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A definition framework for building adaptation projects

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ABSTRACT

Building adaptation encompasses a range of construction activities that improve existing building conditions and extend the effective lives of buildings. The scopes of building adaptation projects vary, and may include rehabilitating failing structures, improving environmental performances, and changing functional uses. In order to address multiple aspects of building adaptation, different terminologies are used in the literature and in practice, including refurbishment, retrofitting, rehabilitation, renovation, restoration, modernization, conversion, adaptive reuse, material reuse, conservation, and preservation, amongst others. These terminologies are often used interchangeably with overlapping definitions, causing a lack of clarity in the addressed scope of work. An extensive literature review of terminologies related to building adaptation was conducted and the most common and applicable terminologies were identified. Recent definitions, applications, and scope for the identified terminologies are reviewed. Based on this classification, a definition framework is developed enabling precise categorization of building adaptation projects, and application is demonstrated in multiple case studies. The proposed definition framework is a valuable reference for future researchers and practitioners to clearly and consistently define the scope of work in their building adaption projects, and thus avoiding the high costs arising from codes, specifications, and project descriptions that confuse these definitions.

1. Introduction

Many aspects of building obsolescence affect the quality and performance of a building after its useful life. These include reduced environmental, economic, functional and social performances (Langston, Wong, Hui, & Shen, 2008; Ren, Shih, & Mckercher, 2015). A building facing obsolescence is often economically unsustainable, has low occupant comfort and satisfaction, and has increased energy use and water consumption. Responsive, appropriate and timely building adaptation and renewal are essential in extending a building's effective life span. Building adaptation can provide considerable environmental, social and economic benefits, making it a sustainable alternative to demolition and new construction (Conejos, Langston, & Smith, 2013; Noorzalifah & Kartina, 2016).

Adaptation of existing building stock can lead to a reduction of waste material, preservation of natural resources, improvements in energy use and carbon emissions, as well as the preservation of embodied energy in comparison to demolition and new construction (Yung & Chan, 2012). Adaptation projects can also improve the quality and comfort of existing buildings, leading to occupant satisfaction as well as preservation of cultural and social values of historical buildings (Chan, Cheung, & Wong, 2015; Remøy & Wilkinson, 2012). Building adaptation is typically less expensive than demolition and new construction and can improve the economic viability of dated buildings (Chan, Cheung, & Wong, 2015; Langston et al., 2008; Shipley, Utz, & Parsons, 2006; Wadu Mesthrige, Wong, & Yuk, 2018).

The scope of building adaptation projects can be broad and varies between each project. Scope variations are due to many factors, including type and scale of buildings, existing conditions and requirements for adaptation, and construction activities conducted during these projects (Thuvander, Femenías, Mjörnell, & Meiling, 2012). Many different terminologies are used in the literature and in industry to specify the scope of building adaptation projects. The variability in the definition of building adaptation projects is a reflection of the broad scope of these projects. Some of the terminologies often used to describe aspects of building adaptation include refurbishment, retrofitting, rehabilitation, renovation, restoration, modernization, conversion, adaptive reuse, material reuse, conservation, and preservation, amongst others. These terminologies are often used interchangeably due to overlapping scopes and lack of clarity for their appropriate uses (Douglas, 2006). There are many examples in the literature that refer to similar adaptation projects in terms of type, scale, and construction, but use different terms to describe the adaptation scope. For example, Passer, Ouellet-Plamondon, Kenneally, John, and Habert (2016) and

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Zaragoza-Fernandez et al. (2014) use the terms refurbishment and rehabilitation, respectively, to describe window replacements and insulation improvements in existing buildings (Fernández, Tarrío-Saavedra, Naya, & Jorge, 2014; Passer et al., 2016).

The objective of this paper is to develop a definition framework that avoids costly confusion by enabling clear and consistent use of building adaptation terms based on the characteristics and scope of each project. The proposed definition framework can be used as a reference for future researchers and practitioners to clearly and consistently define the scope of work in their building adaption projects. It is acknowledged that the adoption of a clear and consistent definition framework can avoid the high costs arising from codes, specifications, and project descriptions that confuse these definitions.

To achieve this objective, this paper first identifies the most common terminologies relating to building adaptation projects, investigates their definitions, and categorizes them based on their applications. An extensive literature review of terminology related to building adaptation is conducted and the most common and applicable terminologies are identified. The identified terminology includes building refurbishment, retrofitting, rehabilitation, renovation, adaptive reuse, conversion, and material reuse. Literature review on the identified terminology is conducted using published peer-reviewed journals and conference papers from 2015 to the present.

An overview and definition breakdown for each term is provided. The typical scope for each term is identified, and common strategies are demonstrated along with examples of their application. Our findings suggest all building adaptation projects can be divided into the two major categories of refurbishment and adaptive reuse. These two major categories are further broken down into several subcategories including retrofitting, rehabilitation, and renovation for refurbishment, and building conversion and material reuse for adaptive reuse. The definition framework is developed using this categorization. Several case studies of building adaptation projects are used to validate the framework through functional demonstration.

The remainder of the paper is structured as follows. Section 2 describes the research methodology and the results of the literature analysis. In Section 3, the results of building adaptation project categorization, the definition of various terms, and the developed definition framework are presented. The function of the definition framework is presented in Section 4 by conducting a case study analysis. Lastly, Section 5 concludes with the key results of this study, research limitations, and lessons learned.

2. Literature review methodology

The literature review methodology consists of the following two steps: (1) Determining the most common terminologies used to describe building adaptation projects; and (2) Analyzing the literature related to the determined terms.

2.1. Determining common building adaptation terminologies

Common building adaptation terminologies were selected from several relevant terminologies present in the literature. Refurbishment, renovation, retrofit, rehabilitation, adaptive reuse, conversion, modernization, material reuse, and revitalization were considered as the relevant terminologies based on the authors' experience in the field of building adaptation. The scope of this research does not include historical and heritage restoration and terms related to these topics were omitted (e.g., preservation and conservation). The Scopus search engine was used to find the number of published articles, including peer-reviewed journal articles and conference papers, which include each term in their title. The terms 'adaptive reuse' and 'material reuse' were searched as phrases; the word 'building' was added before other relevant terms and phrases being searched (e.g., building renovation).

As presented in Fig. 1, there are over 1600 papers published from 2011 to 2020 involving the selected terminologies including retrofitting, renovation, rehabilitation, refurbishment, material reuse, building conversion and adaptive reuse. In order to conduct a thorough analysis of definition used in a range of different studies, the scope of this literature review is limited to published articles from 2015 to 2020. In addition, through preliminary analysis it was concluded that technical terminology related to building adaptation and project scopes have been changing significantly over time. Thus, recent literature was selected for an in-depth analysis to capture current usage.

The number of published articles regarding relevant terms between 2015–2020 are as follows: (1) building refurbishment: 168, (2) building retrofit: 292, (3) building rehabilitation: 115, (4) building renovation: 311, (5) adaptive reuse: 99, (6) building conversion: 49, (7) building modernization: 33, (8) material reuse: 93, and (9) building revitalization: 23. The authors identified common terminologies as those for which there were close to, or more than, 50 articles published, so that broad geographic and temporal trends could be identified. Hence, revitalization and modernization were excluded, and refurbishment, retrofitting, rehabilitation, renovation, adaptive reuse, and material reuse were included.

2.2. Analyzing the literature related to chosen building adaptation terms

The information about the number of published articles related to the most common terminologies in the past five decades was retrieved from the Scopus database. An overview of how the focus of research on building adaptation has changed over time and which terms were of most interest among researchers is presented in Fig. 1. It can be observed that the average number of published articles about building adaptation from 2001 to 2010 and from 2011 to 2020 is approximately 10 and 40 times the average number of publications in the 1970s, respectively. Interpretting trends, in the context of increased world populations, wealth and academic publishing rates from 1970 to 2020 is challenging. However, the increase in research in this field may partly be due to building adaptation gaining acceptance during the past two decades as a sustainable approach to asset and urban management. Concepts of building refurbishment, retrofitting, rehabilitation and renovation are more established. The average number of published articles regarding these topics is 2.75 times more than the average number of publications regarding adaptive reuse, material reuse, and building conversion from 2010 to 2020. In addition to these broad subject and temporal trends, geographic and cultural differences can be revealing.

To explore geographic differences, the number of published articles related to the most common terminologies was retrieved and categorized per country of focus from 2015 to the present. The number of articles was normalized by dividing it by the country's Gross National Product (GNP). Table 2 illustrates how the most common terminologies were adopted around the world and how different countries have contributed to the published articles during the past five years. Based on Table 2, building refurbishment is of more interest in North America, Europe, China, and Australia; and Europe is the main contributor by publishing 90 % of the published articles (Table 2a).

The summary of terminologies associated with building adaptation projects is presented in Table 1. A summarized definition, scope and advantages for each category are presented.

As shown in Table 2b–d, the terms building rehabilitation, retrofitting, and renovation are used all around the world, and all continents have contributed to publishing with these terms. On average, Europe, Asia/Australia, America, and Africa have published 75.2 %, 15.03 %, 6.16 %, and 3.61 %, respectively, of the total published articles regarding building rehabilitation, retrofitting, and renovation. North America, Eastern Asia, Europe, Russia, and Australia have made the largest contribution of publications on adaptive reuse and building conversion by publishing almost 97 % of the published articles (Table 2e and f). Material reuse has a similar distribution to adaptive reuse and building conversion; an exception to this finding is Canada's

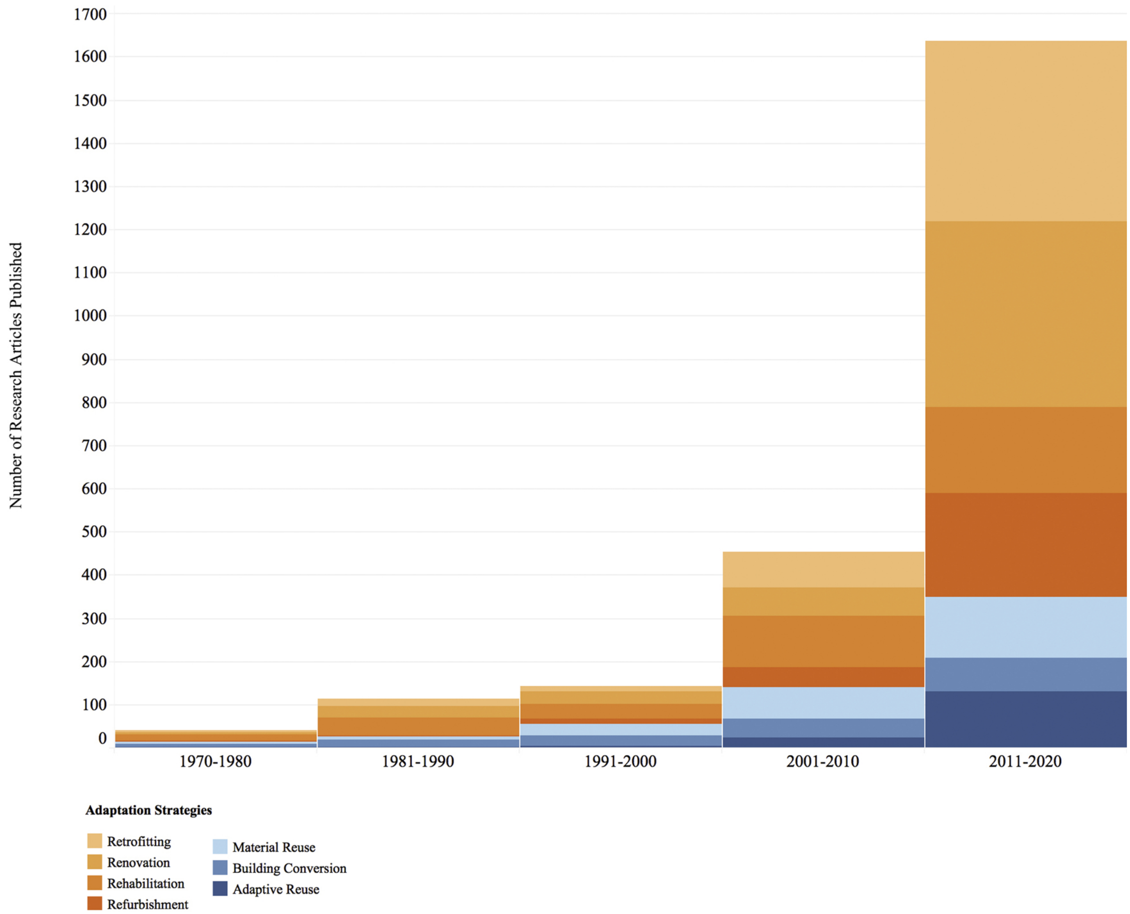


Fig. 1. Number of research articles published on the most common adaptation terminology.

lack of contribution to material reuse, however compensated by research on this topic in South America (Table 2g).

Lastly, the authors reviewed the titles and abstracts of all relevant research and ontological articles since 2015. These articles were reviewed and analyzed in depth. The results of this literature review are summarized in Table 3. In order to effectively compare the articles and identify the scope of each terminology, the focus and strategy of each article is characterised by column and row membership.

Regarding refurbishment, retrofitting, rehabilitation, and renovation, the articles mainly focus on improving the sustainability of existing buildings by conducting different adaptation strategies (e.g., replacing the windows, improving insulation, reinforcing building structure, and using renewable sources of energy). Most of the articles relating to adaptive reuse and building conversion investigate the impacts of changing the function of the buildings and reusing their materials on overall sustainability improvement. Additionally, some articles focus on the impacts of policies and regulations on adaptive reuse and building conversion, advantages and disadvantages of these projects, development of decision-making methodologies, and explain strategies for improving the performance of these projects. As such, the focus of articles associated with material reuse is mainly on the sustainability, advantages and barriers of material reuse, investigation of the potential of material reuse, and strategies to maximize the material reuse (e.g., deconstruction and disassembly) considering the reuse and recycling strategies.

3. Results: a definition framework

This section is divided into four subsections. The first subsection presents the results of categorizing the terminologies related to building adaptation projects based on the literature review. The second subsection explains the definition, scope of application, and barriers to implementation for each type of building adaptation. The provided definitions for terminologies are summarized in the third section. Lastly, the definition framework is presented.

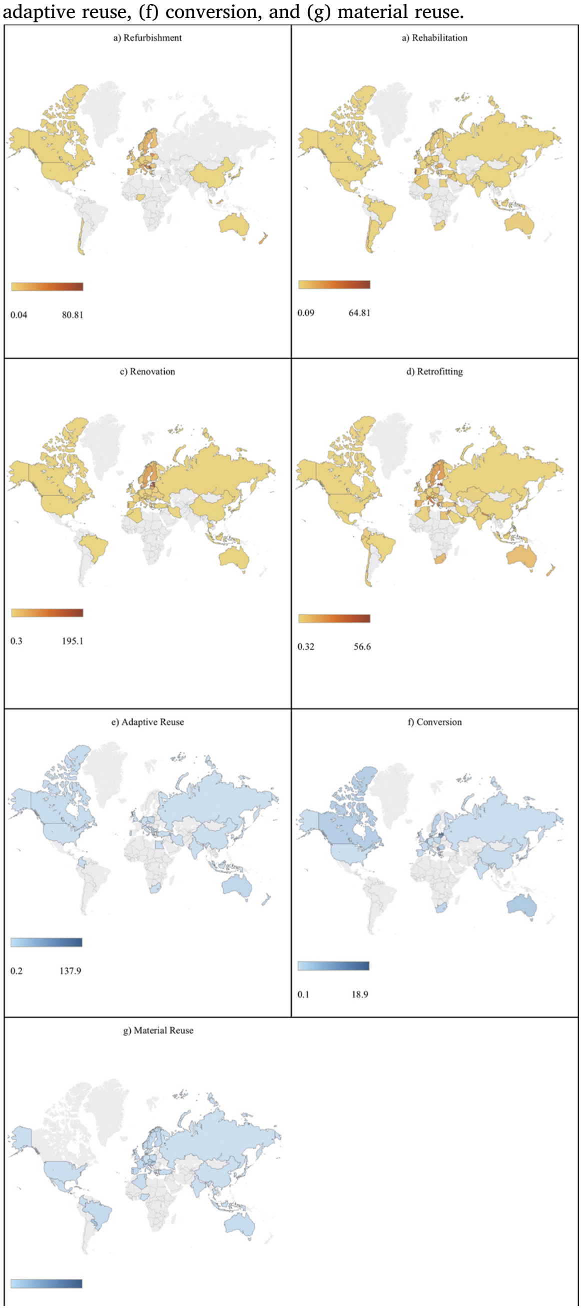
3.1. Categorization of building adaptation projects

The categorization of definitions, demonstrated in Fig. 2 and Table 4, is derived from the extended literature review conducted, analysis and comparison of terms described in detail in the following sections. A summarized description of terminology categorization in described in the following. Building refurbishment defines the process of improving the existing conditions of buildings and making improvements for the *existing use* (Hassan, Ali, Chua, & Baharum, 2017). Building retrofitting, renovation, and rehabilitation are defined as subcategories of building refurbishment. The term adaptive reuse covers the concepts of building conversion, including reusing an existing building for a *different use*, and the reuse of salvaged materials in a building for a *different use* (i.e., material reuse). Building retrofitting covers non-structural strategies, while rehabilitation always involves a structural scope. Building renovation, conversion and material reuse can involve both structural and non-structural elements. Fig. 2 illustrates a categorization of building adaptation projects. As shown in this figure, building adaptation can be subdivided into the two major categories of refurbishment and adaptive reuse. The two terms are further broken down to explain the detailed scope of refurbishment and adaptive use, respectively.

Table 1
Summary of the definition of building adaptation terminologies based on the following key refernces: **1) refurbishment:** (Ghose et al., 2017; Institute of Historic Building Conservation, 2019a; Passer et al., 2016); **2) retrofitting:** (Albatici et al., 2016; Antoine et al., 2016; Ma et al., 2012); **3) rehabilitation:** (Brás et al., 2017; Garrido et al., 2016); **4) renovation:** (Ástmarsson et al., 2013; Jensen & Maslesa, 2015); **5) adaptive reuse:** (Bullen & Love, 2011; Conejos et al., 2011; Langston et al., 2008); **6) conversion:** (Purwantiasning et al., 2013; Živković et al., 2015), **7) material reuse:** (Kralj & Markic, 2008; Park & Tucker, 2017).

Category	Definition	Scope	Advantages	Key References
Refurbishment	Building refurbishment is the process of improving the existing conditions of a building for the *existing* use. It can include the restoration of the previously acceptable conditions or making improvements to the existing systems, including the addition of energy-efficient strategies and renewable energy production.	● Repair ● Maintenance ● Building Upgrade ● Energy Efficiency	● Reducing the life cycle impact of existing buildings	(Ghose et al., 2017; Institute of Historic Building Conservation, 2019a; Passer et al., 2016)
Retrofitting	Building retrofitting involves the addition or upgrading of an existing building with features or capacities that it was not initially constructed with, to improve energy use and efficiency. Retrofitting focuses mainly on improvements to the envelope, systems and the addition of renewable energy sources.	● Energy Efficiency ● Building Envelopes ● Replacing HVAC Systems ● Addition of Renewables	● Improving energy efficiency ● Improving occupant comfort	(Albatici et al., 2016; Antoine et al., 2016; Ma et al., 2012)
Rehabilitation	Building rehabilitation involves the process of repairing, altering, or adding to a deteriorating building to make it compatible for use. Rehabilitation always involves elements that are damaged or deteriorating, and often includes the structure but can involve system, building openings and envelope.	● Damaged structures ● Deteriorating systems, envelope and openings	● Avoiding demolition ● Increasing building safety ● Extending the life cycle of buildings	(Brás et al., 2017; Garrido et al., 2016)
Renovation	Renovation is the process of replacing or fixing the outdated components or remodeling the interior spatial layout of existing buildings.	● Remodel ● Energy efficiency ● Aesthetic appearance ● Interior design	● Improving appearance and occupant comfort ● Restoring energy efficiency	(Ástmarsson et al., 2013; Jensen et al., 2018)
Adaptive Reuse	Adaptive reuse is the process of reusing an obsolete and derelict building by changing its function and maximizing the reuse and retention of existing materials and structures.	● Change the function of buildings ● Rehabilitation ● Renovation ● Retrofitting ● Material reuse	● Preventing demolition/decreasing waste ● Increasing economic/social performance	(Bullen & Love, 2011; Conejos et al., 2011; Langston et al., 2008)
Conversion	Building conversion is the strategy of adapting obsolete and abandoned buildings that do not satisfy their users or are not used anymore by changing their function.	● Change the function of buildings ● Rehabilitation ● Renovation ● Retrofitting	● Decreasing material use and greenhouse gas emission ● Increasing living quality	(Purwantiasning et al., 2013; Živković et al., 2016)
Material Reuse	Material reuse is the process of partially repairing or refurbishing recovered materials from existing buildings to use them more than once for different purposes.	● Recover and reuse existing materials	● Minimizing waste ● Decreasing material and energy use	(Kralj & Markic, 2008; Park & Tucker, 2017)

Table 2
Number of published articles in countries demonstrated per one trillion dollars of GNP: (a) refurbishment, (b) rehabilitation, (c) retrofitting, (d) renovation, (e) adaptive reuse, (f) conversion, and (g) material reuse.



3.2. Definition of terminologies

An overview of the scope involved in each terminology is represented visually in Table 4. All terminologies are separated by the identified categories of refurbishment and adaptive reuse. For each terminology, examples are provided for each applicable area of improvement. The existing and adapted building condition is demonstrated for each example, with the applicable demolition scope of each highlighted in red.

3.2.1. Refurbishment

Building refurbishment is defined as the process of improving the existing conditions of a building and may include the addition of elements for the improvement of energy efficiency (Table 4). Refurbishment can be used to address a range of scopes, including maintenance, repair work, and alteration (Institute of Historic Building Conservation, 2019a). Refurbishment is mainly involved in improving the environmental and operating costs of existing buildings. Increasing insulation and window replacements are highlighted as the most common refurbishment strategies, followed by mechanical system upgrades and changes to the building, including window-wall ratio and structure (Table 3).

Incorporating energy-efficient mechanisms, including thermal improvements to the building envelope, and improving system performance, covers the most common definition of building refurbishment in the literature. These strategies can include thermal recladding, reglazing, alteration of wall-window ratio, incorporating new HVAC systems and technologies, and providing electrical upgrades (Ghose, Mclaren, Dowdell, & Phipps, 2017; Kamaruzzaman, Lou, Zainon, Mohamed Zaid, & Wong, 2016; Passer et al., 2016; Sesana, Grecchi, Salvalai, & Rasica, 2016). These changes have direct improvements in overall energy usage, amongst other benefits such as improved building quality and aesthetics (Lidberg, Olofsson, & Trygg, 2016). Building refurbishment can additionally refer to the addition of active systems, such as renewable energy production (Brandão de Vasconcelos, Cabaço, Pinheiro, & Manso, 2016) and the addition of passive systems including solar shades (Ghose et al., 2017; Passer et al., 2016).

Other approaches to the definition of refurbishment work include the scope of building repair work, renovations and alterations, and structural rehabilitation in addition to making environmental improvements. Building refurbishment projects can be divided into three categories to include minor, medium and major refurbishment works. Minor refurbishment considers the next five years and involves maintenance and repair objectives that are economically justified within this shorter time frame. Medium refurbishment considers the extension of the economic life of the building by 15 years and involves the improvement of building finishes and services and excludes structural repairs. Major refurbishment considers the life of the building beyond 15 years and involves significant alterations to an existing building, including structural, to make it comparable to a newly constructed building (European Commission, 1998; Hassan et al., 2017).

The focus of building refurbishment can be summarized as reducing the life cycle impact of existing buildings (Schwartz, Raslan, & Mumovic, 2016). Building refurbishment is the umbrella term of retrofitting, rehabilitation and renovation, which are futher explored in this paper as various facets. Retrofitting involves the addition of new materials and elements that were not part of the existing building in order to bring about environmental efficiencies. Rehabilitation addresses the need to improve the failing aspects of an existing building, mainly involving the structure (Vilches, Garcia-Martinez, & Sanchez-Montañes, 2017). Building renovation work focuses on the aesthetic aspects of refurbishment and can include structural or non-structural improvements.

3.2.1.1. Retrofitting. Existing buildings make up the largest portion of the built environment, with a major segment built before energy conservation considerations (Albatici, Gadotti, Baldessari, & Chiogna, 2016; Paradis, 2012) and hence are not compatible with modern standards of energy efficiency (and comfort). A large portion of the existing building stock is, therefore, in need of reconstruction. In the existing building stock, 50 % of energy used is spent on space heating and cooling and more than 15 % is spent on water heating (Pasichnyi, Levihn, Shahrokni, Wallin, & Kordas, 2019). Therefore, the reduction of space heating and cooling demand, and the introduction of active energy generation can contribute positively to the reduction of carbon dioxide emissions from buildings. Heat loss in buildings through walls, roofs and floors as well as glazed areas results in 60 % of energy use in a typical building. Most of this energy is lost because of a lack of adequate insulation; therefore, the addition of thermal insulation is highlighted as one of the most efficient strategies in retrofitting (Garay, Arregi, &

Table 3
Summary of literature review for building refurbishment, rehabilitation, retrofitting, renovation, adaptive reuse, building conversion, and material reuse. The reviewed literature include: **1) refurbishment:** (Ali et al., 2018; Brandão de Vasconcelos et al., 2016; Ghose et al., 2017; Kamaruzzaman et al., 2016a; Lidberg et al., 2016; Passer et al., 2016; Schwartz et al., 2016a; Sesana et al., 2016; Vilches et al., 2017); **2) rehabilitation:** (Abbas et al., 2018; Alba-Rodríguez et al., 2017; C. P. Almeida et al., 2018a; Almeida et al., 2015; Alonso et al., 2017; Brás et al., 2017; Brás & Gomes, 2015; Garrido et al., 2016; Saez & Shivanagari, 2019; Thibodeau et al., 2019); **3) retrofitting:** (Albatici et al., 2016; Antoine et al., 2016; Ferrari & Zagarella, 2015; Garay et al., 2017; Hagentoft, 2017; Mata et al., 2018; Mauro et al., 2015; Pardo-Bosch et al., 2019; Pasichnyi et al., 2019; Raimondi et al., 2016); **4) renovation:** (Andrić et al., 2017; Dalla Mora et al., 2018; Ding et al., 2019; Ferrari & Zagarella, 2015; Fotopoulou et al., 2018; Helander & Singh, 2016; Mateus et al., 2019; Milić et al., 2019; Per et al., 2018; Ramírez-Villegas et al., 2019; Serrano-Jimenez et al., 2017; Thomsen et al., 2015); **5) building conversion:** (Chan et al., 2015b, 2015c, 2015a; Cianci & Molinari, 2018; Ojikpong et al., 2016; Petković-Grozdanovića et al., 2016; Ren et al., 2015; Wadu Mesthrige et al., 2018b; Živković et al., 2016); **6) adaptive reuse:** (Al-Obaidi et al., 2017; Celadyn, 2019; Dewiyana et al., 2016; Günçe & Misirlisoy, 2019; Haidar & Talib, 2015; Li et al., 2018; Louw, 2016; Remøy & Wilkinson, 2012; Rodrigues & Freire, 2017; Sanchez & Haas, 2019; Tam & Hao, 2019); **7) material reuse:** (Cruz Rios et al., 2019; Diyamandoglu & Fortuna, 2015; Hosseini et al., 2015; Kozminska, 2019a; Ng & Chau, 2015; Nußholz & Whalen, 2019; Park & Tucker, 2017; Rose & Stegemann, 2018; Sakaguchi et al., 2016; Sanchez & Haas, 2018).

	Reference	*Focus*																										
		Sustainability				Material Reuse/ Recycle				Building Envelope					Building MEP			Building Structure		Change of Function						Waste/ Material Management		
		Environmental	Economic	Social	Policy	Challenges/Barriers	Strategies to Maximize	Potentials	Deconstruction	Cladding Replacement	Window Replacement	Insulation Improvement	Solar Shading Integration	Energy Transfer Ratio	HVAC	Lighting/Electrical	Active Systems	Structural Reinforcement	New Structure Addition	Industrial to Residential	Industrial to Commercial	Other to Residential	Commercial to Other	Other to Other	Other to Commercial	Waste Management	Reuse	Recycle
Refurbishment	(Vilches et al., 2017)	●									●	●			●													
	(Passer et al., 2016)	●									●	●																
	(Schwartz et al., 2016)	●	●								●	●		●														
	(Ali et al., 2018)	●	●									●		●		●		●										
	(Ghose et al., 2017)	●									●	●	●	●	●	●												
	(Kamaruzzaman et al., 2016)	●										●			●	●												
	(Sesana et al., 2016)	●									●	●			●													
	(Lidberg et al., 2016)	●										●			●													
	(Brandão de Vasconcelos et al., 2016)	●	●								●	●																
Rehabilitation	(Saez & Shivanagari, 2019)																									●		
	(Thibodeau et al., 2019)																									●		
	(Alba-Rodríguez et al., 2017)	●	●								●							●								●		
	(Garrido et al., 2016)																	●										
	(Brás et al., 2017)			●														●										
	(C. P. Almeida et al., 2018)																									●		
	(R. Almeida et al., 2015)	●	●								●																	
	(Brás & Gomes, 2015)	●										●						●										
	(Alonso et al., 2017)	●								●									●									
	(Abbas et al., 2018)		●															●	●									
Retrofitting	(Albatici et al., 2016)	●	●	●							●	●			●		●											
	(Antoine et al., 2016)	●		●							●	●			●		●											
	(Mata et al., 2018)	●	●								●	●			●	●												
	(Pasichnyi et al., 2019)	●	●								●	●			●	●												
	(Raimondi et al., 2016)	●									●	●	●	●	●	●			●									
	(Ferrari & Zagarella, 2015)	●	●								●	●			●	●	●											
	(Garay et al., 2017)	●									●	●																
	(Pardo-Bosch et al., 2019)	●	●								●	●			●	●	●											
	(Hagentoft, 2017)	●									●	●																
	(Mauro et al., 2015)	●	●								●	●	●		●													
Renovation	(Helander & Singh, 2016)	●																										
	(Jensen et al., 2018)	●									●	●			●	●												
	(Ferrari & Zagarella, 2015)	●	●								●	●		●	●											●		
	(Thomsen et al., 2015)	●		●						●	●	●			●			●										
	(Andrić et al., 2017)	●									●	●																
	(Serrano-Jimenez et al., 2017)	●								●	●	●			●													
	(Dalla Mora et al., 2018)	●	●								●	●			●	●		●										
	(Ding et al., 2019)																									●		
	(Fotopoulou et al., 2018)	●								●																		
	(Mateus et al., 2019)	●	●								●	●		●	●		●											
	(Milić et al., 2019)		●								●	●																
	(Ramírez-Villegas et al., 2019)										●	●			●													
Building Conversion	(Živković et al., 2015)	●	●	●																		●						
	(Wadu Mesthrige et al., 2018a)			●																●								
	(Ren et al., 2015)		●		●																●							
	(Chan et al., 2015a)		●	●																●	●							
	(Chan et al., 2015b)			●	●															●	●							
	(Chan et al., 2015c)				●															●	●							
	(Ojikpong et al., 2016)		●	●																					●			
	(Petković-Grozdanovića et al., 2016)																			●								
	(Cianci & Molinari, 2018)			●																		●						
Adaptive Reuse	(Günçe & Misirlisoy, 2019)	●	●	●																				●				
	(Sanchez & Haas, 2019)	●	●																				●					
	(Li et al., 2018)		●		●															●	●							
	(Tam & Hao, 2019)	●	●	●																				●				
	(Remøy & Wilkinson, 2012)	●	●		●																	●						
	(Haidar & Talib, 2015)		●		●																			●				
	(Dewiyana et al., 2016)	●																		●								
	(Rodrigues & Freire, 2017)	●	●																						●			
	(Al-Obaidi et al., 2017)	●		●																					●			
	(Louw, 2016)	●	●	●																	●							
	(Celadyn, 2019)	●																						●				
Material Reuse	(Park & Tucker, 2017)						●	●																			●	
	(Hosseini et al., 2015)	●	●	●		●	●	●																			●	●
	(Cruz Rios et al., 2019)	●				●																					●	
	(Diyamandoglu & Fortuna, 2015)	●	●						●																		●	
	(Rose & Stegemann, 2018)							●	●																		●	●
	(Sakaguchi et al., 2016)								●																		●	
	(Kozminska, 2019)						●		●																		●	
	(Nußholz & Whalen, 2019)		●				●		●																		●	
	(Ng & Chau, 2015)	●							●																		●	●
	(Sanchez & Haas, 2018)	●	●																								●	

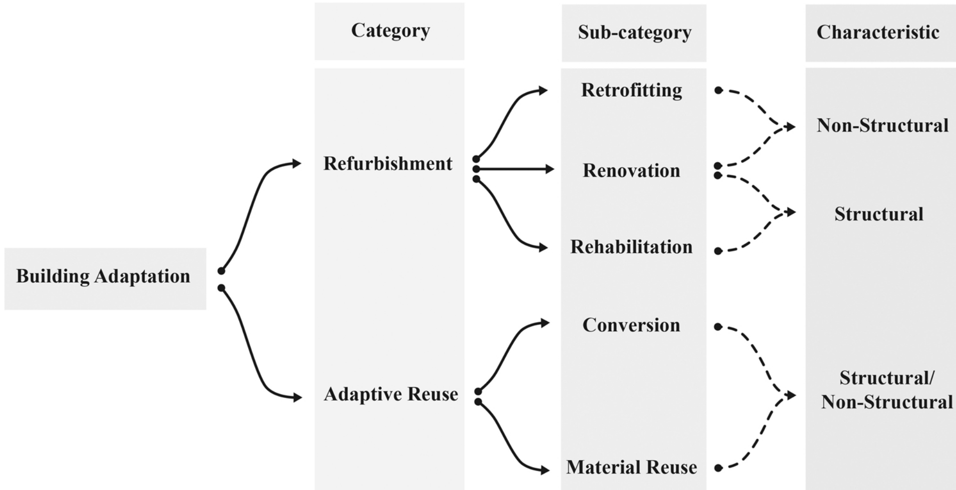
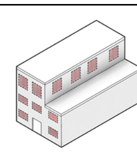
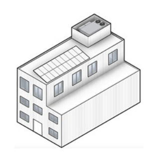
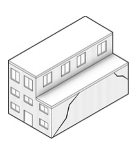
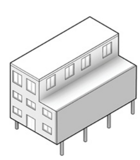
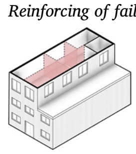
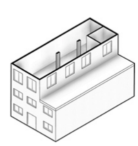
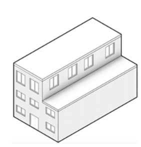
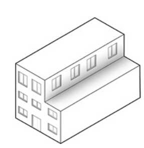
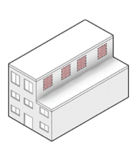
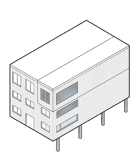
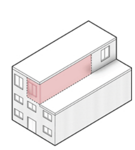
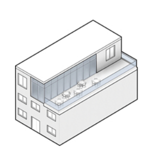
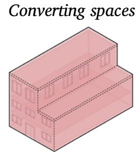
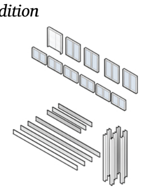
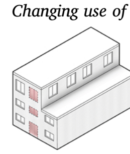
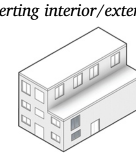


Fig. 2. Breakdown of Building Adaptation in Two Categories of Refurbishment and Adaptive Reuse. Each of the categories are divided into the subcategories of Retrofitting, Renovation, Rehabilitation, Conversion and Material Reuse, tagged by their structural characteristic.

Elguezabal, 2017).

Building retrofitting can be defined as a subcategory of building refurbishment, with a focus on additions to the existing building for improving energy efficiency and performance. Retrofitting activities involve the following categories: reducing heating and cooling demands, improving HVAC efficiency, and integrating active and renewable energy systems. Building retrofits, therefore, involve the addition or upgrading of an existing building with features or capacities that

Table 4
Scope of application associated with different subcategories of building refurbishment and adaptive reuse.

Adaptation Terminology		Structural Improvements		Other Improvements	
		Existing Building	Adapted Building	Existing Building	Adapted Building
Refurbishment	Retrofitting	——	——		
				Replacing windows, increasing insulation and addition of renewable energy sources and efficient HVAC	
	Rehabilitation			——	——
		Reinforcing of failing structuring			
	Renovation				
		Changing the interior layout, replacing walls with columns		*Replacing exterior cladding*	
Adaptive Reuse	Conversion				
		Converting spaces through an addition		*Changing use of the building and converting interior/exterior spaces*	
	Material Reuse				
		Demolition and retrieval of salvageable materials for reuse in other structures		*Removal and reuse of building materials in the same building*	

were not included in initial construction (Table 4) (Antoine, Antoine, & Rofaïda, 2016; Eames et al., 2014; Imaz, 2019; Institute of Historic Building Conservation, 2019b; Ma, Cooper, Daly, & Ledo, 2012).

Retrofitting involves a balance of various elements to achieve optimal results. Retrofitting is highly efficient when a whole building strategy is examined but can also be comprised of singular strategies or strategies phased throughout several years. Retrofitting of buildings includes passive and active strategies. Insulation of walls, roofs and floors, the addition of more efficient windows or green roofs on existing buildings, draught-proofing of fenestrations, and installation of more energy-efficient doors and windows are examples of passive building retrofitting strategies (Ferrari & Beccali, 2017; Kamaruzzaman et al., 2016; Passer et al., 2016; Sesana et al., 2016). Installation of new or more efficient heating or cooling systems, solar panels lighting control systems (e.g., sensors and LED lighting), high-efficiency mechanical systems, smart controls and metering systems for building management systems, and upgrading of piping systems are examples of active retrofitting strategies.

Retrofitting measures aim at reducing operative energy demand, and the reduction of lighting loads is becoming increasingly important, particularly the effect of natural daylighting optimization (Raimondi, Santucci, Bevilacqua, & Corso, 2016). Other examples include the addition of cooling systems or replacement with in-ground or passive cooling strategies, the addition of renewable energy systems, including photovoltaics and geothermal heating, and reduction of water use, including efficient water fitting and smart controls (Albatici et al., 2016; Brandão de Vasconcelos et al., 2016; Institute of Historic Building Conservation, 2019b). Inclusion of passive systems and technologies including smart metering systems and intelligent occupant controls for improvement of occupant comfort as well as improvements to the energy efficiency of the building, is also part of retrofitting (Albatici et al., 2016).

Benefits of retrofitting include reduced dependence on energy sources, improvements to indoor air quality and comfort, and reduction of global warming potential. Other benefits include a reduction in maintenance and repair costs and overall improved socio-economic well-being of the existing building stock (Pardo-Bosch, Cervera, & Ysa, 2019). In the process of retrofitting, costs and payback regarding each strategy ultimately lead to a feasibility assessment and decision making process (Albatici et al., 2016). Barriers to retrofitting include a lack of understanding of benefits and access to reliable information and financial models. These include high costs, risk management and long pay-back periods, amongst others. Other identified obstacles include the complexity involved in large-scale retrofitting projects, lack of clear definitions and scopes, and lack of expertise in the industry (Pardo-Bosch et al., 2019). The large-scale implementation of energy efficiency strategies can be extended to include "multi-system nexus," life cycle improvements and socio-economic well-being (Pasichnyi et al., 2019). Active retrofitting options that include systems upgrades and mechanical systems are highlighted as more most effective compared to passive strategies involving the building envelope (Ferrari & Beccali, 2017).

In contemporary retrofitting projects, it is essential to consider net-zero strategies and the importance of limiting waste to landfills (Ferrari & Beccali, 2017). An important aspect of the proliferation of retrofitting projects lies in the reduction of risks and uncertainties. The retrofitting strategies studied include insulation of walls and attics, heating systems, the addition of smart monitoring systems and photovoltaic panels (Pardo-Bosch et al., 2019). The importance of integrated evaluation of not only energy efficiency but life cycle costs, quality of materials, and overall durability, is paramount. While some strategies can provide instant reductions in energy demands, they might have demanding life-cycle costs and effects such as increased global warming potential. Therefore, careful consideration regarding life cycle implications and costs are required (Hagentoft, 2017).

3.2.1.2. Rehabilitation. Rehabilitation typically involves the repair and restoration of basic systems and the structure of a deteriorating building to the status of a previously acceptable condition. Rehabilitation is therefore undertaken to make a building compatible with continued use. The scope of work for a rehabilitation project refers to strengthening or replacing deteriorating or damaged structural elements, repairs to the building envelope, roof and openings. For mechanical and electrical systems in a building, parts are either replaced or entire systems are rebuilt. In the process of a rehabilitation project, building systems are updated to local codes and necessary adjustments are made (Coffey, 1994). Building rehabilitation can include structural strengthening or replacement of structural components (Garrido, Correia, Keller, & Branco, 2016). Rehabilitation work at the scale of the building envelope is focused on reducing discomfort due to relative humidity, air and water leakage, and structural failures (Brás, Valença, & Faria, 2017) (Table 4).

The focus of rehabilitation projects is mainly on structural measures, as well as waste management strategies, including recycling and reusing materials. Rehabilitation is often not concerned with the improvement and replacement of building systems. Also, rehabilitation is not typically focused on building envelope improvements, while the scope of window or cladding replacement can overlap with the need for structural rehabilitation. Rehabilitation is equally focused on environmental and economic benefits while addressing social benefits (Table 3).

The management of the construction and demolition waste in rehabilitation work is highly important. In the process of rehabilitation, the two main activities conducted are the dismantling of troubled areas, and remediation and new construction work (Sáez & Osmani, 2019). The scope of building rehabilitation projects can include direct rehabilitation of the structure and the combination of rehabilitation with other refurbishment strategies and the integration of new construction (Thibodeau, Bataille, & Sié, 2019).

The rehabilitation efforts defined here focus on structural repairs that will make buildings safe and habitable. In order to determine the viability of a rehabilitation project, both economic and life cycle assessments are compared to the option of demolition and new construction (Alba-Rodríguez, Martínez-Rocamora, González-Vallejo, Ferreira-Sánchez, & Marrero, 2017). Rehabilitation work is most influential for improving the environmental life cycle due to the prevention of demolition (Thibodeau et al., 2019). The environmental impact of rehabilitation of a failing structure is estimated to be approximately 60 % less than demolition and new construction (Alba-Rodríguez et al., 2017). Furthermore, rehabilitation of old buildings is regarded as a way to prevent de-population in urban centers and to prevent abandonment of old buildings (Almeida, Ramos, & Silva, 2018).

3.2.1.3. Renovation. According to the literature shown in Table 3, the term building renovation is most commonly used in European countries. The definition of building renovation and the scope of the activities associated with renovation varies across countries. For example, in Austria and Switzerland, renovation is recognized as a range of simple maintenance and modernization works for improving occupant comfort. In Finland, building renovation is focused on renewing the heating systems of the existing buildings to fix damaged components and improve occupant comfort. In France, the majority of renovation projects are dedicated to improving existing energy efficiency measures of buildings that have degraded over their lifecycle. These renovations include renewing the building envelope's insulation, replacing windows with double glazed ones and fixing HVAC systems. Renovation activities in Germany are usually conducted to meet market demands, to make buildings more attractive for users, or to address building shortfalls acknowledged by building inspecting officials. In Sweden, the main trend of renovation projects is to repair or replace the heating systems, water management and sewage systems, and electrical systems of existing buildings to restore them to their original conditions (Itard & Meijer, 2008; Vainio, Kotala, Rakkolainen, & Kupila, 2002).

Based on the various scopes of renovation projects studied, renovation can be defined as the process of replacing or repairing outdated components or remodeling the interior spatial layout of existing buildings. Renovation addresses conditions that are no longer economical or energy-efficient, or do not satisfy the occupants or users while keeping the function of the building intact. The goal of a renovation project is to restore a building's original conditions, or improve a building's architectural aspects and appearance for enhanced comfort levels and attractiveness (Table 4) (Ástmarsson, Jensen, & Maslesa, 2013; Jensen & Maslesa, 2015).

The majority of research studies have considered renovation projects that focus on environmental sustainability by improving the energy efficiency of the buildings (Table 3). The main problem with considering energy efficiency improvement as a strict requirement for renovations is that other focuses of building renovation include occupant comfort, architectural quality and economic feasibility (Per, Maslesa, & Berg, 2018). To address this problem, recent research studies, particularly in Sweden, have focused on the social and economic sustainability of renovating existing buildings (Thuvander et al., 2012; Vainio, 2011). Based on these findings, a building should be renovated if it no longer satisfies the requirements of energy, economic, and/or social sustainability. For example, an energy-efficient building can be renovated if its interior design does not satisfy the occupants anymore to address social sustainability or it is not economically viable, therefore jeopardizing its economic sustainability (Femenías, Mjörnell, & Thuvander, 2018).

3.2.2. Adaptive reuse

Adaptive reuse is defined as the process of extending the useful life of historic, old, obsolete, and derelict buildings. Adaptive reuse also considers new use requirements, socio-cultural demands, and environmental regulations. Adaptive reuse projects seek to maximize the reuse and retention of existing structures and fabrics as well as to improve economic, environmental, and social performance of buildings (Bullen & Love, 2011; Conejos, Langston, & Smith, 2011; Langston et al., 2008; Larkham, 2002). These characteristics makes adaptive reuse a sustainable alternative to demolition and new construction (Sanchez & Haas, 2019; Sugden & Khirfan, 2017). In summary, adaptive reuse projects have two different aspects: (1) changing the function of a building or some parts of the building, which is known as building conversion, and (2) recovering and reusing existing materials of a building, which is referred to as material reuse (Table 4). The following two sections explain the concept and scope of these terms.

3.2.2.1. Conversion. The concept of building conversion became well-known in the 1970s when many industrial buildings in the downtown cores of Western cities were abandoned due to the shift of manufacturing to developing countries. Rapid and fundamental changes in the politics of developed countries during the 20th century led to the majority of industries from developed countries moving to developing and underdeveloped countries (Chan, Cheung, & Wong, 2015; Ren et al., 2015). As a result of this movement, industrial buildings were abandoned and dilapidated over time. Thus, building conversion emerged as a sustainable alternative to reuse the abandoned industrial buildings for different purposes instead of demolition and new construction (Cantell, 2005). Building conversion became particularly common in Great Britain, France, Germany, and the United States.

Building conversion is the strategy of adapting obsolete and abandoned buildings, which do not satisfy their users or are not used anymore, by changing their function (either partially or entirely) (Purwantiasning, Mauliani, & Aqli, 2013). Building conversion is similar to building refurbishment, including a similar scope with the addition of changing the function of buildings (Table 4). Many previous studies used the term building conversion for projects that changed the function of a building from a particular type to another. Converting buildings from industrial to residential or commercial (Chan et al., 2015a; Petković-Grozdanovića, Stoiljković, Keković, & Murgul, 2016; Ren et al., 2015; Wadu Mesthrige, Wong, & Yuk, 2018), residential to commercial (Ojikpong, Agbor, & Emri, 2016), and commercial to any type (Abdullah & Will, 2015; Remøy & Wilkinson, 2012; Sanchez & Haas, 2019) are among the most popular types of conversion in the literature. A building conversion project can be guided by the following three principles: (1) selecting the new function as a long-lasting alternative, which is compatible with the users' requirements, building's characteristics and spatial layout, as well as the environmental, economic, and social characteristics of the surrounding area, (2) designing the project to be compatible with the historical background of the building, new codes, regulations, architectural and aesthetic qualities of the surrounding buildings, and (3) considering the requirements of sustainable development to enhance the sustainability performance of the building (Loures & Panagopoulos, 2007; Živković, Kurtović-Folić, Jovanović, Kondić, & Mitković, 2016).

By reusing existing buildings and preventing demolition, building conversion results in environmental advantages including (1) reducing construction waste, (2) consuming fewer natural resources and raw materials, (3) decreasing energy consumption, (4) emitting less greenhouse gases, (5) controlling urban sprawl, and (6) conserving embodied energy (Conejos et al., 2013; Langston et al., 2008; Sanchez & Haas, 2019; Yung & Chan, 2012). Regarding social advantages, building conversion can improve safety, quality of living, occupant health (Aigwi, Egbelakin, & Ingham, 2018; Shen & Langston, 2010). Building conversion can also enhance the property value of a building and its surrounding buildings, increasing the economic viability of the building, and generating 25 % more jobs per square meter (Chan et al., 2015a; Sanchez & Haas, 2019).

The scope of building conversion projects is broader than building refurbishment, and therefore faces more challenges and uncertainty. For example, owners and investors often refuse to consider conversion because of the higher risk of return on investment compared to new construction (Shipley et al., 2006). Also, the probability of cost and time overruns is higher in building conversion projects since they usually deal with vacant and old buildings that have many unknown conditions. Encountering latent defects, contamination and hazardous materials, and structural instability are examples of unknown conditions that can dramatically increase the cost and duration of these projects (Bullen, 2007).

As such, a series of regulatory challenges must be addressed, particularly regarding heritage buildings. Regulatory challenges include obtaining required permissions to change the function of a building, satisfying the requirements of building code regulations, and complying with laws and regulations regarding heritage buildings. According to the literature, the process of obtaining required permissions and certificates to start a building conversion project could double the project time and increase the cost by 30 % (Yung & Chan, 2012). Furthermore, several technical and functional challenges should be considered (Bullen, 2007). For example, changing the interior spatial layout or exterior appearance of a building can be limited by the structural layout therefore limiting the range of new functions that can be considered for the building.

3.2.2.2. Material reuse. The construction industry is responsible for 40 % of global resource consumption (Pacheco-Torgal et al., 2014) and is the main contributor of waste generation (Zhao, Dai, Lin, & Tang, 2010). The scarcity of natural resources required to produce new materials (Cruz Rios, Grau, & Chong, 2019) and high amounts of waste generation (Park & Tucker, 2017) are two serious threats facing industries in general, and the construction industry in particular. Waste management is a sustainablity strategy that helps reduce the amount of resource consumption and waste generation by maximizing the recovery of waste materials and minimizing landfill disposal as much as economically and technically possible. This strategy is focused primarily on reducing the amount of material consumption, and then reusing or recycling existing materials (Kralj & Markic, 2008; Park & Tucker, 2017).

The definitions of these terms (i.e., reduce, reuse, and recycle) in the context of the construction industry are highlighted. Reduce is defined as the decrease in the use of construction materials during new construction or building adaptation projects. Achieving this goal requires improving the performance of materials during the production phase, as well as the strategies of building design and construction by leveraging new technologies and tools (e.g., building information modeling (BIM) in the design stage, and off-site prefabrication for construction stage) (Thomsen, Rose, Morck, Jensen, & Østergaard, 2015). Reducing material use is mainly associated with the process of new construction or with a new addition during a building adaptation project.

Material reuse and recycling are closely related to the building end of life (i.e., demolition or deconstruction). Since building demolition and adaptation both contribute to waste generation (Diyamandoglu & Fortuna, 2015), material reuse and recycling apply to both kinds of projects. Reuse is defined as the process of partially repairing or refurbishing recovered materials to use them more than once for different purposes (Kralj & Markic, 2008; Park & Tucker, 2017). The recovered materials can be reused as if their condition is satisfactory for new purposes. The recovered materials from a building can be either reused in the same building during the building refurbishment or adaptive reuse or be sent to a market place to be sold and reused in different projects either within or oustide the construction industry (Table 4). The latter approach is considered when adapting a building is not valuable and the building is demolished (De Brito & Dekker, 2004; Hosseini, Rameezdeen, Chileshe, & Lehmann, 2015).

Recycling aims to convert waste materials into new materials or objects through comprehensive remanufacturing (Kralj & Markic, 2008). Although recycling has received more attention in the construction industry to date, and the recycling rates of some construction materials has risen above 90 %, the problems associated with natural resource consumption and construction waste production are not entirely mitigated. Recycling rates are based on the amount of waste sent to recycling companies rather than the actual amount of recycled materials (Rose & Stegemann, 2018). Even if the recycling rate is representative, recycling is not the most sustainable approach in waste management since it is still highly wasteful and usually decreases the quality of materials. In other words, materials entail a loss of utility after recycling. Energy and natural resource consumption, pollution generation, and greenhouse gas emissions are less for reuse. In addition, reusing materials saves more costs by consuming less energy and resources, provides revenue from selling used materials, and does not down-cycle the materials (Kralj & Markic, 2008; Roussat, Dujet, & Mehu, 2009). For example, a lumber beam can still be reused as a beam after recovery, while the beam would be chipped for producing chipboards during a recycling process, which have less utility than a lumber beam (Rose & Stegemann, 2018). Hence, recycling should be considered only when material reuse is not possible (Stahel, 2016).

While material reuse has many advantages, several technical and organizational barriers make its implementation in the construction industry difficult. Technical barriers include a lack of design of existing buildings for easy deconstruction and disassembly (Durmisevic & Binnemars, 2014; Tingley & Davison, 2012), requiring excessive time and labor compared to demolition, having the risk of encountering contaminated materials during deconstruction (Hosseini et al., 2015), uncertain quality of recovered materials (Coelho & de Brito, 2011), large sizes and heavy weights of construction materials, which limits their mobility, and unique conditions of each building for disassembly (Kibert, 2016). Other challenges and organizational barriers to reuse include a lack of effective regulations for promoting material reuse (Durmisevic & Binnemars, 2014), a lack of financial support from governmental agencies (e.g., municipalities) (Kozminska, 2019; Nußholz & Whalen, 2019), the low cost of material disposal that makes it more economical option in light of higher initial cost of material reuse (Coelho & de Brito, 2011), the necessity of having a suitable on-site storage for storing the recovered materials (Denhart, 2010), and a lack of robust and practical marketplaces (salvage yards) to accommodate selling and buying recovered materials (Rose & Stegemann, 2018).

There are strategies highlighted in the literature that allow stakeholders involved in the construction industry to eliminate barriers and promote material reuse: (1) designers can consider the requirements of design for deconstruction and disassembly and try to maximize the reuse of recovered materials; (2) builders can implement novel methods and technologies during construction and deconstruction to facilitate reusing recovered materials and disassembling used ones, respectively; and (3) policymakers can make reuse of materials economically competitive by increasing the costs of material disposal, provide financial incentives to accommodate material reuse, and legislate facilitating regulations to promote deconstruction and incorporation of recovered materials in new construction (Hosseini et al., 2015; Kralj & Markic, 2008; Kühlen, Volk, & Schultmann, 2016; Park & Tucker, 2017; Rose & Stegemann, 2018).

3.3. Definition framework

Based on the comprehensive literature review analysis and the categorization conducted for building adaptation terminologies, a definition framework was developed to facilitate identifying the type of terminologies involved in adaptation projects (Fig. 4). Within this framework, it is possible to include aspects of refurbishment in all building adaptation projects. Building adaptation projects can, therefore, be defined as ranging from being exclusively refurbishment focused, to containing a combination of multiple adaptive reuse and refurbishment strategies. The framework first determines if the building under study is undergoing a change of use, and then determines the inclusion of material reuse. After determining the primary category of building adaptation definition, the framework further breaks down refurbishment into it multiple sub-categories. The framework considers aspects of improvement for each subcategory, including structural and energy use improvements, to suggest more detailed definitions.

4. Case study analysis

The definition framework is validated through functional demonstration on several building adaptation case studies. As a sample, the scope of one of these case studies and adaptation strategies considered during adaptation is explained comprehensively and the application of the framework is demonstrated by identifying the type of adaptation terminologies involved in the case study. The steps taken to use the framework are summarized in Table 5.

The transformation of 530 dwellings was completed as a part of a more substantial development to transform existing inhabited social buildings in Bordeaux, France. The existing buildings were built in the early 1960s. In the adaptive reuse and extension of this project, winter gardens and expanded balconies were added in order to primarily improve the overall quality of each unit in terms of the improved building envelope, light, use and views (Fig. 3). This project was successful in terms of physical and economic transformations to an existing building while transforming it into suitable and desirable living units with improved environmental and comfort performance and context relevance (Lacaton, Vassal, & Abalos, 2011). In order to maximize natural daylighting, large windows were added to the south façade as well as an extension to add winter gardens and balconies to all the units. There were no significant structural activities done to the existing building, and a separate new external structure was built to support the new building envelope, winter gardens and balconies.

Table 5
Steps for using the developed definition framework for the case study.

Steps	Question	Answer
1	Are there any **Improvements** made to the building in terms of structure, energy use, and/or architecture (spatial layout, organization or aesthetics)?	**Yes.**
2	Are there any aspects of **Reuse** involved in the project, including change of use or reuse of materials?	**Yes.** Balconies added and existing balconies changes to winter gardens. The building was partially *Converted.*
3	Are any of the **Materials** reused?	**No.** There is no *Material Reuse* in this project.
4	The two primary categories of ***Refurbishment*** and ***Adaptive Reuse*** are involved in this Building Adaptation project.	
5	Is the existing **Structure** altered or enhanced?	**No.** There is no *Rehabilitation* in this project.
6	Are there **Energy Efficiency** measures implemented?	**Yes.** Improved glazing and insulation have been added. The building is *Retrofitted.*
7	Are there any **Architectural** improvements implemented?	**Yes.** The entire building has been re-clad, the entrance and lobby have been improved, the aesthetic quality of the entire building has been improved. The building is *Renovated.*
8	Has the **Function** of the building changed?	**Yes.** Balconies were added and existing balconies changes to winter gardens. The building was partially *Converted.*
9	The secondary definitions of ***Retrofitting, Renovation*** and ***Conversion*** apply to this Building Adaptation project.	

As shown by the application of the definition framework in Fig. 4, and as summarized in Table 5, this adaptation project can be categorized as a combination of adaptive reuse and building refurbishment. Building conversion is the applicable subcategory of adaptive reuse, and retrofit and renovation are the relevant subcategories of building refurbishment that were involved in this project. The same procedure (reviewing the scope and adaptation strategies of the project and identifying the adaptation terminologies) was conducted for other case studies. These results are summarized in Table 6.

5. Discussion and conclusion

Many different terminologies are used in the literature and in industry to specify the scope of building adaptation projects, but not always consistently. This research found that the terms refurbishment, retrofitting, rehabilitation, renovation, adaptive reuse, and material reuse have been used commonly over the past five years (2015–2020). To enable clear and consistent use of building adaptation terms moving forward, this paper contributes a definition framework based on a comprehensive literature review of peer-revied journal articles and conference proceedings. It is expected that the developed definition framework can be used as a reference in academia and the industry to clearly and consistently defining the scope of work of various types of building adaptation projects, with the aim of minimizing the shortcomings of the current overlaps and confusions in applying definitions to a certain scope. The expected benefits from a coherent and consistent reference for terminology related to building adaptation include cost savings and improved efficiency from consistent codes, specifications and project descriptions that would otherwise lead to confusion and redundancies.

At a high-level, we distinguish adaptive reuse from refurbishment by a change in a building's function or use. Adaptive reuse then encompasses building conversion and material reuse, whereas refurbishment encompasses retrofitting, rennovation, and rehabilitation. Most of

Fig. 3. Transformation of 530 Dwellings is an adaptation of three 1960s housing blocks (Ruault, 2019).

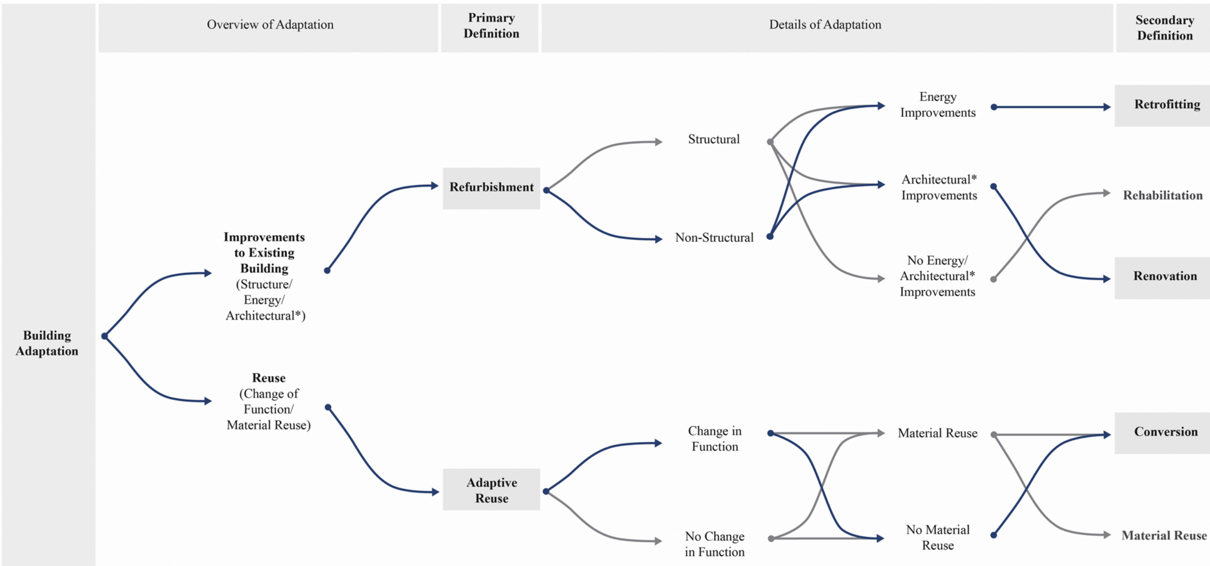
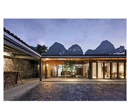


Fig. 4. Definition Framework for Determining the Scope of a Building Adaptation Projects - A combination of any of the different illustrated paths can be applied to a building adaptation project. The 530 dwellings project illustrated in Fig. 3 and Table 5 is used as a demonstration.
⟶ Demonstration of definition of scope of 530 dwellings in Bordeaux, France.
⟶ All other options not applicable to 530 dwellings in Bordeaux, France.
**Architectural improvements include: spatial (i.e. layout, organization, etc.) and aesthetic (i.e finishes, coverings, etc.) improvements.*

Table 6
Demonstration of developed definition framework in multiple building adaptation case buildings. [Image references: (Arban, 2010, 2019; ERA Architects, 2019; Imaz, 2019; Yuyang, 2019)].

Case Study		Adaptation Scope	Terminologies
	**The Senate of Canada Building** Ottawa, Canada 2019 Diamond Schmitt Architects + KWC Architects (Arban, 2019)	• Train station to a government building • Material reuse • Replaced windows • Increased energy efficiency • Rehabilitated structure • Remodeled and constructed interior spaces	• Refurbishment: Rehabilitation Renovation Retrofit • Adaptive Reuse: Conversion Material Reuse
	**Canadian Museum of Nature in Ontario** Ottawa, Canada 2010 KPMB Architects (Arban, 2010)	• No change in use • No material reuse • Renovated the interiors • Structural improvements • Improved building performance • Added new spaces • Enlarged windows to improve daylighting	• Refurbishment: Rehabilitation Renovation Retrofit
	**Advertising Office** Madrid, Spain 2019 C asa Josephine Studio (Imaz, 2019)	• Motorcycle workshop to office • No material reuse • No structural improvements • Interior remodeling	• Refurbishment: Renovation • Adaptive Reuse: Conversion
	**Ken Soble Tower** Hamilton, Canada 2021 ERA Architects (ERA Architects, 2019)	• No change in use • No material reuse • Recladding of façade and adding insulation • Replaced elevators and HVAC systems • Replaced all windows • Removed balconies	• Refurbishment: Renovation Retrofit
	**XY Yunlu Hotel** Guangxi, China 2019 Atelier Liu Yuyang (Yuyang, 2019)	• Farmhouse to a hotel • No material reuse • Structural improvement • Renovated building interior • Improved daylighting with larger windows	• Refurbishment: Rehabilitation Renovation • Adaptive Reuse: Conversion

these project scopes can include structual and non-structural modifications, except for retrofitting, which is limited to non-structural changes, and rehabilitation, which is limited to structural changes.

It is not surprising that these terms could be confused or used interchaneagably, as they share subsets of various activities: replacing, adding, repairing, remodeling, reusing, and changing use. Moreover, the activities performed within refurbishment projects are a subset of those performed within conversion projects, which additionally include change of use, all of which can take place in conjunction with material reuse during adaptive reuse projects. Finally, the details of the activities themselves are important, particularly the type of improvements being made (e.g., energy-related, non-energy related, or none at all), in order to determine the type of refurbishment being made (retrofitting, rehabilitation, or renovation).

As a response to COVID-19, there has been an increasing number of temporary conversion of various types of facilities to COVID-19-specific care such as medical units, for overflow of COVID intensive care and overflow of non-COVID care, supply storage and homeless shelters. A study by JLL identified 80 temporary facilities across the United States able to accommodate more than 20,000 beds. These facilities range from large arenas and conference centers to office spaces and hotels (Johnson, 2020). The inherent flexibility in such buildings such as flexible open plans, non-centralized HVAC systems and temporary interior divisions make them ideal for temporary conversion. Buildings that are able to incorporate future adaptability and in the response to COVID are able to temporarily convert to other uses, are defined in literature as adaptable buildings. Adaptable buildings are defined as structures that enable alteration strategies, allowing them to respond to changing environments and occupant requirements (Addis & Schouten, 2004; Gosling, Sassi, Naim, & Lark, 2013).

To be truly sustainable and resilient, a building design must account for future flexibility and opportunities to adapt to occupant's demands and to enable accommodation of future uses (Manewa, Siriwardena, Ross, & Madanayake, 2016). There are many identified effective design-based strategies for enabling adaptability. Some of these include the layering of different building systems, accurate documentation, over-designing structural capacity, designing for disassembly, simplicity of structure, systems and plan and modularity. Amongst these, open and accessible plans, over-designing structural capacity, and layering are highlighted by the industry as the most effective strategies to making future adaptive reuse possible (Gosling et al., 2013; Ross, Chen, Conejos, & Khademi, 2016).

The current response to COVID-19 highlights the importance of developing buildings that are responsive to circumstantial, environmental and demographic changes (Kinnane et al., 2016). The term "temporary conversion" as sub-category of adaptive reuse and conversion is expected to gain more importance in research and practice post-COVID, as we begin to navigate a new normal with a perspective on other factors that will affect our built environment, including the effects of climate change in the following decades. The scope, definition and application of temporary conversions need to be investigated in depth in the future of this work.

As demonstrated by this paper's case studies, the proposed definition framework can be used to clearly articulate the project scope by answering a few relatively simple questions. Judging by the exponential increase in published literature on building adaptation projects over the past several decades, we suspect research in this field to continue growing. This growth will make the proposed definition framework a useful reference point, but also suggests it will be important for future researchers to eventually revisit these terminologies to ensure alignment with the potentially changed nature of future project scopes.

Declaration of Competing Interest

None.

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