buildings

MDPI

Article

Is the Concept of Zero Waste Possible to Implement in Construction?

Bogumiła Kapica, Wojciech Targowski and Andrzej Kulowski *

Faculty of Architecture, Gdańsk University of Technology, 11/12 G. Narutowicza Street, 80-233 Gdańsk, Poland; bogkapic@pg.edu.pl (B.K.); wojtargo@pg.edu.pl (W.T.)
* Correspondence: kulowski@pg.edu.pl; Tel.: +48-501-052-874

Abstract: The scientifically treated problem of reusing building materials appeared in the literature more than 50 years ago. This paper includes an analysis of the characteristics of recycled building materials, which is a prerequisite for rational recycling. The analysis and simulation of building stocks at different scales has led to the conclusion that the most important link in the transformation of the construction industry towards the widespread use of reused materials is the unification of the demolition, storage, and redistribution systems. System solutions based on policy studies for each of the first three phases of a building's life cycle assessment (LCA), i.e., design, legislation, and construction, were proposed. It was also recognised that the socially widespread habit of reusing building materials requires a properly conducted educational process and legalisation at the state level. This article presents proposals for educational activities along with the definition of the individual stages of the process of recycling building materials. The expected results are the decarbonisation of the building industry and communities, the growth of sustainable systems, and lowering the environmental impacts of buildings.

Keywords: recycling; reused building materials; sustainable design process; waste management; circular building system; building law; complex construction projects; project citizenship behaviour

check for updates

Citation: Kapica, B.; Targowski, W.; Kulowski, A. Is the Concept of Zero Waste Possible to Implement in Construction? *Buildings* **2024**, *14*, 428. https://doi.org/10.3390/buildings14020428

Academic Editors: Riccardo Maddalena, Ana Bras, Antonios Kanellopoulos and Junjie Zeng

Received: 12 September 2023
Revised: 20 October 2023
Accepted: 15 January 2024
Published: 4 February 2024

1. Introduction

The circular economy is the most important solution and one of the modern needs of human civilization. The construction industry accounts for one third of the world's waste production [1], the vast majority of which could be reused to lower the environmental impact of buildings and improve sustainable systems and their impacts on the urban environment.

Implementing zero waste in the existing structure of the construction industry requires the creation of a system focused on the mass development of demolition materials. Its functioning is based on three elements.

The first stage is to prepare a building design that takes into account its last life cycle—demolition. Above all, this involves the use of materials and their joints such that they can be reused and, only as a last resort, recycled.

The second is the certification of demolition materials, restoring their lost technical and functional attributes, or giving them new ones corresponding to a new form of their use. This refers to, for example, the structural parameters confirmed by an authorised institution, fire resistance, safety of use, resistance to atmospheric influences, etc.

The third element is the legalisation of the design process and obtaining permits for implementing the project in which the demolition materials will be used.

The authors believe that a sufficient body of studies on reused materials is a deep need of eco-oriented societies, of the construction sector following the requirements of the EU, and for implementing policies based on sustainable development.

The problem of waste from the construction sector has been presented in the literature since 1965 [2]. However, architecture worldwide knows much older examples of the spectacular reuse of building materials. This was happening as early as in ancient Egypt (20th–18th c. BC) [3,4], late antique and early medieval Hispanic architecture (5th–10th c. CE) [5], medieval churches (11th–12th c. CE) [6–8], and English Tudor buildings (15th–17th c. CE) [9]. Countries that are aware of this problem, mostly located in Europe, have already established effective waste-management facilities.

The heated discussion surrounding zero-scale economic trends began with Wolman's publication [2], in which he singles out building materials as one of a city's metabolic needs. A quarter of a century later, building materials are the main components of the metabolism of the anthroposphere [10–12], along with water, biomass, and energy [13]. In the theory of building layers [14], two of them stand out as important, but they are not very long-lived in the context of civilizational life. The layer called structure (construction) has a durability of between 30 and 300 years, and the skin (elevation) has one of only 20 years. The relatively new concept of sustainable construction mentions recycling in two of the six principles: reusing building components and using materials that can be refurbished and used outright [15]. The design model associated with this theory, which assumes the possibility of dismantling and recovering materials in advance, includes the reuse of raw materials at the design stage and assumes the dismantling of the building [16]. The CTC (cradle-to-cradle) model compares the biological cycle to the technological cycle and emphasises the possibility of circulating matter, including in the construction industry [17–19]. The concept of a blue economy lists the zero-scale and cyclical system of production in the four pillars of nature's efficiency [20]. It also promotes the concept of the fully waste-free management of building materials. In turn, the study of circular economics [21] and its graphic model [22], in contrast to the linear one, shows that waste can be a raw material for subsequent products, which was confirmed by later research [23]. The discussion surrounding sustainability and selective demolition is currently continuing in the USA, Asia, and Europe [24–26]. The contemporary scientific literature notes the theme of the reuse of materials and the concept of zero waste as a peculiar contemporary fashion; this is the lifestyle of younger generations that is strongly promoted on social media [27]. The motivation to reuse materials once produced is an expression of the conscious need for pro-ecological societies. This mainly applies to a wide range of goods purchased, used, and disposed of on a daily basis, including appliances, electronics, clothing, vehicles, etc. An expression of this pro-ecological awareness is the growing trend of 'reuse is cool', which is observed in social behaviour [27]. The construction industry and building materials are, for technical and economic reasons, far from the everyday lives of consumers. Creating a common, positive social attitude towards the reuse of demolition building materials is a natural continuation of the above-mentioned 'reuse is cool' trend.

In reference to the solutions existing in a few European countries, this article discusses system solutions that include the secondary use of demolition materials, starting from the concept phase, moving through the design and formal phase, and moving to the execution and construction phase (according to LCA). Attention was paid to solutions in which demolition materials are used in a new function that is completely different from the original one, becoming a material for creative activities. The concept of 'zero waste' discussed in this article aims at a model of the full reuse of building materials based on the broadly conceived processes of social education and is a significant and important response to global warming.

The objective of this article is to present the technical, organisational, and economic aspects of the 'zero waste' concept, along with its cultural background and non-technical activities that enhance its social impact. An important part of this paper is the discussion on the architectural and aesthetic values of building materials found in secondary circulation. This article presents the sociological and creative aspect of the use of demolition materials in depth, which is absent in the literature on the subject. This promotes discussion on giving these materials a 'new face', which is a significant factor in spreading the zero-waste concept.

The subject of the study was the properties of the reused materials, processes supporting the use of secondary materials during design and construction, and finally the analysis of European markets, which can serve as a model for other countries. The article raises the sociological and creative aspects of the use of demolition materials, which have been completely absent in the literature on the subject. It favours considerations in the ennoblement of these materials, which could be an important factor in the development of the zero-waste concept.

Detailed research on the practical features of demolition materials divided into categories, along with their evaluation, is an innovative element that is yet to be discussed in the literature.

The paper consists of the following four chapters: this 'Introduction', where the historical background is discussed, including a literature review. The chapter 'Materials and Methods' lists the methods used in the study of demolition materials and the categories used in selecting the case studies. In the next chapter, 'Results', the results of the research and the characteristics of the discussed materials are presented (Tables 1 and 2 and Figure 1), case studies are proposed (Figures 2–7), and organisational processes are categorised (Table 3). At the end of this chapter, Table 4 presents the desired directions of the development of the construction sector in order to activate its participants to use secondary building materials. In the next chapter, 'Discussion', the authors discuss aesthetic, philosophical, and sociological issues related to the subject of the article. The 'Conclusions' chapter unequivocally confirms the thesis stated in the title that the concept of zero waste is possible to implement in the construction sector. The authors indicated the desired directions of development of this branch of the economy in order to implement the pro-ecological assumptions of the paper.

2. Materials and Methods

Reused building materials are characterised by a large variety of physical and structural features, partly inherited from their original function, and in part changed by their long-term use, dismantling, and storage conditions. In some cases, one can even talk about the 'new face' of reused materials, created by the new context of their use. This article presents the characteristics of reused building materials in the current state of their presence on the market and the figures on the use of different types of materials [28].

Reused materials have been tested for features such as the time and cost of recovery, ease and cost of transport, storage, and the possibility of secondary use. The results of the study are presented in Table 1. Building materials are categorised in column A according to their purpose and origin. Under the label 'finishings', there are materials such as tiles, parquet, ceramics, fittings, and system stairs. The following columns present the evaluated features of each type of material. A three-stage scale was adopted (1—low, 2—medium, 3—high). The cost includes various factors, such as type of work, tools, and equipment used. Transport is assessed in column C according to its ease of implementation (depending on the dimensions and weight) and costs (use of specialised means of transport). In turn, column D presents the ease of storage, which, due to the conditions and longevity of storage in most materials, depends on their water resistance. The last features considered (column E) were usability and ease of use. External sources of research [29] are used to show the quantities of reuse recycled materials between 2018 and 2022 in the Benelux, France, the UK, and Ireland.

The analysis also covers the history, theory, design, distribution, and tools of the spatial management of the recycling process. The literature analysis covers the period from 1965 to the present day. Cases from countries where the circular economy of building materials is successful and worth following are also shown [1,29,30].

These case studies were selected according to the order of the listed types of materials in Table 1. The intention of the authors was to show buildings of high architectural value.

The objective of the research is to present the transformation of the reuse of demolition materials from a purely utilitarian need to the concept of total waste management based on the philosophy of sustainable development.

3. Results

3.1. Reused Materials—Their Features and Rating of Usefulness

The demolition materials that are suitable for reuse by their nature, primarily due to their high mechanical resistance, include demolition brick, wood, stone, structural steel, diamond brick, and construction rubble. Other materials that can be reused on a smaller scale include window and door joinery, aluminium window frames, roof tiles, heating and electrical components, thermal and acoustic insulation, paper, glass, and finishing materials.

The architectural aspect of Table 1 is important, as it shows the broad spectrum of reused and reusable materials. The most universal building materials are the traditional ones characterised by the highest durability (demolition brick, wood, stone). This suggests they should be the preferred choice for investments that require analogous primary raw materials. Table 1 shows that the sourcing and reuse of reused materials is a simple way to generate less waste and a dominant trend in deepening the ecological aspect of architecture and construction.

Table 1. Characteristics of reused building materials.

	A	B	C	D	E
1	Type /Name	Recovery Time ∣ Cost (Scale 1–3)	Transport Ease ∣ Cost (Scale 1–3)	Storage Ease + Cost (Scale 1–3)	Possibilities Use ∣ Build Ease (Scale 1–3)
2	Demolition Brick	Time (1) depending on the degree of purification Cost (3) manual labour	Ease (2) Cost (1) delivery truck	(1) in stacks, outdoors, it takes up relatively little space	Use (3) walls, ceilings, gabions, small architecture Build Ease (3) traditional methods
3	Diamond Brick	Time (1) quick process of cutting out a large area Cost (3) specialised work + diamond saw	Ease (1) Cost (3) pallets, forklift, delivery truck	(1) on pallets, outdoors	Use (1) Walls Build Ease (1) requires specialised calculations and skills
4	Rubble	Time (2) depending on the type Cost (1) low	Ease (2) Cost (1) tip truck	(2) containers or mounds, outdoors	Use (2) aggregate for concrete, gabions, base layers Build Ease (2) fragmentation, gabion requires additional expenditure
5	Wood	Time (2) cleaning (paint, nails) Cost (2) manual labour	Ease (2) Cost (1) depending on the length	(2) depending on the dimensions, indoors	Use (3) façades, fences, structure Build Ease (3) traditional methods
6	Doors	Time (1) short Cost (1) low	Ease (2) Cost (1) delivery truck	(2) large dimensions, indoors	Use (2) interiors, façades, furniture Build Ease (2) require modifications

Table 1. *Cont.*

	A	B	C	D	E
7	Windows	Time (1) short Cost (1) low	Ease (2) Cost (1) trolleys for transport	(3) fragile glass, dimensions, indoors	Use (2) two-layer façades due to insulation requirements, greenhouses, small architecture Build Ease (2) little flexibility
8	Roof Tiles	Time (2) fragile Cost (2) manual labour	Ease (2) Cost (1) delivery truck	(1) in stacks, outdoors, take up relatively little space	Use (3) walls, roofs, gabions Build Ease (2) depending on the type and degree of purification
9	Stone	Time (2) heavy Cost (2) carrying, lifting	Ease (1) large, heavy Cost (2) lift, tipper	(1) in stacks, outdoors, take up relatively little space	Use (3) walls, fences, façades, interiors, gabions Build Ease (3) traditional methods
10	Installations	Time (1) depending on the type Cost (1) manual labour	Ease (3) Cost (1)	(2) indoors, small elements	Use (2) heaters, storage tanks, pumps, photovoltaic panels, fireplaces, switches Build Ease (1) like new, require cleaning
11	Steel	Time (2) heavy Cost (2) carrying, lifting	Ease (1) Cost (2) long, heavy	(3) long piles, protection against weather conditions	Use (3) structure Build Ease (2) modification to the required span
12	Insulation	Time (2) brittle, light Cost (2) manual labour, hard recovery	Ease (3) Cost (1) small, light	(1) in stacks, outdoors, take up relatively little space	Use (3) rarely, due to the risk of lowering the insulating properties Build Ease (1) like new
13	Paper	Time (2) fragile Cost (1) manual labour	Ease (3) Cost (1)	(2) indoors, in stacks	Use (1) insulation, finishings Build Ease (2) requires additional interventions: fragmentation, gluing
14	Finishings	Time (2) fragile Cost (3) needs cleaning	Ease (2) Cost (1)	(1) in stacks, outdoors, take up relatively little space	Use (3) tiles, parquet floors, terraces, ceramics, fittings, system walls Build Ease (2) traditional methods
15	Glass	Time (3) fragile Cost (3) manual labour	Ease (1) Cost (2) fragile, risk of injury	(2) outdoors, in containers, panes with special protection	Use (2) walls, façades, gabions, interiors, ballast Build Ease (3) additional interventions: shredding, stacking, cutting

Reusing non-obvious materials such as glass [31], concrete pavement [32], mineral wool [33,34], and rubble [35] is reflected in the scientific research and literature of the twenty-first century.

Attention is drawn to the effectiveness of trading in reused building materials in the UK, French, and Benelux markets (Figure 1). Figures on the use of reused materials by individual countries are presented in Table 2.

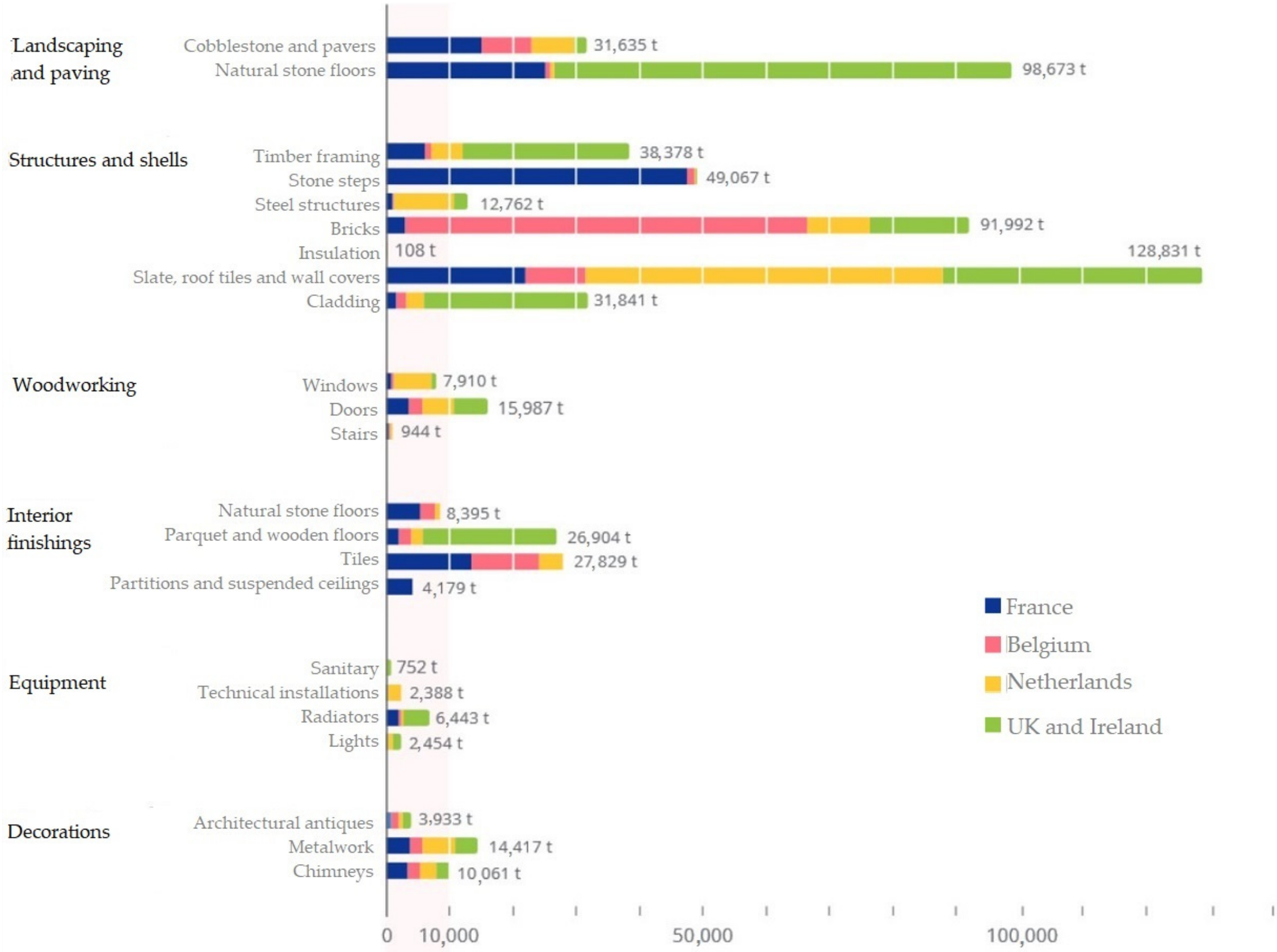


Figure 1. Scope of trade in reused building materials (in tonnes) in the UK, French, and Benelux markets. Reprinted with permission from Ref. [29]. 2023, INTERREG NORTH-WEST EUROPE.

Table 2. Figures on the use of different types of reused materials in 2018–2022, total quantities (in tonnes) of each material, data with permission from INTERREG NORTH-WEST EUROPE [29].

Materials, Products or Equipment	Total	France	Belgium	The Netherlands	UK
Landscaping and paving					
Cobblestone and pavers	31,634.56	15,053.37	7836.03	6759.60	1985.56
Natural stone floors	98,672.88	25,194.75	675.00	597.86	72,205.27
Structures and shells					
Timber framing	38,377.57	6056.49	987.50	5042.26	26,291.32
Stone steps	49,067.14	47,430.87	1253.57	229.71	152.98

Table 2. *Cont.*

Materials, Products or Equipment	Total	France	Belgium	The Netherlands	UK
Steel structures	12,762.39	1012.37	223.21	9498.41	2028.40
Bricks	91,992.49	2933.95	63,506.89	9988.11	15,563.55
Insulation	107.53	7.63	14.82	85.08	-
Slate, roof tiles, and wall covers	128,830.94	22,027.81	9455.69	56,354.37	40,993.08
Cladding	31,840.88	1527.58	1692.56	2690.83	25,929.90
Woodworking					
Windows	7910.48	820.68	316.96	5905.95	866.89
Doors	15,986.94	3462.42	2164.29	5053.97	5306.26
Stairs	943.65	342.88	137.50	391.67	71.60
Interior finishings					
Natural stone floors	8394.86	5268.43	2507.14	619.29	-
Parquet and wooden floors	26,903.72	1900.26	2122.38	1722.26	21,158.82
Tiles	27,828.73	13,462.07	10,614.29	3752.38	-
Partitions and suspended ceilings	4179.33	4146.47	26.50	6.35	-
Equipment					
Sanitary	752.30	31.76	10.00	44.76	665.78
Technical installations	2388.40	266.97	-	2121.43	-
Radiators	6443.32	2054.63	208.21	395.48	3785.00
Lights	2454.25	92.36	130.95	734.92	1496.02
Decorations					
Architectural antiques	3933.31	713.73	1150.00	758.73	1310.85
Metalwork	14,416.96	3769.42	1931.77	5218.25	3497.52
Chimneys	10,061.37	3389.52	1906.25	2688.89	2076.71
TOTAL	**615,884.01**	**160,966.41**	**108,871.52**	**120,660.56**	**225,385.51**

These impressive figures for a relatively small group of European countries indicate that the use of recycled raw materials in other countries has significant room for development.

3.2. Case Studies

Recycled building materials are usually used in line with their original construction or structural function. The added value is then the economic effects and ecological benefits derived directly from this reuse. A special form of secondary use of materials is to give them a new function, where they become a material for creative activities. Seemingly unattractive demolition materials then receive a 'new face', created by a new context of their use, and their new aesthetics become an added value. Projects that make use of demolition materials are discussed in this section, and the architectural paradigm of their use is presented in more detail in Section 4.

Practical examples of the use of reused materials can be found among the objects of world-famous architecture. The architectural motivation for such a solution results from the authentic appearance of recycled materials, carrying a record of their history, so they can speak about the past of a given location, region, and local community. This story also engages users, visitors, and neighbours to rethink their daily waste production choices. In this way, architecture can influence the education of a pro-ecological society.

Figure 2 shows an example of the use of demolition brick. It comes from the demolition of the buildings of the local mine in Ruda Śląska (Poland) and was used to build a single-family house according to the design of Toprojekt Architect Studio. The photos show the versatility of this material, used both in structural walls, in flooring (Figure 2a), and in a fence (Figure 2b).

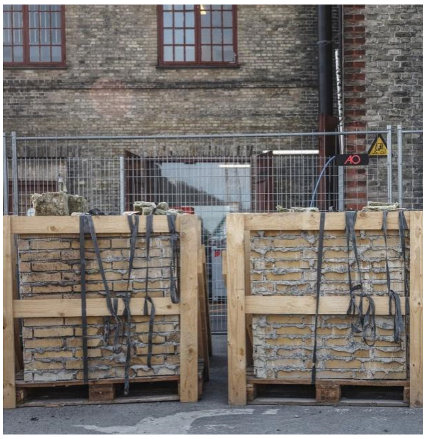
(a)

(b)

Figure 2. Single-family house in Rudy, Poland, by Toprojekt Architect Studio. Inner courtyard (**a**) and fence (**b**). Reprinted with permission from Ref. [36]. 2023, Karol Wawrzyniak.

A material with similar qualities is diamond brick, which can also be a distinctive element of a building's architecture. The ability to vary the direction of the brick arrangement produces unexpected visual effects (Figure 3). Diamond brick can also be used to lay paths, emphasising the versatility of the material used, or provide a uniform style to a building. An example of the use of diamond brick comes from Denmark, where the Lendager Group studio designed the Resource Rows apartment block in Orestad, which was nominated for the Mies van der Rohe award. The innovative nature of this project results from the creatively used variety of colours of bricks. The material comes from the dismantling of historical buildings of Copenhagen breweries, schools, and factories. Square segments of the walls, together with the mortar, were cut out as single units and transported on pallets (Figure 3). This form of obtaining and transporting material increases the investment costs, but the architectural benefits outweigh this (see Table 1, cell 3C). The presented implementation shows that reused material can be an important part of the chain in a circular economy. The object in question was the first motivator to work on this article.

(a)



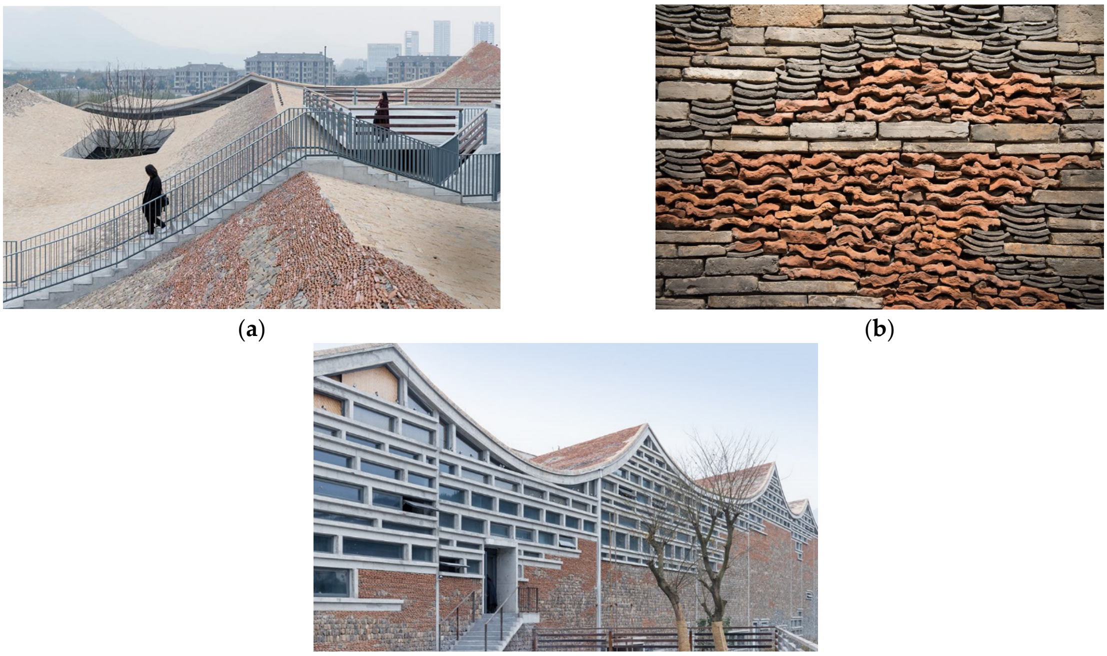
(b)

Figure 3. *Cont.*

(c)

Figure 3. Resource Rows apartment block in Copenhagen, Denmark, by the Lendager Group. Material sourcing at its original location (**a**), transport of the acquired diamond brick (**b**), construction process (**c**). Reprinted with permission from Ref. [37]. 2023, Rasmus Hjortshøj.

Chinese architect Wang Shu, awarded in 2012 by Pritzker, became famous for his designs of buildings in Shanghai, Ningbo, Hangzhou, and Beijing (China), where he poetically uses brick, stone, and tiles [38,39]. The form of the presented Fuyang Cultural Center is very modern, but still pays homage to traditional Chinese architecture. It is not obvious and positively surprising to use tiles as a construction material. Combining them with other elements that are usually treated as worthless building rubble produces a mosaic showing the history of the place (Figure 4). The presented example shows the versatility of tiles (see Table 1, cell 8D), which are used to build the roof and structural-façade walls (Figure 4). The critically acclaimed Wang Shu outlines an important direction of development and a goal that contemporary architecture should pursue, which is to increase the architectural value of reused materials.

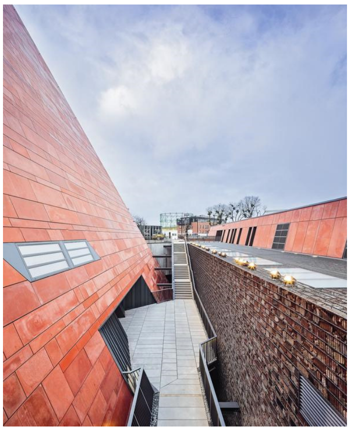


(a) (b)

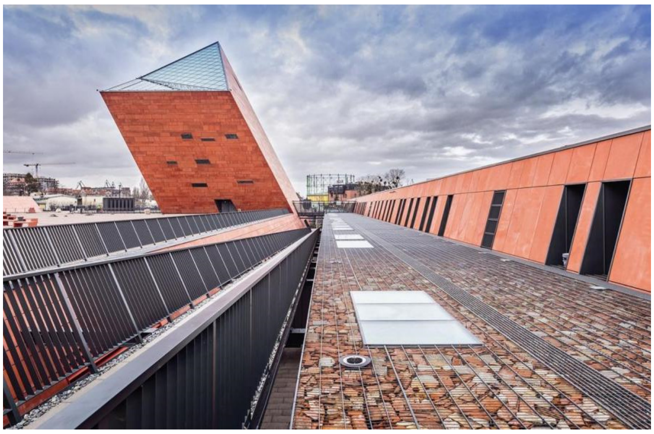
(c)

Figure 4. Fuyang Cultural Center, China, by Amateur Architecture Studio. Recycled roof (**a**), detail of the wall (**b**), façade (**c**). Reprinted with permission from Ref. [40]. 2023, Iwan Baan.

The other presented example of rubble is gabions, as mentioned in Table 1, cells 2E and 4E. They form the external façade of both the walls and roof and can be successfully used as fences and structural elements. Figure 5 presents the Museum of the Second World War in Gdańsk. The building was built in the Wiadrownia district, which was destroyed during the war.



(a)



(b)

Figure 5. Museum of the Second World War in Gdańsk, Poland, by Kwadrat Architectural Studio. Gabions filled with rubble as a façade building material for walls (**a**) and roof (**b**). Reprinted with permission from Ref. [41]. 2023, Marcin Czechowicz, www.mcmproduction.pl, accessed on 3 February 2024.

An object with an attractive reuse of woodwork is the Circular Pavilion in Paris (France), designed by Encore Heureux Architects. The historic doors were obtained from nearby Parisian tenement houses (Figure 6). They were used in an unexpected way to create peaks that elegantly and figuratively refer to the context of the place. The solution used in this façade solves the storage problems listed in Table 1, cell 6D.

(a)

(b)

Figure 6. Circular Pavilion, France, by Encore Heureux Architects. Front (**a**), context of the place (**b**). Reprinted with permission from Ref. [42]. 2023, Cyrus Cornut.

An equally graceful façade solution is old windows. In Kamikatsu (Japan), there is a restaurant and Zero Waste Center with an impressively sized building façade (Figure 7). To reduce the energy usage, two layers of windows were installed to keep out the cold, because the old frames are no longer tight. Divisions on the double façade also solve problems with the overheating of the interior in summer. The layout of the second layer of windows was designed using computer software to achieve the best aesthetic effect.

(**a**) (**b**) (**c**)

Figure 7. Restaurant and Zero Waste Center in Kamikatsu, Japan, by Hiroshi Nakamura and NAP. Façade (**a**), interior (**b**), window layout (**c**). Reprinted with permission from Ref. [43]. 2023, Koji Fujii/TOREAL.

The presented examples have been selected in the order given in Table 1 and testify to the wide possibilities of reusing building materials. They can be used both as structural elements of walls—House in Rudy [36], Fuyang Center [40]; roofs—Museum in Gdańsk [41]; but also as a façade —Resource Rows [37], Circular Pavilion [42], Kamikatsu Center [43]. They come from all over the world and represent the highest level of architecture. The intention in showing them was a paradigm shift—recycling does not always have to be associated with the 'junk' quality of design. It can represent a new direction, a challenge for members of the design process. Case studies can become an inspiration for new investments in light of tightening pro-ecological regulations.

3.3. Support Sources Depending on the Phase of the Building Life Cycle

The building life cycle assessment (LCA) is a recognised quantifier of an object's impact on the environment [44,45]. The proposal to include implementing the concept of zero waste in construction in this analysis is presented in Table 3. The columns expose the presence of this concept in the initial and final stages of the building's life.

Table 3. Directions of implementing the reuse of reused materials.

Stage	Desired Directions of Development	Desired Sources of Support
Design	• design for disassembly at the concept stage • preliminary material search with data mapping	• PR incentives on social media—making investors aware • economic incentives—subsidies for investors/investments/designers
Legislation	• digitisation of official formalities (consumes energy, but does not generate waste—paper)	• legal incentives—facilitating legalisation, certification of materials
Construction	• organisation of demolition companies • unification of the reused materials market • material sourcing applications use of BIM (building information modelling) for more accurate bill of quantities and specification of material orders without unnecessary surplus	• economic incentives—subsidies for investors/investments/designers • education of management teams (site manager) to optimise the construction process • education of contractors, who often have a strong influence on the choices of private investors ('let's listen to experience in the industry')

The first phase of the building's life cycle, i.e., design, in addition to the obvious parameters such as building geometry, and energy consumption [46], should take into account the recovery of materials as early as during the conceptual stage [47]. Mapped data would be helpful for the initial search for locally available materials, for educational purposes and for awareness-raising encouragement in the media [27]. Temporary subsidies for investors, investments, and designers could be a significant source of support until social habits are implemented.

In the second phase, i.e., legislation, the experience gained in the digital circulation of documentation acquired through the mass transition to online mode forced by COVID-19 restrictions is promising [48]. During the lockdown in 2020, far-reaching facilitations in the organisation of office work, including project legislation, were initiated. Government offices have opened up to the possibility of the remote submission of applications and dealing with related matters. Currently, it is possible to submit an application for a building permit and attach the project in electronic form. However, offices are still at the stage of training and equipping them with tools and devices to make the electronic checking of project documents possible. This is dictated by the lack of space to store documentation, but inevitably leads to the legalisation of electronic procedures.

An important element of the legislative phase is the certification of recycled materials. An example is the solutions found in many European countries, where recycled bricks, wood and steel have material passports that legalise their reuse.

The third phase of a building's life cycle, i.e., construction, requires the organisation of demolition companies and the unification of the reused materials market. Creating computer applications to trade reusable materials can also reduce the embodied energy [13]. Significant opportunities to improve this stage are provided by the spread of BIM design technology [49], which is already becoming a reality. BIM technology supports quantitative statements and precise material orders, with surpluses reduced to the bare minimum.

In addition to the phases of the building's life cycle listed in Table 3, education is a very important factor [50,51]. Formally, it is not part of the set of technical concepts that make up the life cycle of a building. The importance of education in both social and qualified terms, i.e., the inclusion of zero-waste concepts in the curricula of schools at all levels, together with the university level, is an important factor in the dissemination of habits of the secondary use of all goods, including building materials [52]. In the context of this article, it is therefore necessary to properly educate both the teams managing the optimisation of the construction process and contractors [53], who often have a significant impact on the choices of investors. All of them can create a climate-neutral community and set a leading example for the rest of the society.

3.4. Proposal for an Economic Model for Trading in Reused Materials at the National Level

The first economic model of trading in reused materials was based on the storage and reclamation of materials [21]. Table 4 presents a proposal for a model whose use would be an ecologically and economically justified direction for the development of the construction sector policy in accordance with the concept of zero waste.

Table 4. Policy proposal for the use of reused building materials.

Phase	Incentives/Tools
Conception	Encouragement in the area of public relations - activities on social media—making investors aware via such activities as a 'free photo session from the implementation' - searching for applications for building materials, design offices, contractors, with inspiring elements such as case studies
Project	Economic Incentives creating programs based on pro-ecological subsidies from the EU, countries, and municipalities supporting: - entrepreneurs—warehouse owners; - investors—co-financing of investments; - designers—co-financing of the design process; - creating regional mapped databases of materials at the level of municipalities
Legislation	Legal Aspects - facilitating the legalisation of reused materials (rubble, wood, steel); - a new form of dividing construction projects into structural and technical is conducive to the approval of projects using reused materials; - electronic platform for approving construction projects
Construction	Planning Tools - unification of the reused materials market; - organisation of demolition companies; - specialisation of construction teams

Activities that encourage investors to take a pro-ecological approach [54,55] to the palette of building materials intended for use in their future investments operate in societies with developed environmental awareness in a manner specific to the economic potential of the given country, in comparison with The Netherlands [30]. Incentives that can play an important role in the conceptual phase of projects include activities on social media aimed at raising investors' awareness. A free photo session of the final effect, for example, can be an important tool. Applications for searching for building materials, design offices, contractors, implementations, and inspirations are also an incentive.

In the design phase, economic incentives are important, which, based on pro-ecological subsidies from the EU, governments, and municipalities, would create support programs for entrepreneurs (warehouse owners), investors (investment co-financing), and designers (co-financing of the time-consuming design process), and the creation of regional mapped material databases at the level of communes. These web portals, mobile phone apps, etc., should contain all the relevant data, such as the type and quantity of materials, contact details, supply, designability, and procedures for obtaining permits.

The legislative phase requires legal incentives in the form of facilitating the legalisation of reused materials (rubble, wood, steel), and the development of an electronic platform for obtaining building permits. A good example of the legalisation of materials is the material passport applied in The Netherlands [30]; thus, in other countries it only needs the support of architects' associations and central politicians. The passport contains information about the product, origin of the material, years of use, its basic properties, quality, quantity, size, colour, and recyclability. The construction phase is related to the development of planning tools that will unify the market of reused materials and support the organisation of demolition companies and the specialisation of construction teams.

4. Discussion—Zero Waste as an Element of the Paradigm of Survival in Architecture

4.1. Continuity

The evolutionary development of architecture was interrupted by the avant-garde revolution, but the atavistic longing to maintain the continuum never allowed for a complete turning away from the past. A comprehensive attempt was made at the turn of the 1980s, when they were satisfied with the passion for postmodern defiance. The building material of modern styles was replaced by clever, often humorous substitutes. The fascination with postmodern architecture has passed and in the multi-threaded, creative, sometimes contradictory thinking about tradition, it is worth noting that the material of the structure, which is more durable than the complete structure of the building, can serve as a link between the past and the present. The original building material can play an important role in maintaining continuity, an immanent condition of recognisable identity.

The complete destruction of the building substance carries a particular danger of a definitive rupture of the continuation. In the discussions on the method of bringing Europe's most important cities back to life after the destruction of World War II, the concept of reconstruction in historical forms prevailed [56]. The correctness of such a decision has been confirmed by the contemporary experience of universal identification of the identity of cities with their reconstructed, historical centre. However, the rebuilt Warsaw Old Town is sometimes perceived as merely an easily acceptable, traditional form—a conservative coating of the internal structure, corresponding to the requirements of modern times [57]. In addition, due to the scale of destruction, the authenticity of the rebuilt urban structures may be questioned. In fact, doubts are justified that undermine the possibility of preserving the identity of monuments when they are completely restored. The use of authentic matter recovered from the rubble contributes to a more favourable treatment of the historical value of the reconstruction, as, when used to faithfully recreate the form, it brings the counterfeit closer to the original. The object gains an individual uniqueness; the condition of the status of the original. This can serve as conclusive for proof of identity.

4.2. Identity

A building was created from the chaos of ruin and reorganised into the geometry of form, preserving the matter, demanding identity. Looking for an analogy of the identity of a building with the issue of determining the identity of an individual human being, we find a bonding factor. It is a question of preserving the identity of the body. Known for his reflections on the authenticity of the monument, the paradox of Theseus' ship consists in the fact that the whole ship survives with the successive replacement of its rotten pieces with new ones, until they are all replaced. This may raise doubts as to its identity [58]. In the case of rebuilding the lost whole from the preserved, original building material, the situation is the opposite—the matter is undoubtedly identical, and the form is recreated. Maintaining continuity is still debatable, but the use of authentic building material, surviving detail, or residual equipment certainly serves to continue the identity. It can be said that when the building material from the ruins was used to erect other buildings in the same city, the historical identity of the city was transferred and preserved along with the material.

In any case, even when a completely new house is created from the recovered building material in a different place and environment, the mystery of its construction gives it an elusive value. The repeated use of material for the construction of new forms resembles the mythical process of reincarnation. The building material receives new incarnations. The cyclically resumed rhythm of the building's life: construction–existence–dismantling, closes the time loop, metaphorically prolonging the duration.

4.3. Artistic Value

Throughout history, the usefulness of recovered building elements has not been measured only by their practical usefulness, reduced to the value of the finished construction material. Their value was widely appreciated as an artistically valuable detail, helpful in building the aesthetic values of newly erected buildings. The benefit of saving a lot of the work of rare, highly qualified builders meant that the procedure of obtaining stone masterpieces at the expense of older buildings has been used since the dawn of time. It was often the case that the most magnificent elements of the buildings became the subject of robberies and war plunder. In 2015, the low level of the Vistula river in Warsaw revealed stone details torn from the capital's buildings, accidentally lost to the water on the way to distant Scandinavia, as a valuable spoil of war of the seventeenth-century Swedish invasion [59]. Without a doubt, the details were intended to be reused there as an ornament of representative buildings.

Objects of art are differentiated into those that are characterised by perfect order and correctness in following tradition, and others that oppose habits, challenging conventions [60]. A harmonious, conventional adaptation of the acquired details, respecting the order sanctioned by tradition, is therefore the first possibility. The second is the use of recovered materials to build new, original value. Various details, combined in a most surprising way, impress with the freshness of the concept. Forms are created from seemingly useless waste doomed to disposal. Their lives are restored to a new, inspiring order.

4.4. Value of Antiquity

People's attitude to novelty is usually distrustful. Contemporary architecture is hardly gaining universal acceptance. A historical object is effectively not subject to aesthetic assessment but can be widely appreciated due to its age. Durability is an asset that is enough for a building to be usually widely and sincerely admired and always respected.

Solidified by the history of a non-existent building, the recovered material has value in itself. Recognising the age and condition of the material builds an extraordinary experience of communing with the past. It is worth noting that this becomes particularly pronounced when the reception is holistic, not limited only to the use of the sense of sight. The texture, the smell, the sound of the recovered materials, full of imperfections, enchants with poetry inaccessible to the eye. In direct contact with matter rich in the experience of time, there is a growing certainty that the reception of architecture is not limited only to visual perception [61].

Today's architecture is successfully experimenting with the secondary use of material. Authentic, age-old building materials, regained for new realisations, to some extent ennobles them from this point of view. In this way, the tame contemporaneity is perhaps more easily accepted by the recipient seeking connections with tradition.

4.5. Symbolic Value

Old, exposed building material successfully serves to enrich the content of symbolic architecture. Often, contemporary demolition material must suffice, associated with the past due to its reuse, but when it is a historical building material, the literary message becomes clearer. In an unrealised competition concept from 1945, the original fragments of the surface collected from the dismantled barricades of the Warsaw Uprising were to be used to line the Old Town Square, creating, in the intention of the authors, an evocative monument to the Uprising [62]. A similar role is played by gabions filled with rubble, symbolising destruction (Figure 7) in the contemporary complex of the Museum of the Second World War in Gdańsk [41,63].

In the case of the Jordanki Cultural and Congress Centre in Toruń, specially prepared brick rubble is exposed on fragments of the façade from under the 'skin' of the concrete (Figure 8), allowing us to discover the Gothic pedigree of the city [64].

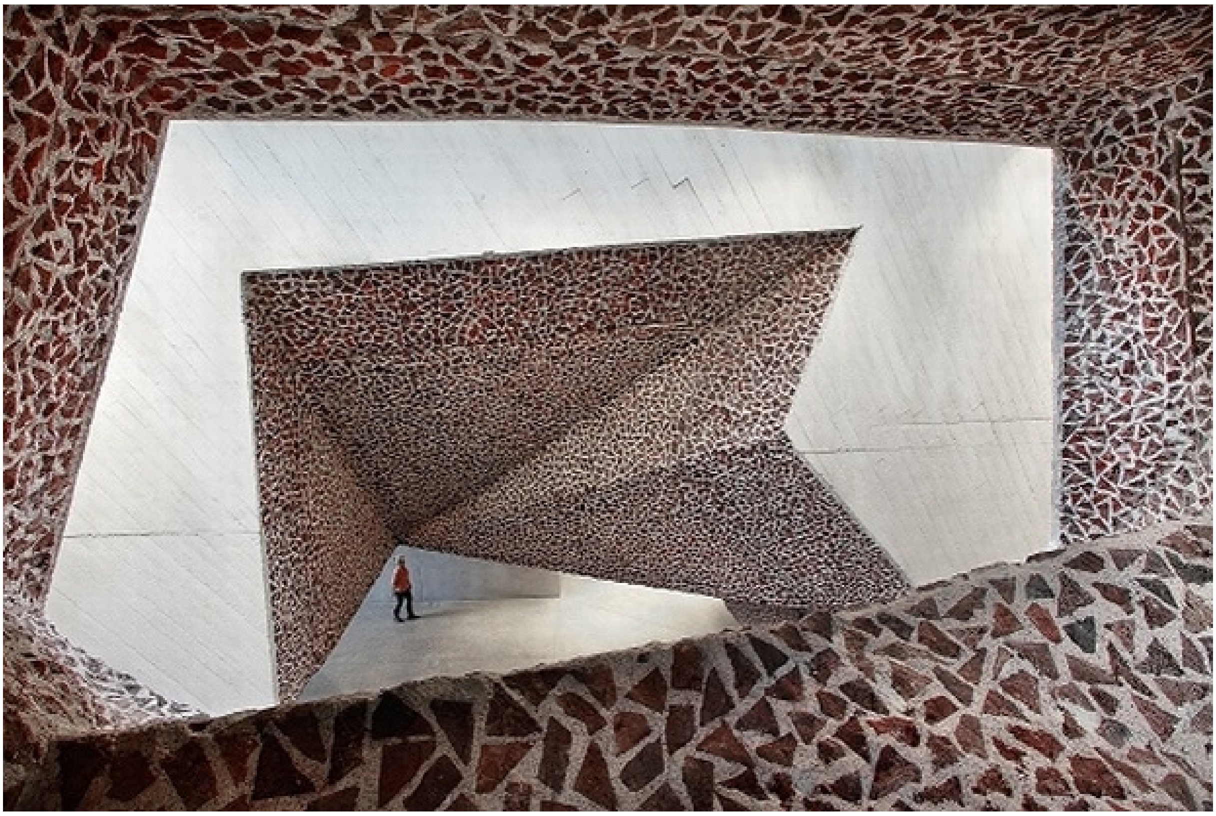


Figure 8. Jordanki Cultural and Congress Centre in Toruń, Poland, by Menis Arquitectos. Broken demolition brick sunken in cement. Reprinted with permission from Ref. [64]. 2023, Małgorzata Replińska, CKK Jordanki, Toruń.

The olive tree preserves the continuity of matter. Releasing subsequent branches, it practically does not age. An old building material regains its youth when it becomes material for a new building. This then gains a unique, individual value. Even in the process of ascension, it has its own history, a specific founding legend, the germ of a new story.

The recovery of building material is environmentally friendly, legitimate in a practical sense, economically viable, and symbolically significant. It also brings a message that is more difficult to grasp. This message is subjected only in part to objective cognitive analysis. It is worth following intuitionists in using the tool of extrasensory cognition. This 'intellectual sympathy' provides a more complete experience than cold judgement, reaching the elusive nuances of the message [65]. At the moment of crossing the information layer of the meaning of architecture, the emotional experience is transferred to the assessment of the events taking place within it, deepening the importance of architecture as a factor enriching the everyday quality [66].

5. Conclusions

According to EUROSTAT data [1], the waste generated after the completion of construction and demolition works exceeds one third of all waste generated in the EU. They are classified as major mineral waste, and their landfill is a burden on the environment as it takes up land space and may cause air, water, and soil pollution. Due to the ecological neutrality of their physical parameters and the susceptibility to re-use indicated in the article, construction and demolition wastes are less of a threat to the environment than an 'ecological bomb' in the form of hazardous waste, but because of their scale, they are a problem of significant social importance.

The subject of the article is demolition waste. As shown, a significant portion of it is suitable for further use, often without any additional treatments. On a massive scale, however, the condition for giving it a 'second life' is to carry out demolition works with the assumption of material recovery and preparing for re-use without significant energy expenditure. With regard to demolition waste, preparing it for re-use means checking, cleaning, or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

A significant condition for success is the synergistic interaction of the economic, ecological, and cultural factors, i.e., savings resulting from the reuse of material already produced once, the benefit in the field of ecology visible to the naked eye, and the consciously applied historicising thread of design solutions, exposing the record of history and the context of the place contained in the disposition of the materials used. Particularly noteworthy is the last factor of this synergy, which is a new value in the area of the creative use of waste materials, in the social perception usually associated only with the purely utilitarian use of cheaper raw material.

The concept of zero waste is based on the organisation of the life cycle of the building and the related design procedure, assuming full recycling of building materials with a derogation resulting only from technical conditions in the field of user safety. This is a concept that requires a shift from consumerism to environmental awareness, which is observed only in a few EU countries using a circular building system. The article proposes an organisational and legal chart of activities leading to the implementation of the concept of zero waste in countries building social approval in favour of giving a 'second life' to the matter of construction.

The presented formula of the use of reused materials and the related trends in shaping architecture determines the direction of development of construction, in which the inquiry about the possibility of using recycled materials is the basic duty of the designer. It is to be hoped that this sustainable and innovative solution of implementing the concept of zero waste on a massive scale will free the construction sector from the infamous burden of being the most polluting branch of the economy.

Author Contributions: Conceptualisation, B.K.; methodology, B.K.; validation, B.K.; investigation, B.K.; resources, B.K.; writing—original draft preparation, B.K. and W.T.; writing—review and editing, B.K. and A.K.; visualisation, B.K.; supervision, A.K.; project administration, A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Acknowledgments: The authors would like to thank Katarzyna Zielonko-Jung for the initial discussions and encouragement for the scientific study of the concept of zero waste in the building industry.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Eurostat. Waste Statistics. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics (accessed on 30 September 2023).
2. Wolman, A. The Metabolism of Cities. *Sci. Am.* **1965**, *213*, 179–190. [CrossRef] [PubMed]
3. Gilli, B. The Past in the Present: The Reuse of Ancient Material in the 12th Dynasty. *Aegyptus* **2009**, *89*, 89–110.
4. Osorio, G.; Silva, L. Out of Ruins: Contextualizing an Ancient Egyptian Spectacle of Architectural Reuse. *Camb. Archaeol. J.* **2023**, *33*, 521–536. [CrossRef]

5. Utrero Agudo, M.d.l.Á. Stratigraphy Matters: Questioning the (Re)Sacralisation of Religious Spaces from Late Antiquity to the Early Middle Ages in the Iberian Peninsula. *Religions* **2023**, *14*, 1199. [CrossRef]
6. Blows, J.F.; Carey, P.J.; Poole, A.B. Preliminary investigations into Caen Stone in the UK; its use, weathering and comparison with repair stone. *Build. Environ.* **2003**, *38*, 1143–1149. [CrossRef]
7. Antonelli, F.; Santi, P.; Renzulli, A.; Santoro Bianchi, S. The Architectural Reuse of Roman Marble and Stone Spolia in the Early Medieval Monte Sorbo Church (Sarsina, Central Italy). *Archaeometry* **2016**, *58*, 353–370. [CrossRef]
8. Sánchez-Pardo, J.; Blanco-Rotea, R.; Sanjurjo, J.; Rodriguez, V. Reusing stones in medieval churches: A multidisciplinary approach to San Martiño de Armental (NW Spain). *Archaeol. Anthropol. Sci.* **2019**, *11*, 2073–2096. [CrossRef]
9. Bailiff, I.K.; Blain, S.; Graves, C.P.; Gurling, T.; Semple, S. Uses and recycling of brick in medieval and Tudor English buildings: Insights from the application of luminescence dating and new avenues for further research. *Archaeol. J.* **2010**, *167*, 165–196. [CrossRef]
10. Baccini, P.; Brunner, P.H. *Metabolism of Anthroposphere: Analysis, Evaluation, Design*, 2nd ed.; The MIT Press: Cambridge, MA, USA, 2012; ISBN 978-026-201-665-0.
11. Kennedy, C.; Pincetl, S.; Bunje, P. The study of urban metabolism and its applications to urban planning and design. *Environ. Pollut.* **2011**, *159*, 1965–1973. [CrossRef] [PubMed]
12. Thorpe, D. Urban Metabolism: Viewing Cities like Bodies can Help Reduce Environmental Impact. 2018. Available online: https://thefifthestate.com.au/urbanism/planning/urban-metabolism-viewing-cities-like-bodies-can-help-reduce-environmental-impact/ (accessed on 30 September 2023).
13. Thormark, C. The effect of material choice on the total energy need and recycling potential of a building. *Build. Environ.* **2006**, *41*, 1019–1026. [CrossRef]
14. Brand, S. *How Buildings Learn: What Happens after They're Built*; Penguin Books: New York, NY, USA, 1994; ISBN 978-014-013-996-9.
15. Kiebert, C. *Sustainable Construction: Green Building Design and Delivery*, 2nd ed.; Wiley: Hoboken, NJ, USA, 2008; ISBN 978-0-470-11421-6.
16. Crowther, P. Developing an inclusive model for design for deconstruction. In *Deconstruction and Materials Reuse: Technology, Economic, and Policy*; CIB Publication: Wellington, New Zealand, 2001; p. 266.
17. Braungart, M.; Mc Donough, W. *Cradle to Cradle*; North Point Press: New York, NY, USA, 2002; ISBN 978-086-54-75-878.
18. Koźmińska, U. Nowe materiały w architekturze mieszkaniowej. Reutylizacja, recykling, upcykling, cradle-to-cradle—Przyszłość czy utopia? (New materials in residential architecture. Reuse, recycling, upcycling, cradle-to-cradle—The future or utopia?) *Hous. Environ.* **2013**, *11*, 256–263.
19. Geist, K. Cradle to Cradle Design—How a Biochemist and an Architect Are Changing the World. 2014. Available online: https://wakeup-world.com/2014/11/26/cradle-to-cradle-design-how-a-biochemist-and-an-architect-are-changing-the-world/ (accessed on 30 September 2023).
20. Pauli, G. *The Blue Economy*; Paradigm Pubs: Taos, NM, USA, 2010.
21. Morseletto, P. Targets for a circular economy. *Resour. Conserv. Recycl* **2020**, *153*, 153. [CrossRef]
22. Lévy, J.-C.; Aurez, V. *L'économie Circulaire: Un Désir Ardent des Territoires*; Presses des Ponts: Paris, France, 2014; ISBN 978-2-85978-485-0.
23. Webster, K. *The Circular Economy*; Ellen MacArthur Foundation Publishing: Isle of Wight, UK, 2017; ISBN 978-0992778460.
24. Schreck, M.; Wagner, J. Incentivizing secondary raw material markets for sustainable waste management. *Waste Manag.* **2017**, *67*, 354–359. [CrossRef] [PubMed]
25. Hossain, M.U.; Wu, Z.; Poon, C.S. Comparative environmental evaluation of construction waste management through different waste sorting systems in Hong Kong. *Waste Manag.* **2017**, *69*, 325–335. [CrossRef]
26. Pantini, S.; Rigamonti, L. Is selective demolition always a sustainable choice? *Waste Manag.* **2020**, *103*, 169–176. [CrossRef] [PubMed]
27. Ramjaun, T.A. Exploring the #zerowaste lifestyle trend on Instagram. *Crit. Stud. Corp. Responsib. Gov. Sustain.* **2021**, *14*, 205–220.
28. Ashby, M.F. *Materials and the Environment. Eco-Informed Material Choice*, 3rd ed.; Elsevier Inc.: Oxford, UK, 2020; ISBN 9780128215210.
29. Bougrain, F.; Doutreleau, M. Statistical Analysis of the Building Elements Reclamation Trade in the Benelux, France, The UK and Ireland, Interreg NWE 739: Facilitating the Circulation of Reclaimed Building Elements (FCRBE). 2022. Available online: https://vb.nweurope.eu/media/16598/statistical-analysis-v15.pdf (accessed on 30 September 2023).
30. Klijn-Chevalerias, M.; Javed, S. The Dutch approach for assessing and reducing environmental impacts of building materials. *Build. Environ.* **2017**, *111*, 147–159. [CrossRef]
31. Jurczak, R.; Szmatuła, F.; Rudnicki, T.; Korentz, J. Effect of Ground Waste Glass Addition on the Strength and Durability of Low Strength Concrete Mixes. *Materials* **2021**, *14*, 190. [CrossRef]
32. Kočí, V.; Kočí, J.; Fořt, J.; Fiala, L.; Šál, J.; Hager, I.; Černý, R. Utilization of Crushed Pavement Blocks in Concrete: Assessment of Functional Properties and Environmental Impacts. *Materials* **2021**, *14*, 7361. [CrossRef]
33. Yap, Z.S.; Khalid, N.H.A.; Haron, Z.; Mohamed, A.; Tahir, M.M.; Hasyim, S.; Saggaff, A. Waste Mineral Wool and Its Opportunities—A Review. *Materials* **2021**, *14*, 5777. [CrossRef]
34. Łaźniewska-Piekarczyk, B.; Czop, M.; Smyczek, D. The Comparison of the Environmental Impact of Waste Mineral Wool and Mineral in Wool-Based Geopolymer. *Materials* **2022**, *15*, 2050. [CrossRef] [PubMed]

35. Contreras-Llanes, M.; Romero, M.; Gázquez, M.J.; Bolívar, J.P. Recycled Aggregates from Construction and Demolition Waste in the Manufacture of Urban Pavements. *Materials* **2021**, *14*, 6605. [CrossRef] [PubMed]
36. Os, A. Dom Rudy w Rudach. Cegła Jako Plastyczna Forma Wyrazu (The Rudy House in Rudy. Brick as a plastic form of expression, in Polish), Bryła Homepage. Available online: https://www.bryla.pl/bryla/7,85301,21703126,dom-rudy-w-rudach-cegla-jako-plastyczna-forma-wyrazu.html (accessed on 30 September 2023).
37. Fundació Mies van der Rohe Homepage. Available online: https://www.miesarch.com/work/4305 (accessed on 30 September 2023).
38. Rawn, E. Material Masters: The Traditional Tiles of Wang Shu & Lu Wenyu. Archdaily. 2015. Available online: https://www.archdaily.com/638948/material-masters-amateur-architecture-studio-s-work-with-tile (accessed on 30 September 2023).
39. Frampton, K. Kenneth Frampton On The Work of Wang Shu and Lu Wenyu. Archdaily. 2017. Available online: https://www.archdaily.com/867419/kenneth-frampton-on-the-work-of-wang-shu-and-lu-wenyu (accessed on 30 September 2023).
40. Pearson, C.A. Huang Gongwang Museum by Amateur Architecture Studio, Fuyang, China, Architectural Record. 2017. Available online: https://www.architecturalrecord.com/articles/12473-huang-gongwang-museum-by-amateur-architecture-studio (accessed on 30 September 2023).
41. Domsta, B. Przeszłość Zamknięta w Podziemiu (The Past Enclosed in the Underground). Architektura Murator. 2017. Available online: https://architektura.muratorplus.pl/realizacje/przeszlosc-zamknieta-w-podziemiu-o-projekcie-muzeum-ii-wojny-swiatowej-bazyli-domsta_7332.html (accessed on 30 September 2023).
42. Frearson, A. Encore Heureux uses recycled materials to build Circular Pavilion in Paris. Dezeen. 2015. Available online: https://www.dezeen.com/2015/12/18/circular-pavilion-encore-heureux-paris-france-recycled-materials-doors/ (accessed on 30 September 2023).
43. Castro, F. Kamikatz Public House/Hiroshi Nakamura & NAP, Archdaily. 2018. Available online: https://www.archdaily.com/892767/kamikatz-public-house-hiroshi-nakamura-and-nap (accessed on 30 September 2023).
44. Andreasi Bassi, S.; Tonini, D.; Ekvall, T.; Astrup, T.F. A life cycle assessment framework for large-scale changes in material circularity. *Waste Manag.* **2021**, *135*, 360–371. [CrossRef] [PubMed]
45. Teng, Y.; Xu, J.; Pan, W.; Yang, Z. A systematic review of the integration of building information modeling into life cycle assessment. *Build. Environ.* **2022**, *221*, 109260. [CrossRef]
46. Decorte, Y.; Steema, M.; Van Den Bossch, N. Effect of a one-dimensional approach in LCA on the environmental life cycle impact of buildings: Multi-family case study in Flanders. *Build. Environ.* **2021**, *206*, 108381. [CrossRef]
47. Ekanayake, L.L.; Ofori, G. Building waste assessment score: Design-based tool. *Build. Environ.* **2004**, *39*, 851–861. [CrossRef]
48. Bai, C.; Quayson, M.; Sarkis, J. COVID-19 pandemic digitization lessons for sustainable development of micro-and small-enterprises. *Sustain. Prod. Consum.* **2021**, *27*, 1989–2001. [CrossRef]
49. Omer, M.M.; Mohd-Ezazee, N.M.A.; Lee, Y.S.; Rajabi, M.S.; Rahman, R.A. Constructive and Destructive Leadership Behaviors, Skills, Styles and Traits in BIM-Based Construction Projects. *Buildings* **2022**, *12*, 2068. [CrossRef]
50. Czarnecki, S.; Rudner, M. Recycling of Materials from Renovation and Demolition of Building Structures in the Spirit of Sustainable Material Engineering. *Buildings* **2023**, *13*, 1842. [CrossRef]
51. Bolden, J.; Abu-Lebdeh, T.; Fini, E. Utilization of Recycled and Waste Materials in Various Construction Applications. *Am. J. Environ. Sci.* **2013**, *9*, 14–24. [CrossRef]
52. Kouvara, A.; Priavolou, C.; Ott, D.; Scherer, P.; van Zyl-Bulitta, V.H. Circular, Local, Open: A Recipe for Sustainable Building Construction. *Buildings* **2023**, *13*, 2493. [CrossRef]
53. Laglera, J.; Collado, J.C.; Jammd, O. Effects of leadership on engineers: A structural equation model. *Eng. Manag. J.* **2015**, *25*, 7–16. [CrossRef]
54. Luo, L.; Yang, Y.; Wu, G.; Zheng, J.; Liu, D. Effects of Organizational Leadership on Project Citizenship Behavior and Management Performance in Complex Construction Projects. *Buildings* **2023**, *13*, 259. [CrossRef]
55. He, Q.H.; Yang, D.L.; Li, Y.K.; Luo, L. Research on multidimensional connotations of megaproject construction organization citizenship behavior. *Front. Eng. Manag.* **2015**, *2*, 148–153. [CrossRef]
56. Friedrich, J. *Odbudowa Głównego Miasta w Gdańsku w latach 1945–1960 (Reconstruction of the Main Town in Gdańsk in the years 1945–1960, in Polish)*; Słowo/obraz terytoria: Gdańsk, Poland, 2015; pp. 82–111; ISBN 9788374532495.
57. Jencks, C. *The Language of Post-Modern Architecture*, 6th ed.; Wiley: Hoboken, NJ, USA, 1991; p. 94; ISBN 978-1854900616.
58. Kołakowski, L. *Moje Słuszne Poglądy na Wszystko (My Correct Views on Everything, in Polish)*, 2nd ed.; Znak: Kraków, Poland, 2000; p. 159; ISBN 978-83-240-1767-6.
59. Gliński, M. XVII-Wieczne-Skarby-Wydobyte-z-Wisly (17th-Century-Treasures-Recovered-43. from-Vistula, in Polish), Culture. 2015. Available online: https://culture.pl/pl/artykul/xvii-wieczne-skarby-wydobyte-z-wisly (accessed on 30 September 2023).
60. Scruton, R. *Beauty—A Very Short Introduction*; Oxford University Press: Oxford, UK, 2011; ISBN 978-0199229758.
61. Pallasmaa, J. *The Eyes of the Skin. Architecture and the Senses*, 3rd ed.; Wiley: Hoboken, NJ, USA, 2012; ISBN 978-1119941286.
62. Piątek, G. *Najlepsze Miasto Świata, Warszawa w Odbudowie 1944–1949 (The Best City in the World, Warsaw in Reconstruction 1944–1949, in Polish)*; Grupa Wydawnicza Foksal: Warszawa, Poland, 2020; pp. 103–104; ISBN 9788328097209.
63. Bittner, A.; Kądziela-Grubman, A.; Kwiatkowska, U. *Muzeum II Wojny Światowej w Gdańsku, Miedzynarodowy konkurs architektoniczny (Museum of the Second World War in Gdańsk, International architectural competition)*; Muzeum II Wojny Światowej: Gdańsk, Poland, 2010; pp. 19–21; ISBN 9788363029951.

64. Cymer, A. Centrum Kulturalno-Kongresowe Jordanki w Toruniu (Jordanki Cultural and Congress Center in Toruń, in Polish), Culture. 2020. Available online: https://culture.pl/pl/dzielo/centrum-kulturalno-kongresowe-jordanki-w-toruniu (accessed on 30 September 2023).
65. Bergson, H. *Introduction á la Métaphysique*; Payot: Paris, France, 2013; pp. 32–33; ISBN 978-2228909198.
66. Krenz, J. *Architektura Znaczeń (Architecture of Meanings, in Polish)*; Wydawnictwo Politechniki Gdańskiej: Gdańsk, Poland, 1997; p. 42; ISBN 83-86537-55-8.