INTEGRATING CIRCULAR ECONOMY AND CONSTRUCTABILITY RESEARCH: AN INITIAL DEVELOPMENT OF A LIFECYCLE "CIRCULARITY" ASSESSMENT FRAMEWORK AND INDICATORS

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Hitherto, the Circular Economy (CE) in construction literature has lacked a holistic framework for assessing the "circularity" of construction activities. This has delayed full transition of the construction industry to CE. The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper presents a significant contribution as it facilitates measuring the industry's transition to CE through twelve "circularity" indicators (CIs) that signify high-level requirements of a construction CE. Grouped in five themes relevant to different stages of a project lifecycle, these indicators assess the "circularity" of construction activities, rather than of tracking their casual links with individual CE concepts. A systematic review assessed "circularity" within the 'constructability' literature, as both 'constructability' and CE share a philosophical focus on resource value, using the proposed framework. Results revealed a weak, but increasing, association between CE and 'constructability', and a variable engagement with different CE themes and indicators. The literature has engaged with indicators that fall inside its comfort zone, i.e., those related to design and construction. This misses the opportunities offered through engaging with other, more challenging, CE themes and indicators providing directions for future research. Moreover, the proposed framework reshapes the relationship between CE and sustainability, 'flipping' the traditional view of CE being subordinate to sustainability. It also has a potential to extend into rating "circularity" by construction firms/projects to identify areas of good practice and those for "circularity" improvements.

Keywords: circular economy, Lifecycle Circularity Assessment Framework, LCAF

INTRODUCTION

The term circular economy (CE) was first introduced by Pearce and Turner (1990). CE has its roots in a variety of ideologies and schools of thought such as regenerative design, performance economy, cradle-to-cradle and industrial ecology (Sauvé *et al.,* 2016; Rizos *et al.,* 2017; De los Rios and Charnley, 2017; EMF, 2013). Moreover, cleaner production (CP) is a relevant concept that can be used to achieve the goals of

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both CE and sustainable development (Ghisellini *et al.,* 2016). Reviewing the scope of CE in the literature reveals two limitations: first, there is no consensus in the literature on the scope of CE. Ghisellini *et al.,* (2016) believe CE should cover the entire life-cycle of any process, taking into consideration its embedded context, and lead to material or energy recovery along with improvement of the entire living and economic model. This holistic approach to CE requires reshaping the entire chain of production, consumption, distribution and recovery (Ghisellini *et al.,* 2018). However, the CE concept is frequently viewed in the literature from the closed material loops and waste management perspectives (e.g. Sauvé *et al.,* 2016; De los Rios and Charnley, 2017; Preston, 2012). Second, the relationship between CE and 'sustainability' is not explicitly addressed, which "is blurring their conceptual contours and constrains the efficacy of using the approaches in research and practice" (Geissdoerfer *et al.,* 2017). The CE concept is frequently perceived as a subordinate to sustainability, being considered as a pathway to product sustainability (De los Rios and Charnley, 2017), and a strategy to achieve a more 'sustainable development' and a harmonious society (Ghisellini *et al.,* 2016). However, actual CE research focuses on waste management having little linkage with sustainable development (Kirchherr *et al.,* 2017); whereas sustainability research in construction is limited to high-performance green buildings and retrofitting (Sanchez and Haas, 2018), and energy consumption and carbon emissions (Pomponi and Moncaster, 2016).

The lack of a valid framework and tools to measure the overall transition of different industries from 'linear' to 'circular' models (EMF, 2015a) is directly linked to the ambiguous scope of CE. Sauvé *et al.,* (2016) believe that CE tends to have narrower objectives than those of sustainable development; it includes a fragmented collection of concepts derived from different scientific fields, some being poorly established (Korhonen et al.,2018). The diversity of concepts, schools of thought, and stakeholders operating in significantly different environments have all blurred the CE concept (Kirchherr *et al.,* 2017). CE research is characterised by a partial approach (Pomponi and Moncaster, 2017), engaging with conceptual discussions about individual concepts of CE, with no practical implementation strategies provided (Suárez-Eiroa *et al.,* 2019). Trends of CE research in construction include construction and demolition (C&D) waste management (Ghisellini *et al.,* 2018), sustainable construction (Kibert, 2016), and industrial symbiosis (Smol *et al.,* 2015).

The first comprehensive definition for 'buildability' (the initial form of 'constructability'), was provided by the Construction Industry Research and Information Association (CIRIA) in 1983 (Kifokeris and Xenidis, 2017). Early definitions of 'constructability' reveal shared objectives with the CE concept; better knowledge and expertise management to review construction processes early in pre-construction and design stages to facilitate ease of construction (CIRIA, 1983), achieve overall project objectives (CII, 1986), and predict obstacles prior to the construction stage (IPENZ, 2008). Nima *et al.,* (2001) listed 23 constructability concepts (CCs), with many in line with CE principles such as: use of prefabrication and off-site construction to avoid adverse weather conditions; planning for good site management, efficient use of resources and improved productivities; efficient use, reuse and recovery of temporary facilities and construction equipment; and improved collaboration through effective use of information technology.

Early constructability definitions have two main limitations. First, they fail to address the totality of the building life-cycle, with a focus on the construction stage, but not on the operation and decommissioning stages. Second, they are motivated mostly by economic, rather than environmental and social objectives. Later definitions (e.g. Gambatese *et al.,* 2007) start to acknowledge the whole building life-cycle, with the IRC (2013) proposing a framework to show how the scope of 'constructability' grew from facilitating building construction to the whole construction life-cycle and improving building performance. This is a natural response to technological and ecological changes and growing societal concerns of sustainability, and it can thus be posited that both constructability and CE have shared objectives of retaining the value of resources for as long as possible whilst also minimising waste.

RESEARCH AIM, OBJECTIVES AND METHODS

Constructability literature provides no empirical evidence of any engagement with CE concepts, and therefore the posited sharing of objectives needs to be assessed using a systemic approach examining industry conformity with CE requirements and exploring areas for "circularity" improvements. Subsequent presenting of such improvements to the industry in the context of objectives shared with a known 'philosophy' (constructability) may result in wider adoption of them. This requires:

1. Proposing a holistic framework, using a 'project life-cycle assessment (PLA)' approach, for "circularity" assessment of construction activities and practices.
2. Assessing conformity of 'constructability' research and practices with CE requirements using the proposed framework.

The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper could have been introduced without the inclusion of "constructability". However, the innovative nature of this initial framework necessitated the need to explore its applicability within a context, i.e., 'constructability'. This gives the proposed framework some meaning and provides an example of how construction processes would benefit from its adoption. This framework includes five main themes aligned with different stages in the project lifecycle. The literature was reviewed for relevance of generic CE concepts and requirements to the five themes. Consequently, these were grouped into twelve "circularity" indicators (CIs) embodying high-level requirements of CE in construction. A systematic review of the literature, including 132 articles, was then conducted to explore whether 'constructability' research and practices fulfil CE requirements, and support the transition of construction to CE.

A Framework for "Circularity" Assessment

Reviewing CE literature in general reveals a few attempts to identify principles, strategic focus areas, and related metrics or indicators to measure the transition to CE. For example, Su *et al.,* (2013) categorize CE practices into four areas: production, consumption, waste management, and other support; each includes practices at different managerial levels of CE: micro, meso and macro. The first three areas perceive CE from the material perspectives, whereas the fourth highlights the role of governments and NGOs in promoting CE. Ellen MacArthur Foundation (2013) introduced a generic framework of four "building blocks" to promote the transition to CE, including: circular product design and production, new business models, building reverse cycle, and cross-cycle collaboration. This shifts the focus from material-centred perspectives, and instead highlights the role of better planning, collaboration, and the use of new business models in the transition to CE. The European Environmental Agency (2016) provides a generic set of policy questions for CE assessment classified under five main areas: material input, eco-design, production, consumption, and waste recycling. This framework is adopted by Elia *et al.,* (2017) to assess different CE concepts based on ability satisfy five CE principles: reducing material inputs, reducing material losses, reducing emissions, using renewable/recyclable resources, and increasing product durability. Suárez-Eiroa *et al.,* (2019) use these principles, complemented with two transversal principles ('designing for CE' and 'educating for CE'), to group practical strategies of CE.

CE literature has two shortcomings: firstly, suggests no valid indicators for assessing the actual transition to CE; and secondly, the transition to CE is not discussed in a specific context i.e., industry. This first issue is addressed in the ‘Circularity Indicators Project’ (EMF, 2015a) that suggests a tool to measure how advanced products and companies are in transitioning to CE using four criteria: inputs in the production process, utility during in-use stage, destination after use, and efficiency of recycling. The ‘Delivering the CE’ report (EMF, 2015b) also suggests a toolkit to measure a country’s level of "circularity" using four metrics, each is linked to one or more relevant assessment criteria. These include resources productivity, circular activities, waste generation, and energy consumption and greenhouse gas emissions.

In construction, Sanchez and Haas (2018) argue that CE principles must be integrated into the construction process. This can be facilitated by more involvement of clients as key drivers in project teams (Haugbølle and Boyd, 2017), including CE decision gates and “pre-project” or “front-end” planning (Sanchez and Haas, 2018), and design and education as transversal elements (Suárez-Eiroa *et al.,* 2019). The UK Green Building Council (2019) report attempted a holistic approach to embedding principles of CE in construction projects, by providing guidance on how to address principles of CE in project briefs. It consists of a list of high-level CE principles to be applied in all construction projects but provides no valid framework of indicators to assess overall “circularity” of project outcomes and does not extend beyond the project brief.

Proposing a 'Lifecycle "Circularity" Assessment Framework (LCAF)':

This paper argues for the project-based nature of the construction process to be embedded in "circularity" assessment, and any framework developed for this purpose to address the totality of the project life-cycle. This requires a link between CE requirements, as perceived in the literature, and different stages of the project life-cycle some of which currently are not well-addressed or are absent (e.g. the ‘decommissioning’ stage). This does not promote 'closing material loops' as a key CE requirement and limits the potential of construction practices to implement CE principles.

The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper adopts a 'project life-cycle assessment (PLA)' approach to measure conformity of the 'constructability' literature to high-level requirements of CE referred to as "circularity" indicators (CIs); rather than tracking its casual links with individual CE concepts. CIs are grouped into five themes relevant to main stages in a construction project life-cycle. Themes include: (1) 'design for circularity' to link to the 'design stage', (2) 'reduced construction impact' to link to the 'construction stage', (3) 'sustainable utilisation and maintenance' to link to the 'operation stage', (4) 'C&D waste mgmt.' to link to 'closing material loops' during 'construction' and 'decommissioning' stages, and (5) 'CE mgmt.' for managerial requirements that cannot be included in other themes.

Generic CE requirements identified in the literature are classified according to their relevance to the five framework themes. Subsequently, these are grouped into twelve "circularity" indicators (CIs) embodying CE requirements relevant to different themes.

Designing for CE plays a transversal role in promoting circularity across product life-cycle (Suárez-Eiroa *et al.,* 2019), which signifies a fundamental change in design practices (De los Rios and Charnley, 2017). In the first theme, 'design for circularity', three CIs are used to assess "circularity" of design practices: 'design solutions to maximise future circularity', 'use of low-impact and innovative materials', and 'embed recycled materials in design'. The first CI is aspirational, as it assesses plans for future "circularity" at the project end-of-life, whereas the other two CIs are active, as they measure "circularity" achieved during project delivery. The second theme, 'reduced construction impact', includes two CI encapsulation requirements relevant to 'reduced material inputs' through more efficient construction processes and equipment sharing, and 'innovative construction methods' e.g., off-site construction and 3D printing.

Table 1: The proposed 'Lifecycle "Circularity" Assessment Framework (LCAF)'

Circularity Themes	Circularity Indicators
Design for Circularity in Construction (Design Stage)	• **Design Solutions to Maximise Future Circularity:** (design for disassembly, longevity, and modularisation • **Use of Low-impact Innovative Materials** • **Embed Recycled Materials in Design**
Reduced Construction Impact (Construction Stage)	• **Reduced Material Inputs:** efficient const. processes, sharing equipment • **Innovative Construction Methods:** e.g. off-site construction, 3D printing
Sustainable Utilisation & Maintenance (Operation Stage)	• **Durability of Building, Asset, or Project:** efficient use, repair, maintenance, and repurpose • **Reduced Environmental Impact of Operation:** CO2 emissions, energy consumption, and domestic waste Mgmt.
C&D Waste Mgmt. (Closing Material Loops)	• **Construction Waste Mgmt.:** waste minimisation material & equipment recovery for onward reuse • **Demolition Waste Mgmt.:** Integrating the 3R framework & waste mgmt. hierarchy
CE Mgmt. (Business Models, Education, and Data Mgmt.)	• **New Business Models and Strategies** • **Planning, Collaboration, and CE Data Mgmt.** • **Education, Training, and Stakeholders CE Awareness**

The third theme, 'sustainable utilisation and maintenance', provides a new understanding of the link between CE and 'sustainable development'. Two CIs are used to group sustainability requirements relevant to the operation stage in construction projects: 'durability of building, asset, or project', and 'reduced environmental impact of operation'. The first indicator includes sustainability requirements related to efficient use, repair, maintenance, and project re-purposing, whereas the second indicators relate to carbon emissions, energy consumption, and waste production and management. The fourth theme, 'C&D waste mgmt.', is concerned with closing material loops in construction. CE is frequently viewed in the literature from the waste management perspectives (Kirchherr *et al.,* 2017), so here two main CIs address the main sources of waste in the construction process. The 'construction waste mgmt.' indicator focuses on waste minimisation strategies, and material and equipment recovery for onward reuse, whereas the 'demolition waste mgmt.' indicator has more focus on integrating the 3R framework and waste management hierarchy. A fifth theme, 'CE mgmt.', is added to include all managerial requirements that cannot be included in other groups. A transition to CE requires a systemic change in the way we do business (McAloone and Pigosso, 2018), and a complete reform of both production and consumption processes (Yuan *et al.,* 2006), which should be transformative rather than just delivering incremental efficiency gains (Preston, 2012). The fifth theme includes three CIs encapsulating managerial requirements relevant to 'new business models and strategies', 'planning, collaboration, and CE data mgmt.', and 'education, training, and stakeholder CE awareness'.

SYSTEMATIC REVIEW

Scope and Strategy

The purpose of this systematic review is to assess the literature for articles associating between the 'circular economy' and different 'constructability' practices using the proposed LCAF framework. Figure 1 demonstrates scope, search strategy, numbers of articles, and analytical strategy used in the systematic review. ‘Google Scholar’, ‘Scopus’, and ‘Web of Science’ databases were used to search relevant literature with no time boundary. The actual search was conducted in December 2019 using the following keywords: "Circular Economy" AND ("Building*" OR "Construction") AND (“Constructability" OR "Constructibility" OR “Buildability"). This covers the three different ‘constructability’ terms used in the literature.

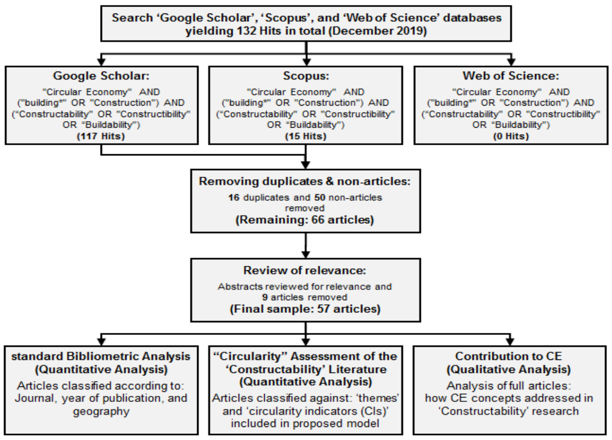

Figure 1: Scope, keywords and strategy adopted in the systematic review

The initial search yielded only 132 hits using three search engines, Figure 1. This reveals a weak association between ‘circular economy’ and ‘constructability’ despite the well-established literature on both topics individually in the 'Construction' and 'Building' literature. For example, the initial search on 'Google Scholar' yielded 49,400 hits for “circular economy”, 42,200 hits for different terms of 'constructability', and only 117 hits for the association between the two topics. Similarly, ‘Scopus’ returned only 15 hits, while the 'Web of Science' returned no hits. Furthermore, 61.21% (71/116) of articles in the initial sample were published in the period 2018-2019. This reveals the growing trend of integrating CE concepts into constructability practices; an evolution that supports the suggestion made earlier of a means to wider CE adoption. The initial sample was refined by removing 16 duplicates and 50 non-articles. Consequently, the remaining 66 articles were reviewed for their relevance to the scope of this research, and 9 articles were excluded as they provided no precise association between CE and constructability. The final sample comprised 57 articles, including: empirical articles, conceptual articles, and conference papers.

Data Analysis: "Circularity" of 'Constructability' Research

The final sample, including 57 articles, was analysed to examine published evidence to provide deeper insights into the adoption of CE concepts in the constructability literature. Analysis included: standard bibliometric analysis, as well as quantitative and qualitative analysis with respect to the LCAF framework proposed in this paper. Articles were quantitatively categorised according to their relevance to the 5 themes and 12 "circularity" indicators (CIs) included in the proposed framework. Moreover, studies in the final sample were qualitatively analysed to enrich discussions and capture the main argument in each of these studies. Results for different themes and associated "circularity" indicators (CIs) were depicted using radar diagrams to explore engagement of constructability literature with CE concepts and identify areas for further "circularity" development. Data analysis shows that articles in the final sample have most engagement with 'CE mgmt.' 36.84% (21/57), and 'design for circularity' 35.09% (20/57) themes. The other three themes of "circularity" reveal lower levels of engagement: 'C&D waste mgmt.' 17.54% (10/57), 'reduced construction impact' 15.79% (9/57), and 'sustainable utilisation and maintenance' 12.28% (7/57), Figure 2.

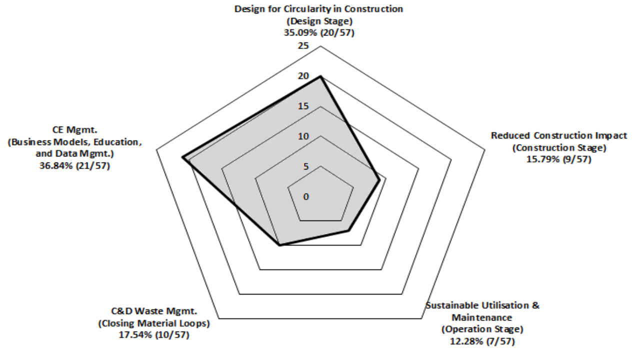

Figure 2: Engagement of literature with "circularity" themes

Data analysis across "circularity" indicators (CIs) provides deeper understanding of areas of good practice and those appropriate for "circularity" improvements, Figure 3. At this early stage of engagement with CE, constructability literature engages with CIs that fall inside researchers' 'known' comfort zone, i.e., those related to design and construction stages; require little effort and yield acceptable results. This approach has similarities with the innovation adoption curve of Rogers and indicates an industry at the first stage of CE adoption (innovators).

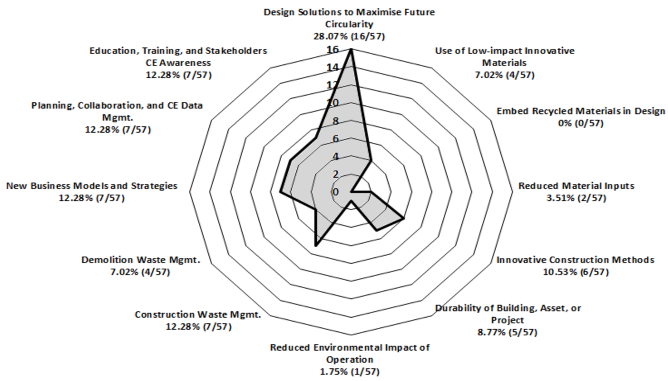

Figure 3: Engagement of literature with 'Circularity Indicators (CIs)'

The high level of engagement with the 'design for circularity' theme highlights the role that design plays in promoting circularity throughout the whole building life-cycle. However, results revealed that this engagement is mostly aspirational as more articles are concerned with 'design solutions to maximise future circularity' 28.07% (16/57); whereas fewer engaged with the 'use of low-impact and innovative materials' 7.02% (4/57), and the 'embed recycled materials in design' indicator was totally overlooked 0% (0/57).

The proposed framework includes three construction-related indicators for which variable levels of engagement were identified: 'construction waste mgmt.' with focus on waste minimisation and equipment recovery for onward reuse 12.28% (7/57); 'innovative construction methods' 10.53% (6/57), and 'reduced material inputs' (concerned with the use of efficient processes and equipment sharing) that received only 3.51% (2/57).

Moreover, articles showed little interest in 'demolition waste mgmt.' 7.02% (4/57), keeping a weak link with CE concepts related to buildings' end-of-life stage. Unexpectedly, articles revealed little engagement with 'sustainable utilisation and maintenance' indicators relevant to the 'operation' stage: 8.77% (5/57) for 'durability of building' relevant to efficient use/repair/maintenance and building repurposing; and only 1.75% (1/57) for 'reduced environmental impact of operation' relevant to carbon emissions and energy consumption topics.

In contrast, the final sample revealed greater engagement with the three 'CE mgmt.' indicators, with 12.28% (7/57) each; seeking opportunities offered by new CE managerial strategies relevant to these indicators.

CONCLUSION

This paper makes a significant contribution to both construction circular economy (CE) and 'constructability' paradigms. Reviewing CE in current construction literature reveals two main limitations delaying the transition to CE: first, the lack of a holistic framework for project life-cycle assessment (PLA) of "circularity" within construction activities; second, the lack of clarity about the relationship between CE and sustainability concepts and any overlap between them. The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed here represents an innovative and novel departure point for the future transformation of CE in construction. This is through making the effectiveness of CE transition propositions measurable via assessment of the overall construction activities' "circularity" across the entire project life-cycle. The proposed framework includes twelve "circularity" indicators (CIs) grouped in five themes relevant to different stages of a project life-cycle. CIs represent stage-relevant, high-level requirements of CE in construction, with each encapsulating larger numbers of theme-relevant CE concepts. This helps identify areas of good practice and those appropriate for "circularity" improvements. This paper also extends the scope of CE through integrating sustainability notions relevant to the 'operation' stage into a broader framework for "circularity" assessment. This represents a shift in previous understanding of the link between CE and sustainability in construction; 'flipping' the traditional view of CE being subordinate to sustainability.

This paper argues that full transition to CE requires holistic understanding of complex CE solutions combining multiple concepts across the entire project life-cycle. Data analysis revealed a weak association of 'constructability' with CE in general, and variable engagement with themes and indicators included in the LCAF framework. Two main findings are worthy of emphasis. First, the totality of the framework, including all themes and CIs, needs to be considered, as close engagement with only one theme may initially be apparent. For example, the high engagement of 'constructability' with the design theme is only aspirational and has not resulted in actual embedment of circular materials in building design. Second, low results for individual CIs may seem casual, simple and unrelated, but a cross-theme approach can establish that more complex CE solutions may be required. For example, effective C&D waste management and closing material loops require close collaboration between all stakeholders, active CE data management, new business models in construction supply chains, and effective use of BIM tools to combine circular materials in design. Future research will seek to verify and validate the proposed LCAF framework using real-life project example(s) and feedback from construction practitioners (early adopters and early majority representing pragmatists and mainstream market) to insure its adequacy for “circularity” assessment, and explore its potentials for supporting decision-making in construction projects. This will allow the connection between the LCAF framework and 'constructability' to drop away.

REFERENCES

Construction Industry Institute (CII) (1986*) Constructability: A Primer*, Austin, TX: University of Texas.

Construction Industry Research and Information Association (CIRIA) (1983) *Buildability: An Assessment*, London: Construction Industry Research and Information Association

De los Rios, I C and Charnley, F J (2017) Skills and capabilities for a sustainable and circular economy: The changing role of design, *Journal of Cleaner Production*, **160**, 109-122.

Elia, V, Gnoni, M G and Tornese, F (2017) Measuring circular economy strategies through index methods: A critical analysis, *Journal of Cleaner Production*, **142**, 2741-2751.

Ellen Mac-Arthur Foundation (EMF) (2013) *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition, UK*, Available from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf [Accessed 1st April 2020].

Ellen Mac-Arthur Foundation (EMF) (2015a) *Circularity Indicators: An Approach to Measuring Circularity, UK*, Available from https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Project-Overview_May2015.pdf [Accessed 1st April 2020]

Ellen McArthur Foundation (EMF) (2015b) *Delivering the Circular Economy: A Toolkit for Policymakers, UK*, Available from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_PolicymakerToolkit.pdf [Accessed 1st April 2020].

Gambatese, J A, Pocock, J B and Dunston, P S (Eds,) (2007) *August, Constructability Concepts and Practice*, Reston, VA: American Society of Civil Engineers.

Geissdoerfer, M, Savaget, P, Bocken, N M and Hultink, E J (2017) The Circular Economy - A new sustainability paradigm? *Journal of Cleaner Production*, **143**, 757-768.

Ghisellini, P, Cialani, C and Ulgiati, S (2016) A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, **114**, 11-32.

Ghisellini, P, Ripa, M and 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.

Haugbølle, K and Boyd, D (Eds) (2017) *Clients and Users in Construction: Agency, Governance and Innovation*, Oxon: Taylor and Francis.

Institute for Research in Constructability - IRC (2013) *Constructibilité: Cahier Pratique, Le Moniteur Des Travaux Publics Et Du Bâtiment*, Available from https://www.estp.fr/la-constructibilite [Accessed 6th April 2020].

Institution of Professional Engineers New Zealand (IPENZ) (2008) *Constructability: Practice Notes*, New Zealand, Available from https://d2rjvl4n5h2b61.cloudfront.net/media/documents/Practice_Note_13_Constructability.pdf [Accessed 6th April 2020].

Kibert, C J (2016) *Sustainable Construction: Green Building Design and Delivery*, Chichester: John Wiley and Sons.

Kifokeris, D and Xenidis, Y (2017) Constructability: Outline of past, present and future research, *Journal of Construction Engineering and Management*, **143**(8), 04017035.

Kirchherr, J, Reike, D and Hekkert, M (2017) Conceptualizing the circular economy: An analysis of 114 definitions, *Resources, Conservation and Recycling*, **127**, 221-232.

Korhonen, J, Honkasalo, A and Seppälä, J (2018) Circular economy: The concept and its limitations, *Ecological Economics*, **143**, 37-46.

McAloone, T C and Pigosso, D C (2018) Designing Product service systems for a circular economy, *In*: M Charter (Ed.) *Designing for the Circular Economy*, London: Routledge.

Nima, M A, Abdul-Kadir, M R, Jaafar, M S and Alghulami, R G (2001) Constructability implementation: A survey in the Malaysian construction industry, *Construction Management and Economics*, **19**(8), 819-829.

Pearce, D and Turner, R K (1990) *Economics of Natural Resources and the Environment*, Hemel Hempstead: Harvester Wheatsheaf.

Pomponi, F and Moncaster, A (2016) Embodied carbon mitigation and reduction in the built environment-what does the evidence say? *Journal of Environmental Management*, **181**, 687-700.

Pomponi, F and Moncaster, A (2017) Circular economy for the built environment: A research framework, *Journal of Cleaner Production*, **143**, 710-718.

Preston, F (2012) *A Global Redesign? Shaping the Circular Economy*, London: Chatham House.

Rizos, V, Tuokko, K, Tuokko, K, Behrens, A and Behrens, A (2017) *The Circular Economy: A Review of Definitions, Processes and Impacts, CEPS Research Report No 2017/8*, Brussels: CEPS.

Sanchez, B and Haas, C (2018) Capital project planning for a circular economy, *Construction Management and Economics*, **36**(6), 303-312.

Sauvé, S, Bernard, S and Sloan, P (2016) Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research, *Environmental Development*, **17**, 48-56.

Smol, M, Kulczycka, J, Henclik, A, Gorazda, K and Wzorek, Z (2015) The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy, *Journal of Cleaner Production*, **95**, 45-54.

Su, B, Heshmati, A, Geng, Y and Yu, X (2013) A review of the circular economy in China: moving from rhetoric to implementation, *Journal of Cleaner Production*, **42**, 215-227.

Suárez-Eiroa, B, Fernández, E, Méndez-Martínez, G and Soto-Oñate, D (2019) Operational principles of circular economy for sustainable development: Linking theory and practice, *Journal of Cleaner Production*, **214**, 952-961.

The European Environment Agency (2016) *Circular Economy in Europe: Developing the Knowledge Base*, Luxembourg: The European Environment Agency.

The UK Green Building Council (2019) *Circular Economy Guidance for Construction Clients*, UK: Green Building Council.

Yuan, Z, Bi, J and Moriguichi, Y (2006) The circular economy: A new development strategy in China, *Journal of Industrial Ecology*, **10**(1-2), 4-8.