Building design and construction strategies for a circular economy

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Published in:
Architectural Engineering and Design Management

DOI (link to publication from Publisher):
10.1080/17452007.2020.1781588

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Eberhardt, L. C. M., Birkved, M., & Birgisdottir, H. (2022). Building design and construction strategies for a circular economy. *Architectural Engineering and Design Management*, *18*(2), 93-113. https://doi.org/10.1080/17452007.2020.1781588

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Systematic Literature Review Protocol (based on de Almeida Biolchini et al., 2007)

Protocol Steps	**Answers or Definitions**
Data collection	
1. Question Formularization	
1.1. Question Focus	To identify in which direction is the construction sector moving in terms of designing and constructing buildings for a circular economy i.e. state-of-the-art
1.2. Question Quality and Amplitude	
1.2.1. Problem	As more and more circular economy initiatives have emerged within recent years within the built environment it is increasingly important to understand what design and construction strategies are available/used in relation to circular economy how and to which degree they are applied in research and in practice (i.e. state-of-the-art) in order identify gaps and provide direction for future research to promote a more comprehensive circular economy adoption in the construction sector.
1.2.2. Question	What are the existing/applied building design and construction strategies for a circular economy? How are they applied and what are their level of readiness (i.e. research level, research and development and/or building project application?
1.2.3. Keywords and Synonyms	The main keywords are related to circular economy, buildings, strategies. A pre-search was used to help plan the search string and define synonyms of the main keywords in relation to the resources available. "Design" returned in too many irrelevant publications outside of the scope of the study at hand and was thus excluded as a keyword. To obtain more relevant results the keywords are targeted the publications' titles, abstracts and keywords. <u>Main keywords and synonyms:</u> • Circular economy: circle economy • Building: built environment, construction, civil engineering, • Strategy: approach, method, concept, principle, framework, guideline, guidance, guide
1.2.4. Intervention	The circular economy strategies/principles for building life cycle design will be observed and registered in a spreadsheet during the review process.
1.2.5. Control	None
1.2.6. Effect	A comprehensive database of building design and construction strategies for a circular economy, classified according to
1.2.7. Outcome Measure	-Number of desing and construction strategies -Description of the strategies characteristics, level of application and readiness
1.2.8. Population	- Scientific publications regarding building design and construction strategies in relation to circular economy - Publications from from private or public stakeholders engaged in circular economy in the building sector
1.2.9. Application	Circular economy and sustainability research fields within the built environemnt; researchers, industry practitioners e.g. designers and decision makers
Experimental Design	No statistical method will be applied
2. Sources Selection	
2.1. Sources Selection Criteria Definition	Databases with available web-search mechanisms using keywords, high volume of indexed papers and proven relevance in the field of research as well as grey literature (i.e. non-peer-reviewed material) from relevant industry stakeholders e.g. Ellen MacArthur Foundation
2.2. Studies Languages	- English - Danish publications were incuded as the authors native language is danish
2.3. Sources Identification	
2.3.1. Sources Search Methods	Web-based academic database search engines Cross-references (backward snowballing)
2.3.2. Search String	("circular economy" OR "circle economy") AND ("built environment" OR building OR construction OR "civil engineering") AND (approach OR method OR strategy OR concept OR framework OR principle OR taxonomy OR guideline OR guide) *Adaptions and adjustments to the string are made according to each database's rules for search queries.
2.3.3. Sources List	<u>Main database:</u> Scopus (content coverage: indexed references, peer-reviewed) <u>Secondary database for cross checking:</u> topic search in Web of science (content coverage: indexed cited references, peer-reviewed) and title search (to limit the number of hits) in Google Scholar (content coverage: indexed cited references, peer-reviewed, grey literature) and as a control to make sure everything relevant has been captured As CE has lagely been developed in the grey literature Google Scholar was also used to capture grey literature
2.4. Sources Selection after Evaluation	Scopus; Web of Science; google scholar, cross references.
2.5. References Checking	N/A
3. Studies Selection	
3.1. Studies Definition	
3.1.1. Studies Inclusion and Exclusion Criteria Definition	The studies must meet the following inclusion criteria: 1) contain at least one building design and construction strategy that is explicitly related to the circular economy concept 2) the strategy must focus on the building's resources and embodied environmental impacts. 3) The design and construction strategy must focus solely on the design and construction of new buildings thus excluding building renovation as well as building extensions 3) The study must provide a sufficient level of information i.e. information about the strategies application in a building context
3.1.2. Studies Types Definition/ Qualification Criteria	- Journal papers, conference papers and grey literature will be selected regardless of their research approach. - Primary data (i.e. original studies/sources) is included - As the CE concept builds on a large body of pre-existing work of which the construction sector is consolidating, secondary data (i.e. systematic comparisons between primary studies) is includede to obtain aggregated information.
3.1.3. Procedures for Studies Selection	The search strings must be run at the selected sources. The publications will be qualitatively selected according to three filters: Filter 1 - Reading the title, abstract, keywords Filter 2 - Reading the Introduction and Conclusion Filter 3 - Reading the full publication Finally, backward snowballing was perfomed i.e. using the reference list of the selected publications to identify new papers to include.
3.2. Selection Execution	
Initial Studies Selection	Check 'Data Extraction' spreadsheet
Studies Quality Evaluation	N/A
Selection Review	N/A
Data analysis	
4. Information Extraction	
4.1. Information Inclusion and Exclusion Criteria Definition	Coding was used for the information extraction of the selected publications. Check 'Data Extraction' spreadsheet
4.2. Data Extraction Forms	
4.3. Extraction Execution	
Objective Results Extraction	
i) Study Identification	
ii) Study Methodology	
iii) Study Results	
iv) Study Problems	

Subjective Results Extraction	
i) Information through authors	
ii) General Impressions and Abstractions	
4.4. Resolution of divergences among reviewers	
5. Results Summarization	Check sections 4 and 5 in the manuscript
5.1. Results Statistical Calculus	
5.2. Results Presentation in Tables	
5.3. Sensitivity Analysis	
5.4. Plotting	
Data reporting	
5.5. Final Comments	Check sections 4 and 5 in the manuscript
Number of Studies	
Search, Selection and Extraction Bias	
Publication Bias	
Inter-Reviewers Variation	
Results Application	
Recommendations	

Building design and construction strategies for a circular economy

Data extraction

No.	Title	Author	Source	Year	Location study	Building case (if relevant)	Study method									Building design and construction strategy	Characteristic(s)	Application level				Readyness level			Cestrategy								Project stage										Project/building types								
							Systematic literature review	Literature review	Case study	Framework	Life cycle assessment	Tool	Survey	Workshop	Expert interview			Building	Component	Material	General	Theoretical	Experimental	Consolidated	Reduce	Reuse	Repair	Refurbish	Remanufacture	Replace	Recycle	Energy recovery	Planning	Design	Tender	Procurement	Manufacturing	Construction	Commissioning	Operation/ maintenance	Decomission/ demolition	Renovation	Residential house	Olympic park	Town hall	Office	Office park	Police center	Hospital	Care home	Health care center
1	Integrated facades as a product-service system - Business process innovation to accelerate intergral product implementation	Azcarate-Aguerre J. F., den Heiner A. and Klein T	Scopus	2018	Netherlands			x							x	Assembly/disassembly			x			x			x		x			x																							
2	Developing strategies for managing construction and demolition waste in Malaysia based on the concept of circular economy	Esa R. M., Halog A. and Rigamonti L.	Scopus	2016	Japan	Malaysia	x		x	x						Standardisation	Construction and demolition waste minimization			x		x			x								x	x				x			x											
																Assembly/disassembly	Construction and demolition waste minimization			x		x			x	x							x	x																		
																Modularity	Construction and demolition waste minimization			x		x			x																											
																Prefabrication	Construction and demolition waste minimization			x		x			x																											
																Adaptability/flexibility	Construction and demolition waste minimization			x		x			x	x																										
																Material selection/substitution	Construction and demolition waste minimization			x		x			x	x					x		x	x																		
																Component and material optimisation	Construction and demolition waste minimization waste targetsSite waste management (collecting/sorting/crushing)			x		x			x	x					x		x	x		x		x			x	x										
																Symbiosis/sharing	Construction and demolition waste minimization			x		x			x	x					x						x															
3	Comparing linear and circular supply chians: A case study from the cosntruction industry	Nasir M. H. A., Genovese A., Acquaye A. A., Koh S. C. L.	Scopus	2017	England	-		x	x		x					Secondary materials	reduce impacts, insulation material			x		x			x								x	x																		
4	Evaluation of the impacts of end-of- life management strategies for deconstruction of a high-rise concrete framed office	Chau, C.K., Xu, J.M., Leung, T.M., Ng, W.Y.,	Snowballing	2017	China				x		x					Assembly/disassembly	to salvage materials at their EoL		x	x		x				x	x			x	x	x								x	x										
5	Circularity in the built environment: case studies a compilation of case studies from the CEx00	Ellen MacArthur foundation	Grey literature	2016	Unknown	France			x							Reusing existing building/components/materials	Floor boards, cement tiles and rubble			x				x		x		x															x	x								
																Secondary materials	textile and cellular glass			x				x	x						x													x								
																Material selection/substitution	Eco-materials from renewable sources			x				x	x																			x								
						England			x							Prefabrication	Minimize onsite waste e.g. glue laminated timber		x					x	x	x							x	x							x			x							
																Component and material optimisation	Reducing excavation by chosing a shallow raft foundation		x					x	x								x	x										x							
																Secondary materials	Recycling of surplus gas pipeline for structure, Concrete			x				x	x	x							x	x										x							
																Modularity	Minimize onsite waste		x					x	x								x	x				x			x			x							
																Assembly/disassembly	To reuse materials	x	x	x				x	x	x							x	x							x			x							
																Optimized shapes/dimensions	Minimize onsite waste, Ordering to precise material specifications			x				x	x	x							x	x										x							
																Material selection/substitution	Changing types of material for easy disassembly and assembly, reuse and recycling			x				x	x	x							x	x										x							
																Short use	Using structure for another purpose after initial use	x						x		x								x										x							
																Material storage	Avoid degradation	x						x	x	x							x	x							x			x							
						Netherlands			x							Assembly/disassembly	For temporary use, reuse, reduction of construction time,	x	x					x		x							x	x							x				x						
																Prefabrication	E.g. wooden components		x					x																					x						
																Material selection/substitution	High quality reusable materials			x				x		x							x	x							x				x						
																Component and material optimisation	Minimise the use of concrete			x				x	x																				x						
																Short use	Short building life span for 20 to accommodate shifting municipality borders	x						x		x								x											x						
																Material storage	Temporary storage of materials	x						x		x															x				x						
						Netherlands			x							Reusing existing building/components/materials	Reuse of existing surrounding buildings	x						x	x	x							x	x							x					x					
																Assembly/disassembly	To reuse of metal structure		x					x		x							x	x							x					x					
																Material storage	transforming the building into a material deposit where materials are temporarily stored	x						x		x															x					x					
																Material selection/substitution	Using materials that can be reused			x				x	x	x							x	x												x					
																Optimized shapes/dimensions	Reduce use of materials, Light weight structure		x	x				x																												
																Secondary materials	Waste wood for facades			x				x	x																					x					

						Scotland			x							Secondary materials	Insulation materials. Plastic kitchen worktops			x				x	x								x	x									x								
																Material selection/substitution	Structural insulated panels (SIPs), materials that can be recycled, durable plastickitchen work tops			x				x							x												x								
																Prefabrication	Off site construction to save money		x					x	x	x							x	x							x		x								
																Assembly/disassembly	For deconstruction		x					x							x										x		x								
																Modularity	Control of waste and cost,	x	x					x	x	x							x	x							x		x								
						France			x							Adaptability/flexibility	The compound was designed to be flexible	x						x									x	x				x										x			
																Modularity	The compound was	x						x									x	x				x										x			
																Secondary materials	Materials with recycled content			x				x	x								x	x														x			
																Material selection/substitution	Floors for reuse and recycling		x					x		x					x		x	x						x	x							x			
																Durability	The compound was designed to be durable. Use of durable materials	x		x				x													x											x			
						Germany			x							Adaptability/flexibility				x				x			x			x			x	x						x	x							x			
																Material selection/substitution	Bio-composite, reduce env. Impacts			x				x	x								x	x						x	x							x			
																Assembly/disassembly			x					x			x			x			x	x						x	x							x			
6	Building revolutions applying the circular economy to the built environment	Cheshire D.	Grey literature	2016	England	-			x							Layer independence	Ease of replacement, salvaging, adaptability, making the parts independant from each others		x	x				x			x			x	x									x											
																Component and material optimisation	Minimise the number af different types of components and materials		x	x				x		x																									
																Modularity	allowing upgrade, demount and reconfiguration of structure, reuse	x	x					x		x																									
																Accessibility	Provide good access for deconstruction, especially connections		x	x				x		x																									
																Optimized shapes/dimensions	Design components sized to suit appropriate means of handling		x					x		x																									
																Prefabrication	Reclamation and reuse		x					x		x																									
																Standardisation	-		x					x		x																									
																Durability	Durable materials, resilience, prolonging service life, repair and upgrade, remanufacture		x	x				x		x	x		x																						
																Adaptability/flexibility	life prolonging, different/new uses,	x						x		x																									
																Assembly/disassembly	Facilitating adaptability, reuse, recycling,	x	x					x		x																									
																Material selection/substitution	Matching lifetime with material selection, biological materials, technical materials			x				x		x					x																				
7	Circular economy in construction: current awareness, challenges and enablers	Adams K. T., Osmani M., Thorpe T. and Thornback J.	Scopus	2017	England	-							x	x		Assembly/disassembly	Building /component/product level, flexibility				x	x					x			x				x						x	x	x									
																Adaptability/flexibility	-				x	x				x		x			x			x						x											
																Standardisation	-				x	x												x																	
																Modularity	-				x	x												x																	
																Component and material optimisation	Using less material				x	x				x								x																	
																Material selection/substitution	use less hazarous materials, recycled materials,				x	x																x													
																Secondary materials	use secondary materials				x	x																x													
																Durability	Prolong life span				x	x																													
																Prefabrication	-				x	x															x	x	x												
8	Salvaging bulding materials in a circular economy: A Design using BIM-base whole-life performance estimator	Akanbi L. A., Oyedele L.O., Akinade O. O., Yjayi A. O., Delgado M. D., Bilal M. and Bello S. A.	Scopus	2018	England			x	x							Material selection/substitution	-			x		x				x					x			x							x										
																Assembly/disassembly	-		x			x				x					x			x							x										
																Prefabrication	-		x			x				x					x			x							x										
																Standardisation	-		x			x				x					x			x							x										
																Layer independence	according to anticipated life span		x			x				x					x			x							x										
9	Thermodynamic insights and assessment of the circular economy	Cooper S. J. G., Giesekam J., Hammond P. G., Norman J. B., Owen A., Rogers J. G. and Scott K.	Scopus	2017	England	-		x		x		x				Optimized shapes/dimensions	reducing impacts and material consumption			x		x			x																										
																Material selection/substitution	Durability, non toxic, recyclability, substituting with wood, stronger materials			x		x																													
																Reusing existing building/components/materials	E.g steel beams		x			x			x			x																							
																Adaptability/flexibility	e.g. of building, extensive refurbishment in which primary use changes	x				x						x												x		x									

10	Building a circular future	Guldager K. and Sommer J.	Grey literature	2016	Denmark	Denmark			x							Assembly/disassembly	Concrete elements		x			x				x							x	x							x					x					
																Material selection/substitution	choose material with properties that ensure they can be			x		x				x																									
																Durability	Use materials of high quality that can handle several life			x		x				x																									
																Layer independence	Make the long lasting building elements flexible, so the short lasting elements can be easily changed		x			x				x																									
																Standardisation	Using standardized elements, ensure material reuse		x			x				x																									
																Modularity	Use modular systems where elements can be replaced		x			x				x																									
																Prefabrication	use prefab elements for a quicker and more secure assembly and disassembly		x			x				x																									
																Accessibility	Make the construction accesible in order to minimize assembly and disassembly		x			x				x																									
																Adaptability/flexibility	flexible building design that allows for the funcitons to adapt	x				x				x																									
11	Circle house	Circle House Partners	Grey literature	2018	Denmark	Denmark			x		x					Assembly/disassembly	to ease reuse and recycling and continued circulation e.g. facades.		x				x			x	x			x	x												x								
																Standardisation	Using same component types		x				x																				x								
																Material selection/substitution	Materials that are recyclable, maintenance free, Choosing maintenance free building materials			x			x				x				x										x			x								
																Adaptability/flexibility	To be able to expand, modify according to change in use	x					x																					x								
																Accessibility	Accesible TBS		x				x				x			x											x			x								
12	Embodying circularity through usable relocatable modular buildings	Kyrö R., Jylhä T., Peltokorpi A.	Scopus	2019	Finland	Finland		x	x	x					x	Modularity	In order to adapt/reuse buildings over time	x						x	x									x															x	x	x
																Adaptability/flexibility		x						x	x		x			x				x					x										x	x	x
13	Economi-environmental indicators to support investment devisions: A focus on the building's end-of-life stage	Fregonara E., Giordano R., Ferrando D. G. and Pattono S.	Scopus	2017	Italy	Italy			x							Assembly/disassembly	Facade, focus on joint connections		x	x						x															x										
14	Design for change an circularity - accomodating circular material & product flows in construction	Geldermans R. J.	Scopus	2016	Netherlands									x		Assembly/disassembly	Dimensions and connections		x	x		x				x					x																				
																Adaptability/flexibility	Joint connections, Distinguish generic elements with a long lifespan and high architectural value and specific changeable elements with a varying, shorter lifespan. Over	x	x			x				x					x			x																	
																Standardisation	To define conditions for recycling			x		x				x					x			x																	
																Short use	Defining the use and performance span of a building has to be part of the design process in order for material- and product choices to be adjusted to it optimally.	x		x		x				x					x			x																	
																Material selection/substitution	Defining the use and performance span of a building has to be part of the design process in order for material- and product choices to be adjusted to it optimally.			x		x				x					x			x																	
																Layer independence	Clear definitions are required of which components belong to which 'shearing layer', with specific attention for intersection-zones.		x			x				x					x			x																	
																Material selection/substitution	use material and products that keep or increase their value			x		x				x					x			x																	
15	Evaluating the transition towards cleaner production in the construction and demolition sector of China: A review	Ghisellini P., Ji x., Liu G. and Ulgiati S.	Scopus	2018	China	China	x									Prefabrication	waste minimisation, cost and time optimization		x			x			x	x								x																	
																Component and material optimisation	Using less material, reducing amount of waste goint to landfill, reducing env. Pollution and economic benefits			x		x			x	x					x		x	x				x			x										
																Reusing existing building/components/materials	-		x	x		x			x	x					x		x	x				x			x	x									

																Modularity	-	x				x			x								x	x																	
																Secondary materials	-			x		x			x								x	x																	
16	Construction and demolition waste best management practice in Europe	Gálvez-Martos J., Styles D., Schoenberger H. and Zeschmar-Lahl B.	Scopus	2018	Spain	EU		x							x	Prefabrication	Avoid cutt-offs		x			x				x					x			x																		
																Assembly/disassembly	for reuse and recycling, easy to			x		x			x	x					x			x																		
																Material storage	Avoid material loss			x		x				x					x			x																		
																Accessibility	To maximize recovery of materials at end-of-life make all elements visible		x	x		x				x					x			x							x											
																Standardisation	To maximize recovery of materials at end-of-life, avoid off-cutts			x		x			x	x					x			x							x											
																Reusing existing building/components/materials	Reuse of whole building is the best CE option	x				x			x	x					x			x							x											
																Adaptability/flexibility	-				x	x			x									x																		
																Component and material optimisation	Design for waste targets, avoid, monitor, collect and sepparate waste + site waste management plan			x		x			x									x							x											
																Optimized shapes/dimensions	Simplify the building form to reduce site cutting and use manufacturer dimensions for specific elements, avoid over ordering, Minimize on-site cutting	x	x	x		x			x									x																		
																Material storage	Minimize the need for stockholding (that will potentially damage materials), e.g. by choosing materials with just-in-time delivery.			x		x			x									x																		
17	Recovery and reuse of structural products from end-of-life buildigns	Hopkinson P., Chen H., Zhou K. Wang Y., Lam D.	Scopus	2019	England	-		x								Reusing existing building/components/materials	Reuse of components		x			x				x																										
																Secondary materials	Building steel and concrete recycling			x		x									x																					
																Assembly/disassembly	reuse	x				x				x								x																		
																Prefabrication	structural elements for recovery		x							x																										
																Durability	high value durable products		x			x				x																										
																Adaptability/flexibility	reuse	x				x				x								x																		
18	Circular Economy in the building sector: Three cases and a collaboration tool	Leising E., Quist J. and Bocken N.	Scopus	2018	Netherlands	Netherlands			x	x		x			x	Symbiosis/sharing	sharing water, waste and energy, create value from waste, outsourcing surplus energy supply from renewables			x				x									x	x												x	x				
																Assembly/disassembly	to regain material value at the buildings EoL, create value from waste		x	x				x		x							x	x												x	x				
																Material selection/substitution	C2C certified materials, create value from waste, substitute with renewables, particularly energy			x				x									x	x												x	x				
																Optimized shapes/dimensions	Optimise material efficiency e.g. reducing the spatial needs for clients of the building to be built	x						x									x	x													x				
																Secondary materials	Reusing secondary materials in the building			x				x		x					x		x	x												x					
19	Can social sustainability values be incorporated in a product service system for temporaty public building modules?	Kurdve M. and de Goey H.	Scopus	2017	Sweden			x	x							Modularity	Temporay buildings, cheaper standard buildings, lean production	x						x	x	x																									
																Standardisation	cheaper standard buildings	x						x	x	x																									
																Optimized shapes/dimensions	building materials are ordered in amounts as needed			x				x	x	x																									
																Assembly/disassembly	To increase life of the temporary building the modules are possible to reuse	x						x	x	x																									
20	Capital project planning for a circular economy	Sanchez B. and Haas C.	Scopus	2018	Canada	-				x						Assembly/disassembly	-	x				x																													
																Durability	-	x				x																													
																Adaptability/flexibility	-	x				x																													
21	A novel selective disassembly sequence planning method for adaptive reuse of buildings	Sanchez B and Haas C.	Scopus	2018	Canada	-		x	x							Assembly/disassembly	Recovering components, disassembly planning performed one component at a time considering a given method per component		x			x				x							x																			
																Adaptability/flexibility	Adaptive reuse, reduse building cost and increase the building components life cycle times		x			x			x	x							x																			

22	The circular economy in the built environment	Zimmermann, R., O'Brian, H., Hargrave, J., & Morrell, M.	Grey literature	2016	England	-			x	x						Assembly/disassembly	enhancing the effective second use and reuse pathways for components and materials.		x	x				x		x					x									x	x										
																Material selection/substitution	Renewable energy sources and materials, reducing impacts and cost			x				x	x																										
																Modularity	Enabling adaptability	x	x					x	x	x					x			x																	
																Prefabrication	adaptable mixed-use spaces	x	x					x	x															x											
																Adaptability/flexibility	accommodate future change such as remodelling, expansion or disassembly	x	x					x		x														x											
																Accessibility	allow for easy access to building services or include demountable and reconfigurable façade systems.		x					x						x										x											
																Layer independence	each element may easily be separated and removed.		x					x		x	x		x	x	x			x																	
23	Circular construction Most opportunities for demolishers and wholesalers	van Sante, M.	Grey literature	2017	Unknown	-			x							Assembly/disassembly	reuse of building materials	x	x	x				x		x								x																	
																Component and material optimisation	Using fewer materials		x	x				x	x																										
																Material selection/substitution	using natural, renewable building materials such as wood.			x				x	x																										
24	Strategies for applying the circular economy to prefabricated buildigns	Minunno R., O'grady T. Morrison G. M, Gruner R. L. and Colling M.	Google scholar	2018	Australia	-		x		x						Prefabrication	reduction, reusability, adaptability, recyclability	x	x			x			x	x					x																				
																Secondary materials	integration of scrap/waste into new components,		x	x		x																													
																Adaptability/flexibility	Reduction throgh life extension	x				x			x														x												
																Assembly/disassembly	Component reuse		x			x				x								x																	
																Reusing existing building/components/materials	Reuse of entire components		x																																
																Material selection/substitution	Design for recycling			x		x									x										x										
25	Design for disassembly and deconstruction - challenges and oppotunities	Rios C. F., Chong W. K. and Grau D.	Snowballing	2015	USA	-		x								Assembly/disassembly	Restore use of the demolished materials, conserve materials	x		x		x			x	x					x			x																	
																Modularity	to allow DfD		x			x																													
																Prefabrication	to allow DfD		x			x																													
																Standardisation	to allow DfD		x			x																													
																Optimized shapes/dimensions	that allows standardisation		x			x																													
																Accessibility	to allow DfD				x	x																													
26	Applying circular economy principles to building materials Front-running companies' business model innovation in the value chain for buildings	Nussholz J. L. K. and Milios L.	Google scholar	2017	Germany	-		x	x							Assembly/disassembly	recover materials and components	x	x	x				x		x								x																	
																Adaptability/flexibility	To adapt to available materials				x			x		x					x			x						x											
																Standardisation	-				x			x										x																	
																Modularity	-	x						x										x																	
																Material selection/substitution	Specify recyclable material			x				x							x			x																	
																Durability								x																											
																Secondary materials	Design to reintegrate secondary production			x				x										x																	
27	Toward a ressource-efficient Built Environment A litererature review and conceptual model	Ness D. A. and Xing K.	Web of science	2017	Australia	-		x		x						Adaptability/flexibility	closing the material loop,	x	x			x			x	x								x																	
																Assembly/disassembly	improve adaptability		x			x			x									x							x										
																Modularity	improve adaptability, disassembly and reuse		x			x				x				x				x						x											
																Durability	for longetivity			x		x																													
28	Rebeauty Nordic built component reuse	Vandkunsten Architects	Grey literature	2017	Denmark				x		x					Secondary materials	Mock-ups of reused building components and materials. Focus: facades and interior wall systems. Bricks, Concrete, wood, windows, reduce material use, waste and env. Impacts		x	x			x		x	x		x			x			x			x	x				x									
																Reusing existing building/components/materials			x	x			x		x	x		x			x			x			x	x				x									
																Assembly/disassembly			x	x			x		x	x					x			x			x	x				x									
29	Upcycle house - genbrug fra inderst til yderst	Kleis, B.	Grey literature	2013	Denmark				x		x					Secondary materials	Reduce CO_2	x		x				x	x									x									x								
30	Det vedligeholdelsesfri hus - Tradition	Kleis, B.	Grey literature	2014	Denmark				x		x					Durability	Design for maintenace free the next 50 years, reduce CO_2			x				x	x									x									x								
																Material selection/substitution	Choosing materials that are maintenace free the next 50 years, reduce CO_2			x				x	x									x									x								
																Component and material optimisation	Reduce the amount of materials used, mostly bricks and wood			x				x	x									x									x								

31	Det foranderlige hus	Kleis, B.	Grey literature	2013	Denmark				x		x					Adaptability/flexibility	Reuce CO2, robust durable materials, easy adaptable rooms and funktions	x		x				x	x									x						x			x								
																Assembly/disassembly	facade elements are design to be disassembled in sektiones en remounted for adaptability + The	x	x					x	x									x									x								
																Modularity	The house is designed in modules that can be disassembled	x						x	x									x									x								
																Durability	Reduce CO2, durable demountalbe and replacable building components		x					x	x									x									x								
																Optimized shapes/dimensions	Reduce CO3, optimized room sizes that makes them adaptable	x						x	x									x									x								
																Reusing existing building/components/materials	The building is desinged for adaptability reusing exiting stuctures and components		x					x	x									x									x								
																Component and material optimisation	Using one material for the building envelope that can handle load, vapour, isolation, adaptability (porebetonblokke)			x				x	x									x									x								
																Accessibility	All technical installations are accessible		x					x	x									x									x								
32	Det vedligeholdelsesfri hus - Fornyelse	Kleis, B.	Grey literature	2014	Denmark				x		x					Durability	Maintenance free for the next 50 years, all low qualiy matrials are protected, timeless architecture	x		x				x	x									x						x			x								
																Assembly/disassembly	Facade is designed for subsequent reuse		x					x	x									x							x		x								
																Material selection/substitution	Choosing durable materials, use of material with lower CO2 = wood. Reusable materials			x				x	x									x						x			x								
																Secondary materials	Use of secondary materials e.g. glass for the building envelope, can be reused again later			x				x	x									x									x								
																Prefabrication	frames modules		x					x	x									x									x								
																Modularity	Production of frame modules and TBS plug in modules		x					x	x									x									x								
																Adaptability/flexibility	designed for decrease or expansion	x						x	x									x						x			x								
33	Idékatalog over designstrategier for design for disassembly i prefabrikeret byggeri	CINARK	Grey literature	2018	Denmark				x							Assembly/disassembly	to preserve eksisting structure/building, reduce CO2 and construction time	x	x			x			x	x								x									x			x					
																Layer independence	easy disassembly and maintenance				x	x				x								x						x			x								
																Prefabrication	easier disassembly		x			x				x								x									x								
																Adaptability/flexibility	Future adaptability, overdimension for future adaptability	x	x			x				x								x						x			x			x					
																Secondary materials	Reduce Co2			x		x			x	x								x									x								

																Accessibility	The materials and instalaltions should be accessible and replacable		x	x		x				x								x						x			x								
																Material selection/substitution	Choosing natural products and materials than can be reused or recycled, durable materials, use pure			x		x				x					x			x									x								
																Standardisation	Ensure reuse and recyucling		x			x				x					x			x									x								
																Optimized shapes/dimensions	Simple shapes are easier to adapt,	x				x				x								x									x								
																Durability	In terms of life prolonging and adaptability			x		x				x								x									x								
																Modularity	easier maintainandce and adaptability		x			x			x	x	x	x						x						x			x			x					
																Reusing existing building/components/materials	Extra space by building on top of an existing buildign using DfD solutions	x				x				x								x									x								
																Component and material optimisation	Minimise the number of different materials used			x		x			x	x								x									x								
34	Embodied carbon mitigation and reduction in the built environment - What does the evidence say?	Francesco Pomponi, Alice Moncaster	Snowballing	2016	UK		x									Material selection/substitution		x		x		x			x																		x								
																Assembly/disassembly					x	x			x																										
																Secondary materials				x		x			x	x								x																	
																Reusing existing building/components/materials		x				x			x	x			x																						
																Material optimisation			x	x		x			x									x																	
																Durability		x				x			x									x																	
																Adaptability/flexibility		x				x			x									x																	
																Prefabrication					x	x			x																										