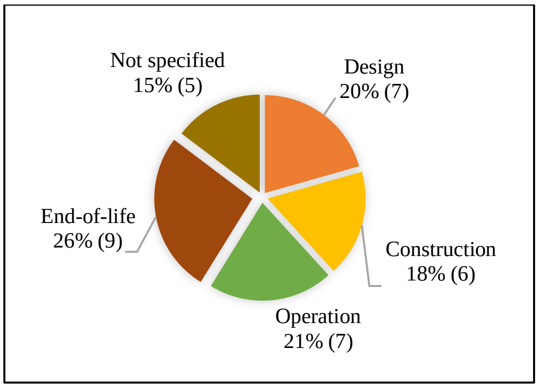

Figure 4: Building lifecycle stages

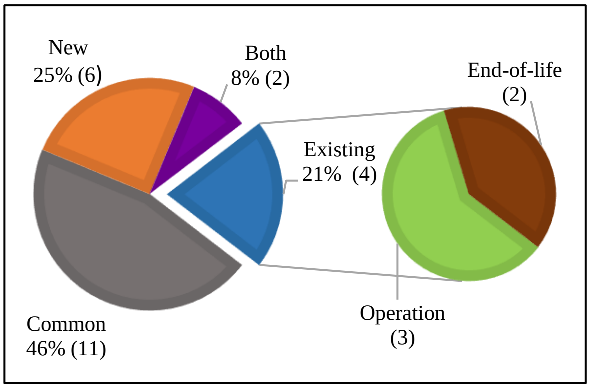

Figure 5: Types of building focused in articles

3.2 CIRCULAR ECONOMY PRINCIPLES APPLICABLE TO THE BUILDING SECTOR

The extensive literature analysis resulted in the identification of a total of 26 CE principles which can be used to represent the building sector, shown in Table 1. As commonly available in the literature as the 3R-framework, the top three CE principles **R**euse, **R**ecycle, and **R**educe have been referred to in the majority of the studies, respectively, 22, 19, and 12 out of 23 in the reviews.

Table 1: Summary of CE principles applicable to building sector

No	CE Principles	Sources																							Total
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	
1	Reuse	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*		21
2	Recycle	*	*		*	*	*	*	*	*	*	*	*			*	*	*	*	*	*		*	*	19
3	Reduce	*	*					*			*	*	*		*	*	*		*	*	*		*		13
4	Repair		*		*				*				*		*	*			*	*					08
5	Refurbish/ Reprocess /Requalification			*	*			*				*	*						*	*					07
6	Remanufacture	*		*	*							*				*				*	*				07
7	Recover									*	*		*		*	*		*							06
8	Replace						*				*	*	*												04
9	Disposal									*			*											*	03
10	Reclaim				*										*					*					03
11	Adaptive reuse															*				*					02
12	Return				*							*													02
13	Reverse						*					*													02
14	Renew																		*	*					02
15	Remarket/ Resell														*			*							02
16	Refuse									*									*						02
17	Upgrade								*						*										02
18	Selective Demolition		*																						01
19	Retain				*																				01

No	**CE Principles**	**Sources**																							**Total**
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	M	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	
20	Relocate												*												01
21	Refit				*																				01
22	Recondition																			*					01
23	Repurpose																			*					01
24	Redesign																		*						01
25	Rehabilitation																			*					01
26	Retrofit				*																				01

Sources: [A] - Nasir *et al*. (2016); [B] - Adams *et al.* (2017); [C] - Cayzer *et al.* (2017); [D] - Mangialardo & Micelli (2017); [E] - Akanbi *et al.* (2019); [F] - Anastasiades *et al.* (2020); [G] - Gallego-schmid *et al*. (2020); [H] - Jansen *et al*. (2020); [I] - Kanters (2020); [J] - Mercader-moyano & Esquivias (2020); [K] - Antonini *et al.* (2021); [L] - Bertino *et al.* (2021); [M] - Dams *et al*. (2021); [N] - Kosanovic *et al.* (2021); [O] - Marika *et al.* (2021); [P] - Torgautov *et al*. (2021); [Q] - Al-Obaidy *et al.* (2022); [R] - Arauzo-Carod *et al.* (2022); [S] - Dabaieh *et al.* (2022); [T] - Huang *et al*. (2022); [U] - Liu *et al.* (2022); [V] - Ruiter *et al.* (2022); [W] - Spisakova *et al.* (2022).

Despite the differences in terminologies, some of these 26 CE principles have some similarities in their meaning. At first, **A**daptive **R**euse is defined as "a process that changes a disused or ineffective item into a new item that can be used for a different purpose" (Department of Environment and Heritage, 2004). It is comparable to the **R**econdition principle, which is defined as restoring an old product and turning it into a new one (Sarfraz *et al.,* 2020). Further, there are similarities between **A**daptive **R**euse and **R**ehabilitation, where **R**ehabilitation is defined as "the process of making a building work again" ([S]; Foster & Kreinin, 2020) or "the process of making something good again" (Cambridge Dictionary, 2022b). Next, the concepts of **R**esell, **R**emarket, and **R**elocation are all included in the **R**euse principle, because **R**euse refers to continuing to use any material, component, or product in its current state for the same function after another consumer no longer finds it useful (Sarfraz *et al.,* 2020; Reike *et al.,* 2018). **R**esell or **R**emarket means selling the material, component, or product to another user for the same function, whereas **R**elocate means that when a building is demolished, its components are taken out and moved to new locations where they are placed for use in different lifecycles ([L]; Reike *et al.,* 2018). Then, **R**eclaim was referenced in three articles, but only one of them [S] used it as a principle of CE, whereas the other two [D; N] used the terms "reclaimed/secondary materials and components" and "reclaim materials for reuse" as strategies to attain CE principles. According to Cambridge Dictionary (2022a), the term **R**eclaim refers to “treat waste materials to get useful materials again or to get useful materials from waste". Accordingly, it can be concluded that it is a component of **R**epurpose or **R**econdition principles. Following that, **R**etrofit and **R**everse principles can also be added to CE principles. The term **R**etrofit is derived from the concept of "adaptation" and refers to significant physical alterations to buildings (Dixon & Eames, 2013; Wilkinson, 2012). It is defined as "any work done to a building that goes beyond maintenance to change its capacity, function, or performance" or "any action to change, reuse, or upgrade a building to fit new conditions or needs" (Douglas, 2006).

Similarly, Saffari and Beagon (2022) denoted that **R**etrofit entails changes to the building sector's fabric, shape, and systems. that go beyond the frequently invisible maintenance and repair. It can happen to entire building or portions of building, for instance one or more floors of a high-rise building (Wilkinson, 2012). Accordingly, **R**etrofit can take a position between the principles of **R**epair and **R**efurbishment. Other one is **R**everse, which is described as "the use of reversible connections is advocated" ([F]; Kozminska, 2020) or "implementing reverse logistics to optimise the system performance" [K]. For example, steel and wood may permit reversibility (Rahla *et al.,* 2021); dismantlable steel connections may be reversible for prefabricated concrete elements, and wooden column-slab systems may be reversible with cross-laminated timber cassettes (Kozminska, 2020). As seen from Table 1, **R**efit principle identified by [D] and placed it between **R**etain and **R**efurbish. **R**efit is defined as "to make repairs or changes to a building, factory, or store to improve it or change its purpose" (Cambridge dictionary, 2022c). It can therefore be incorporated into both **R**epair and **R**etrofit. Further, **R**eplace and **R**edesign principles are mentioned in four [F; J; K; L] and one [R] articles respectively. **R**edesign can be included within **R**eplace principle as it is defined as a more sustainable material, designed and manufactured as an alternative to replace existing material (Cimen 2021; Sarfraz *et al.* 2021).

Afterward, **U**pgrade is defined as the ability of a product to continue being useful under changing conditions by improving the quality, value, and effectiveness or performance

(Linton & Jayaraman, 2005, p. 1814), whereas [L] described **R**efurbishment as the set of interventions aimed at transforming the building through a systematic set of works that can lead to a building that is totally or partially different from the previous one. In addition, Ghisellini *et al.* (2017) noted that refurbishing has the potential to increase a building's lifespan, adapt to new requirements, and/or improve its energy and environmental performance instead of adopting new construction plans. As a result, upgrading can be referred to as "refurbishment of a building or "a component of refurbishment".

The principles of **D**isposal and **S**elective **D**emolition can be taken out of the CE principles for the building sector because they could form part of either **R**euse, **R**ecycle, **R**ecover or **R**eturn. For instance, **R**euse or **R**ecycling can be used as an alternative to incineration or waste disposal to keep building materials and components inside the production cycle [L]. Despite **D**isposal being mentioned in three articles [I; L; W], it cannot be considered a CE principle as it contradicts the idea of circularity. Given that it hurts the environment, it is the least sustainable waste management strategy, including for construction and demolition waste [W; I]. Then, **S**elective **D**emolition was listed only by [B] in the circular aspects of end-of-life. Although **S**elective **D**emolition is preferable to demolition since it can contribute to starting a new lifecycle of materials, components, and parts of buildings through a closed loop [W], these are mostly used in reuse and recycling. In addition, [L] specified that consideration must be given to potential strategies to avoid demolition and disposal of existing buildings as the majority of them were not designed for deconstruction.

Finally, 16 out of the 26 listed principles of CE have been summarised from the discussion. As discussed previously, Cimen (2021), Sarfraz et al. (2021), and Reike et al. (2018) developed different R-frameworks of CE, and summing them gives 15 R-imperatives as depicted in Figure 6. Of them, three principles of Reimagine, Rethink, and Remine are not identified in the list of 26 CE principles applicable to the building sector, shown in Table 1. Out of these three principles, the Rethink principle must be added as it entails intensifying product use as well as rethinking existing strategies and objectives, while principles of Re-mine and Re-imagine can be omitted as they seem to have less potential for application in building sector and due to time consuming process.

This eventually results in a list of 17 CE principles applicable to building sector, as depicted in Figure 6. The CE principles and their descriptions are shown in Figure 6 in the sequence in which they should be applied to a given building sector context. Further, the figure gives an indication on principles that are new additions and which are already available in other less popular R-frameworks of CE (Cimen, 2021; Sarfraz *et al.*, 2021; Reike *et al.*, 2018).

Figure 6: Summary of CE principles applicable to building sector

Considering the other two domains of CE principles, CE Loops and the ReSOLVE model, all these 17 R-imperatives can be logically linked with any one of the four loops and also in any one of the six actions of ReSOLVE model, by referring to addition sources such as Caldas *et al.* (2022); Kennedy and Linnenluecke (2022); Cetin *et al.* (2021); Akhimien, (2020); Gallego-Schmid *et al.* (2020), Hopkinson *et al*. (2020); Mendoza *et al*. (2019); Antikainen *et al.* (2018) and Bocken *et al*. (2016).

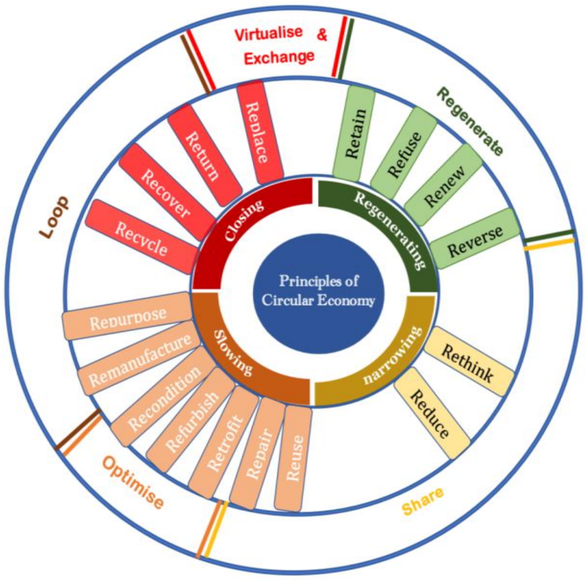

Figure 7: Logical link between R-imperatives and other domains

Figure 7 displays three levels of circles to depict the logical connection between R-imperatives and other CE domains. The inner circle represents the CE loops, while the middle and outer layer represents the R-imperatives that are presented in Figure 6, and the ReSOLVE model, respectively. Additionally, the level of circularity for each principle is expressed using a color-coding where green indicates more circularity whilered represents less circularity.

4. CONCLUSIONS

In this study, CE principles were viewed within the most popular three main domains of R-imperatives, CE Loops, and the ReSOLVE model. A critical review carried out on 23 peer-reviewed scholarly articles retrieved through systematic review using the PRISMA tool indicated that most of the studies (18 out of 23) represented the CE principles within the domain of R-imperatives. The review provided altogether a list of 26 R-imperatives as CE principles applicable to building sector. Of the 26 principles, most of the study contexts (over 12 out of 23) have identified the common 3Rs of Reuse, Recycle, and Reduce. Although some of these principles were referred to by different terminologies, they represented similar concepts or meanings. Upgrade, Reclaim, Rehabilitation, Adaptive Reuse, Refit, Resell/Remarket, Redesign, and Relocate are the concepts which refer to similar meanings of some other concepts in the list of 26 principles. Further, the principles of Disposal and Selective Demolition were excluded from the list of CE principles for building sector as they can be represented to some extent under the principles of Reuse, Recycling, Recovery, and Return. Further, these principles seem to contradict the concept of CE as well. Accordingly, a condensed list of 16 CE principles was derived. When these principles were further compared with previous well-known studies relating to R-frameworks by Cimen (2021), Sarfraz et al. (2021), and Reike et al. (2018), it was identified that three principles of Re-imagine, Remine and Rethink are missing from the list of 16 principles. However, of them, Rethink is taken into account when building sector principles, while the remaining two are eliminated. This adds the seventeenth principle to the list of CE principles applicable to the building sector. Moreover, Retain, Renew, Reverse, Retrofit, and Return are the five principles added as CE principles that are applicable to the building sector in this study compared to previous studies. The current study also establishes a link between the three popular domains for understanding CE principles, including CE loops, the ReSOLVE model, and the R-framework. These models are continuing to evolve, and at this point in time, this logical connection model encompasses all aspects of the various domains of CE principles. This makes it possible to understand the CE principles clearly and thereby enhances their application in the building sector. These review findings can be applied to real life buildings of different types to validate. Further, these principles seem to require appropriate strategies for their adoption. Hence, the current study is extended to explore these aspects.

5. REFERENCES

Aarikka-Stenroos, L. R. (2021). Circular economy ecosystems: A typology, definitions, and implications. In S. Teerikangas, T. Onkila, K. Koistinen, & M. Mäkelä (Eds.*), Research Handbook of Sustainability Agency* (260-276). Edward Elgar Publishing. https://doi.org/10.4337/9781789906035.

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: Current awareness, challenges and enablers. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management, 170*(1), pp.15–24. https://doi.org/10.1680/jwarm.16.00011.

Akanbi, L. A., Oyedele, L. O., Omoteso, K., Bilal, M., Akinade, O. O., Ajayi, A. O., Davila Delgado, J. M., & Owolabi, H. A. (2019). Disassembly and deconstruction analytics system (D-das) for construction in a circular economy. *Journal of Cleaner Production*, *223*, pp.386–396. https://doi.org/10.1016/j.jclepro.2019.03.172.

Akhimien, N. G., Latif, E., & Hou, S. S. (2021). Application of circular economy principles in buildings: A systematic review. *Journal of Building Engineering*, *38*, 102041. https://doi.org/10.1016/j.jobe.2020.102041.

Akhimien, N., Tawheed, A., Latif, E., & Hou, S. (2022). Circular Economy in Buildings. In T. Zhang (Ed.), The Circular Economy - Recent Advances in Sustainable Waste Management. (pp. 1-21). http://dx.doi.org/10.5772/intechopen.107098.

Al-Obaidy, M., Courard, L., & Attia, S. (2022). A parametric approach to optimizing building construction systems and carbon footprint: A case study inspired by circularity principles. *Sustainability*, *14*(6), 3370. https://doi.org/10.3390/su14063370.

Anastasiades, K., Blom, J., Buyle, M., & Audenaert, A. (2020). Translating the circular economy to bridge construction: Lessons learnt from a critical literature review. *Renewable and Sustainable Energy Reviews*, *117*, 109522. https://doi.org/10.1016/j.rser.2019.109522.

Antikainen, M., Uusitalo, T., & Kivikytö-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia CIRP*, *73*, pp.45–49. https://doi.org/10.1016/j.procir.2018.04.027.

Antonini, E., Boeri, A., & Giglio, F. (2021). Classification criteria and markers for Biomimetic Building Envelope Within Circular Economy Principles: A critical review. *Architectural Engineering and Design Management*, *18*(4), pp.387–409. https://doi.org/10.1080/17452007.2021.1891858.

Arauzo-Carod, J.-M., Kostakis, I., & Tsagarakis, K. P. (2022). Policies for supporting the Regional Circular Economy and Sustainability. *The Annals of Regional Science*, *68*(2), pp.255–262. https://doi.org/10.1007/s00168-022-01124-y.

Barreiro-Gen, M., & Lozano, R. (2020). How circular is the circular economy? analysing the implementation of circular economy in organisations. *Business Strategy and the Environment*, *29*(8), pp.3484–3494. https://doi.org/10.1002/bse.2590.

Benachio, G. L., Freitas, M. do, & Tavares, S. F. (2020). Circular economy in the construction industry: A Systematic Literature Review. *Journal of Cleaner Production*, *260*, 121046. https://doi.org/10.1016/j.jclepro.2020.121046.

Bertino, G., Kisser, J., Zeilinger, J., Langergraber, G., Fischer, T., & Österreicher, D. (2021). Fundamentals of building deconstruction as a circular economy strategy for the reuse of construction materials. *Applied Sciences*, *11*(3), 939. https://doi.org/10.3390/app11030939.

Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), pp.308–320. https://doi.org/10.1080/21681015.2016.1172124.

Bolier, M. (2018). Blockchain technology to accelerate the transition towards a circular economy. Delft University of Technology. https://repository.tudelft.nl/islandora/object/uuid:d6736f9b-f870-4736-a5e7-2ef292cf69aa/datastream/OBJ3/download.

Caldas, L. R., Silva, M. V., Silva, V. P., Carvalho, M. T., & Toledo Filho, R. D. (2022). How different tools contribute to climate change mitigation in a circular building environment?—a Systematic Literature Review. *Sustainability*, *14*(7), 3759. https://doi.org/10.3390/su14073759.

Cambridge Dictionary. (2022a). Cambridge Dictionary. Retrieved July 01, 2022, from https://dictionary.cambridge.org/dictionary/english/reclaim.

Cambridge dictionary. (2022b). Cambridge dictionary. Retrieved July 25, 2022, from https://dictionary.cambridge.org/dictionary/english/rehabilitation.

Cambridge dictionary. (2022c). Cambridge dictionary. Retrieved July 26, 2022, from https://dictionary.cambridge.org/dictionary/english/refit.

Cayzer, S., Griffiths, P., & Beghetto, V. (2017). Design of indicators for measuring product performance in the circular economy. *International Journal of Sustainable Engineering*, *10*(4–5), pp.289–298. https://doi.org/10.1080/19397038.2017.1333543.

Çetin, S., De Wolf, C., & Bocken, N. (2021). Circular Digital Built Environment: An Emerging Framework. *Sustainability*, *13*(11), 6348. https://doi.org/10.3390/su13116348.

Çimen, Ö. (2021). Construction and built environment in circular economy: A comprehensive literature review. *Journal of Cleaner Production*, *305*, 127180. https://doi.org/10.1016/j.jclepro.2021.127180.

Dabaieh, M., Maguid, D., & El-Mahdy, D. (2021). Circularity in the new gravity—re-thinking vernacular architecture and circularity. *Sustainability*, *14*(1), 328. https://doi.org/10.3390/su14010328.

Dams, B., Maskell, D., Shea, A., Allen, S., Driesser, M., Kretschmann, T., Walker, P., & Emmitt, S. (2021). A circular construction evaluation framework to promote designing for disassembly and adaptability. *Journal of Cleaner Production, 316*, 128122. https://doi.org/10.1016/j.jclepro.2021.128122.

De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., & Ioppolo, G. (2021). A systematic review for Measuring Circular Economy: The 61 indicators. *Journal of Cleaner Production, 281,* 124942. https://doi.org/10.1016/j.jclepro.2020.124942.

Department of Environment and Heritage. (2004). *Adaptive Reuse*. Canberra: Commonwealth of Australia. https://www.dcceew.gov.au/sites/default/files/documents/adaptive-reuse.pdf.

Dixon, T., & Eames, M. (2013). Scaling up: The Challenges of Urban Retrofit. *Building Research & Information*, *41*(5), 499–503. https://doi.org/10.1080/09613218.2013.812432.

Douglas, J. (2006). *Building Adaptation* (2nd ed.). Butterworth Heinemann. https://books.google.com/books?hl=en&lr=&id=gaqwsLs23mgC&oi=fnd&pg=PP2&dq=Douglas,+J.+(2006).+&ots=EdQC2LWSBI&sig=vjfTqOLDpA8P9O0p9kP5qgzZyv8.

Eberhardt, L., Birgisdottir, H., & Birkved, M. (2019). Comparing life cycle assessment modelling of linear vs. Circular Building Components. *IOP Conference Series: Earth and Environmental Science*, *225*, 012039. https://doi.org/10.1088/1755-1315/225/1/012039.

Ellen MacArthur Foundation. (2015). Growth within: A Circular Economy Vision for a Competitive Europe. https://www.mckinsey.com/capabilities/sustainability/our-insights/growth-within-a-circular-economy-vision-for-a-competitive-europe#/download/%2F~%2Fmedia%2Fmckinsey%2Fbusiness%20functions%2Fsustainability%2Four%20insights%2Fgrowth%20within%20a%20circular%20economy%20vision%20for%20a%20competitive%20europe%2Fgrowth_within.pdf.

Foster, G., & Kreinin, H. (2020). A review of environmental impact indicators of cultural heritage buildings: A circular economy perspective. *Environmental Research Letters*, *15*(4), 043003. https://doi.org/10.1088/1748-9326/ab751e.

Gallego-Schmid, A., Chen, H.-M., Sharmina, M., & Mendoza, J. M. (2020). Links between circular economy and climate change mitigation in the built environment. *Journal of Cleaner Production*, *260*, 121115. https://doi.org/10.1016/j.jclepro.2020.121115.

Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, *178*, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207.

Guerra, B. C., & Leite, F. (2021). Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and Enablers. *Resources, Conservation and Recycling*, *170*, 105617. https://doi.org/10.1016/j.resconrec.2021.105617.

Hopkinson, P., De Angelis, R., & Zils, M. (2020). Systemic building blocks for creating and capturing value from circular economy. *Resources, Conservation and Recycling*, *155*, 104672. https://doi.org/10.1016/j.resconrec.2019.104672.

Huang, Y., Shafiee, M., Charnley, F., & Encinas-Oropesa, A. (2022). Designing a framework for materials flow by integrating circular economy principles with end-of-life management strategies. *Sustainability*, *14*(7), 4244. https://doi.org/10.3390/su14074244.

Jansen, B., Stijn, A., Gruis, V., & Bortel, G. (2020). A circular economy life cycle costing model (CE-LCC) for building components. *Resources, Conservation and Recycling*, *161*, 104857. https://doi.org/10.1016/j.resconrec.2020.104857.

Joensuu, T., Edelman, H., & Saari, A. (2020). Circular economy practices in the built environment. *Journal of Cleaner Production*, *276*, 124215. https://doi.org/10.1016/j.jclepro.2020.124215.

Kanters, J. (2020). Circular building design: An analysis of barriers and drivers for a circular building sector. *Buildings*, *10*(4), 77. https://doi.org/10.3390/buildings10040077.

Kennedy, S., & Linnenluecke, M. K. (2022). Circular economy and Resilience: A Research Agenda. *Business Strategy and the Environment*, *31*(6), pp.2754–2765. https://doi.org/10.1002/bse.3004.

Kosanović, S., Miletić, M., & Marković, L. (2021). Energy refurbishment of family houses in Serbia in line with the principles of Circular Economy. *Sustainability, 13*(10), 5463. https://doi.org/10.3390/su13105463.

Kouhizadeh, M., Zhu, Q., & Sarkis, J. (2019). Blockchain and the circular economy: Potential Tensions and critical reflections from Practice. *Production Planning & Control*, *31*(11–12), pp.950–966. https://doi.org/10.1080/09537287.2019.1695925.

Kozminska, U. (2020). Circular economy in Nordic architecture. thoughts on the process, practices, and case studies. *IOP Conference Series: Earth and Environmental Science*, *588*, 042042. https://doi.org/10.1088/1755-1315/588/4/042042.

Kuzma, E. L., Sehnem, S., Lopes de Sousa Jabbour, A. B., & Campos, L. M. S. (2021). Circular economy indicators and levels of innovation: An innovative systematic literature review. *International Journal of Productivity and Performance Management*, *71*(3), pp.952–980. https://doi.org/10.1108/ijppm-10-2020-0549.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, pp.36–51. https://doi.org/10.1016/j.jclepro.2015.12.042.

Lindgreen, E., Salomone, R., & Reyes, T. (2020). A critical review of academic approaches, methods and tools to assess circular economy at the Micro Level. *Sustainability*, *12*(12), 4973. https://doi.org/10.3390/su12124973.

Linton, J. D., & Jayaraman, V. (2005). A framework for identifying differences and similarities in the managerial competencies associated with different modes of product life extension. *International Journal of Production Research*, *43*(9), pp.1807–1829. https://doi.org/10.1080/13528160512331326440.

Liu, T.-Y., Ho, S.-J., Tserng, H.-P., & Tzou, H.-K. (2022). Using a unique retaining method for building foundation excavation: A case study on sustainable construction methods and circular economy. *Buildings*, *12*(3), 298. https://doi.org/10.3390/buildings12030298.

Mangialardo, A., Micelli, E. (2017). Rethinking the Construction Industry Under the Circular Economy: Principles and Case Studies. In: A. Bisello, D. Vettorato,, P. Laconte, & S. Costa (eds) *Smart and Sustainable Planning for Cities and Regions. SSPCR 2017*. (pp. 333-334). Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-319-75774-2_23.

Marika, G., Beatrice, M., & Francesca, A. (2021). Adaptive Reuse and sustainability protocols in Italy: Relationship with Circular Economy. *Sustainability*, *13*(14), 8077. https://doi.org/10.3390/su13148077.

Mendoza, J. M., Sharmina, M., Gallego-Schmid, A., Heyes, G., & Azapagic, A. (2017). Integrating backcasting and eco-design for the Circular Economy: The Bece Framework. *Journal of Industrial Ecology*, *21*(3), pp.526–544. https://doi.org/10.1111/jiec.12590.

Mercader-Moyano, P., Porras-Pereira, P., & Levinton, C. (2021). Circular economy and regenerative sustainability in emergency housing: Eco-efficient prototype design for Subaşi Refugee Camp in Turkey. *Sustainability*, *13*(14), 8100. https://doi.org/10.3390/su13148100.

Mhatre, P., Panchal, R., Singh, A., & Bibyan, S. (2021). A systematic literature review on the circular economy initiatives in the European Union. *Sustainable Production and Consumption*, *26*, pp.187–202. https://doi.org/10.1016/j.spc.2020.09.008.

Minunno, R., O'Grady, T., Morrison, G., Gruner, R., & Colling, M. (2018). Strategies for applying the circular economy to prefabricated buildings. *Buildings*, *8*(9), 125. https://doi.org/10.3390/buildings8090125.

Nasir, M. H., Genovese, A., Acquaye, A. A., Koh, S. C. L., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. *International Journal of Production Economics*, *183*, pp.443–457. https://doi.org/10.1016/j.ijpe.2016.06.008.

Osobajo, O. A., Oke, A., Omotayo, T., & Obi, L. I. (2020). A systematic review of circular economy research in the construction industry. *Smart and Sustainable Built Environment*, *11*(1), pp.39–64. https://doi.org/10.1108/sasbe-04-2020-0034.

Potting, Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain.* Planbureau voor de Leefomgeving(2544).

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular cities: Mapping Six cities in transition. *Environmental Innovation and Societal Transitions*, *26*, pp.171–194. https://doi.org/10.1016/j.eist.2017.03.002.

Rahla, K. M., Mateus, R., & Bragança, L. (2021). Selection criteria for building materials and components in line with the circular economy principles in the built environment—a review of current trends. *Infrastructures*, *6*(4), 49. https://doi.org/10.3390/infrastructures6040049.

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The Circular Economy: New or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, *135*, pp.246–264. https://doi.org/10.1016/j.resconrec.2017.08.027.

Ruiter, H., De Feijter, F., & Wagensveld, K. (2021). Management control and business model innovation in the context of a circular economy in the Dutch construction industry. *Sustainability*, *14*(1), 366. https://doi.org/10.3390/su14010366.

Saffari, M., & Beagon, P. (2022). Home Energy Retrofit: Reviewing its depth, scale of delivery, and Sustainability. *Energy and Buildings*, *269*, 112253. https://doi.org/10.1016/j.enbuild.2022.112253.

Sarfraz, M., Ivascu, L., Belu, R., & Artene, A. (2021). Accentuating the interconnection between business sustainability and organizational performance in the context of the circular economy: The moderating role of Organizational Competitiveness. *Business Strategy and the Environment*, *30*(4), pp.2108–2118. https://doi.org/10.1002/bse.2735.

Spišáková, M., Mandičák, T., Mésároš, P., & Špak, M. (2022). Waste management in a sustainable circular economy as a part of design of construction. *Applied Sciences*, *12*(9), 4553. https://doi.org/10.3390/app12094553.

Torgautov, B., Zhanabayev, A., Tleuken, A., Turkyilmaz, A., Mustafa, M., & Karaca, F. (2021). Circular economy: Challenges and opportunities in the construction sector of Kazakhstan. *Buildings*, *11*(11), 501. https://doi.org/10.3390/buildings11110501.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), pp.207–222. https://doi.org/10.1111/1467-8551.00375.

Wilkinson, S. (2012). Analysing sustainable retrofit potential in premium office buildings. *Structural Survey*, *30*(5), pp.398–410. https://doi.org/10.1108/02630801211288189.

Williams, J. (2019). Circular cities: Challenges to implementing looping actions. *Sustainability*, *11*(2), 423. https://doi.org/10.3390/su11020423.