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Indicators for Ex-Post Evaluation of Cultural Heritage Adaptive Reuse Impacts in the Perspective of the Circular Economy

Martina Bosone [1], **Pasquale De Toro** [2], **Luigi Fusco Girard** [1,2], **Antonia Gravagnuolo** [1] **and Silvia Iodice** [1,3,*]

1   Institute for Research on Innovation and Services for Development, National Research Council (CNR-IRISS), 80134 Naples, Italy; m.bosone@iriss.cnr.it (M.B.); l.fuscogirard@iriss.cnr.it or girard@unina.it (L.F.G.); a.gravagnuolo@iriss.cnr.it (A.G.)
2   Department of Architecture, University of Naples Federico II, 80134 Naples, Italy; pasquale.detoro@unina.it
3   Joint Research Centre, European Commission, 21027 Ispra, Italy
*   Correspondence: s.iodice@iriss.cnr.it

Abstract: Cultural heritage (CH) is considered a key element of cities and regions' identity and uniqueness, contributing to peoples' wellbeing and health, as well as jobs creation, environmental regeneration and place attractiveness. The adaptive reuse of abandoned and underused CH can be a sustainable strategy for heritage conservation, stimulating local development processes. However, heritage conservation needs large investments, while the resources available are scarce, and investment projects are subject to high uncertainties. Therefore, a careful assessment of impacts is needed to orient and direct CH adaptive reuse projects towards sustainability. Recent studies approach the adaptive reuse of abandoned buildings and sites as an effective circular economy strategy, potentially contributing to climate objectives through environmental regeneration and the reduction of natural resources consumption. However, evaluation tools to assess the impacts and orient adaptive reused interventions in the perspective of circularity are lacking. Through the analysis of 76 literature sources on CH impacts, this article explores how indicators are currently used in CH research and practice as impact assessment tools. More than 3500 indicators were retrieved and classified. Finally, this article proposes a comprehensive evaluation framework to assess the impacts of cultural heritage adaptive reuse in the perspective of the circular economy. The results showed that, while some indicators are available, many circularity aspects are not considered in the current studies on CH impacts.

Keywords: multidimensional indicators; evaluation tools; cultural heritage; adaptive reuse; circular economy; circular city; impact assessment; built environment; sustainable development

1. Introduction

Cultural heritage is considered a key element of city and region identities and uniqueness, potentially contributing to peoples' wellbeing and health, as well as to job creation, environmental regeneration and place attractiveness [1–5]. However, heritage conservation needs large investments, while the resources available are scarce and investment projects are subject to high uncertainties [6–9].

The adaptive reuse of abandoned and underused cultural heritage sites can be a strategy to enhance heritage conservation, stimulating sustainable development processes through new uses of old buildings and sites, co-creating new meanings and re-activating neglected areas, turning them into new vibrant cultural places [10–13]. Adaptive reuse is defined as "any building work and intervention to change its capacity, function or performance to adjust, reuse or upgrade a building to suit new conditions or requirements" [14]. Several authors [10,15,16] have stressed the importance of adaptive reuse for urban regeneration. Günçe and Mısırlısoy [17] explored how investments in adaptive reuse can contribute to revitalise neglected areas, thus improving the living standards for the local community and attracting consequently new investments that foster economic growth in a virtuous circle, enhancing sustainable urban development [18].

According to the recent literature, the adaptive reuse of abandoned and underused buildings and sites, which represent urban "wastes", also supports the implementation of the circular economy model in the spatial dimension [12,19,20].

The interrelations and boundaries between the two concepts of sustainability and circular economy have been addressed in the scientific literature [21], while a clear and agreed definition of circular economy has not yet been established [22,23]. According to the review of literature developed by Geissdoerfer et al. [21], circular economy can be defined as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling." Additionally, Sustainability can be defined as "the balanced integration of economic performance, social inclusiveness, and environmental resilience, to the benefit of current and future generations". In this paper, circular economy is interpreted as a new economic model, the implementation of which is instrumental to achieve long-lasting sustainability.

The current reviews of the literature on circular economy indicators showed that the most used indicators are related to waste management, raw materials, recycling rates, economic performance of circular businesses, energy, toxicity and clean material cycles [24,25]. A different study focused on the objectives of using circular economy indicators, classifying them based on a taxonomy of ten categories: levels, loops, performance, perspective, usage, transversality, dimension, units, formats and sources [26]. In particular, the social and cultural dimension of circular economy seem to be less explored in the studies analysed, providing less consideration on the impacts of circular economy initiatives on people and local communities [22,27,28]. Some initial studies indicate that implementing circular economy [29] may generate positive impacts on human health, pointing out the existence of a relationship between human health and climate change issues [30–33].

Even though circular economy started to be implemented in the built environment and building construction sectors in recent years [34,35], circular economy indicators are rarely applied to the specific cultural heritage sector [36,37]. The concept of cultural heritage adaptive reuse as an instrument to achieve circular economy goals at the territorial scale emerged more recently, but indicators linked to heritage conservation are quite often only linked to the environmental dimension, while integrated and multidimensional approaches are still lacking [11,12].

All in all, when it comes to the relationships between cultural heritage adaptive reuse and circular economy in general, few studies are currently available. Indirect approaches can be identified in the ecosystems services assessment frameworks [38–40]. For example, Stanik et al. [41] analysed cultural heritage from the perspective of cultural ecosystem services, with the aim of identifying and developing an indicator-based framework formed by indicators related to historic land uses and historic elements. Still, Gravagnuolo et al. proposed an evaluation framework for circular economy implementation in the adaptive reuse of cultural heritage [12], while Foster [42] associated the concepts of adaptive reuse, cultural heritage and circular economy, focusing on the environmental benefits of heritage conservation. More in depth, this paper performs a literature review to demonstrate the alignment between circular economy goals and adaptive reuse of heritage assets in a life-cycle perspective. Foster and Kreinin [43] also performed an in-depth review of environmental indicators for the adaptive reuse of cultural heritage in the perspective of the circular economy, able to demonstrate the environmental savings of adaptive reuse. Then, Foster et al. [44] developed a Circular Environmental Impact Indicator Framework for cultural heritage adaptive reuse in order to integrate macro-European Union-level indicators with environmental indicators at the micro scale.

Despite the huge range of studies developed in order to assess the multidimensional impacts of cultural heritage conservation, most of these studies focus on single impacts, for example cultural tourism, cultural and creative sectors, sustainability, wellbeing, while an integrated perspective is still missing and considerable efforts are still necessary [12].

Moreover, the decision-making processes for cultural heritage requires careful attention and cannot ignore the use of appropriate decision-making tools, hence in this context "evaluation can be considered a relevant tool to build choices, to recognise values, interests and needs, and to explore the different aspects that can influence decisions" [45]. Consequently, evaluation methods facilitate the decision-making process when different solutions are available, but different criteria have to be taken into account and the involved decision-makers may be strongly conflicting [46].

Moreover, the adaptive reuse of abandoned buildings and sites can represent a substantial contribution to circular economy implementation in cities and regions, if adequate design and reuse choices are taken, promoting environmental regeneration and avoiding over-consumption of soil, raw materials and other natural resources [12,42].

As there is a high potential for synergic outcomes, investments in cultural heritage adaptive reuse can be effectively directed towards circularity to actually generate net positive economic, social, environmental and cultural impacts in the territories [12,47]. However, evaluation tools to assess the impacts and orient adaptive reuse interventions in the perspective of the circular economy implementation in cities and regions are lacking [48,49].

1.1. Evaluation for Cultural Heritage Adaptive Reuse and the Need for New Criteria and Indicators

The concept of evaluation for cultural heritage and the general development of thematic criteria and indicators emerged since the late 1990s on an international level [50], and this is still confirmed by the more or less recent development of many documents and international papers [15,23–29].

However, despite the large body of literature on heritage evaluation tools and indicators, there is still confusion between terms such as "criteria" and "indicators". In this paper, the definition proposed by Milan Zeleny and recalled in Gravagnuolo et al. [12] is adopted, identifying "criteria" as the specific "points of view" through which a goal or objective is analysed and "indicators" as the elements through which criteria are assessed or "measured"—meaning, with "measure", both qualitative and quantitative assessments.

The objectives of using multidimensional criteria and specific indicators are diverse, from mapping and assessment of heritage attributes and values to ex-ante evaluations to assess heritage conservation vs. transformation choices to ex-post evaluations focusing on the actual impacts generated through heritage investments. In particular, ex-post evaluation is used in order to verify that the established objectives have been met, determining if there are unforeseen or unintended consequences and assessing in the meantime the performance of alternative approaches [51].

Della Spina [16] for example uses multi-criteria techniques in order to evaluate different adaptive reuse strategies, selecting a suitable set of indicators, pointing out the consideration of cultural heritage as a driver of urban development, as already also underlined by Guzmán et al. [52]. Elsorady [53] identifies a set of indicators with the goal of evaluating the compatibility of new uses for the adaptive reuse of heritage buildings, while Kutut et al. [54] analyse indicators to assess whether or not historic buildings should be reconstructed, where reconstruction is meant both as restoration of primary volumes but also preservation of as many authentic elements as possible. Stanik et al. [41] investigate the relationship between cultural heritage and cultural ecosystem services, developing an indicator-based framework aimed at mapping cultural heritage in the spatial dimension. Moreover, Nijkamp [55] gives an overview of cultural heritage evaluation methods, while Nocca [48] deepens the role of cultural heritage for sustainable development, stating that there is an insufficient amount of indicators that demonstrate this relationship.

The European research "Cultural Heritage Counts for Europe" analysed a large literature body on methods and tools for the assessment of impacts of cultural heritage conservation projects, highlighting diverse areas of impact based on the four pillars of sustainability: economic, social, environmental, cultural [56]. The reports of the "Heritage Counts" initiative developed in UK similarly explored the economic impacts of cultural

heritage, deepening also wellbeing aspects [57,58]. Diverse studies focused on indicators to place cultural heritage in the sustainable development agenda [48,49,59,60]. More recently, a research carried out by the "European Spatial Planning Observation Network" (ESPON) underlined the role of Material Cultural Heritage (MCH) as a strategic driver for sustainable territorial development, where MCH is meant as "Objects including different types of immovable (e.g., archaeological sites, cultural landscapes, etc.) and movable (e.g., paintings, books, etc.) MCH recognised as having heritage value in each country [. . .]" [61]. The ESPON research proposes three key indicators to assess the economic impacts of cultural heritage conservation, valorisation and reuse activities: Gross Value Added (GVA) of the share related to MCH; Turnover of the share related to MCH; Number of employees of the share related to MCH. In addition, the study also considered the following indicators to complement the analysis: Value of heritage volunteering; and Expenditure by the public sector on MCH (investments by public authorities on cultural services and spending on conservation, restoration, repair and maintenance of protected constructions).

1.2. Aim and Structure of the Paper

The existing literature body on the linkages between cultural heritage adaptive reuse and circular economy shows a potential in building a comprehensive framework of quantitative and qualitative indicators to assess performances and impacts of adaptive reuse interventions in a circular economy perspective.

Despite many indicators are already in use in the cultural heritage sector and attempts to systematise heritage indicators have been widely developed [48,49,59], the circular economy perspective still needs to be fully implemented. This paper aims to fill this gap by analysing and classifying existing heritage indicators, comparing them with circularity criteria. Through the analysis of 76 literature sources on cultural heritage impacts, this article explores how indicators are currently used in heritage research and practice as impacts assessment tools. More than 3500 indicators were retrieved and classified. Finally, this article explores the concept of circular economy in cultural heritage adaptive reuse, identifying specific impact criteria based on recent scientific literature, highlighting the knowledge gaps for future research.

The following Section 2 describes the methodology developed to analyse and systematise existing heritage indicators, while Section 3 describes the results of the analysis and proposes specific criteria for the future development of heritage indicators in the perspective of the circular economy. Section 4 discusses the results and the knowledge gaps emerging from this study. Section 5 provides critical conclusions, focusing on the limitations of this study and the potential for future research.

2. Methodology

2.1. What Is an Indicator? Some Basic Definitions

The methodology applied was based on previous studies focusing on indicators review, especially Saidani et al. [26], adapted to the specific aim of this research. First, the diverse definitions of indicator were explored, to prepare the successive phase of literature search, analysis and systematisation.

The definition of indicator is not univocally recognised and the nuances between "indicators", "criteria", "objectives" and "attributes" may be not always clear in the applications. Indicators can be interpreted at different decision levels and are always linked to a set of "criteria", meant as "points of view" recognised as relevant [12]. Finally, indicators can be used to assess impacts, i.e., any change from an initial condition to a subsequent condition and they are referred to ex-post evaluation. They can also be used to analyse the state of a certain aspect (ongoing evaluation) and finally they can also support the decision-making phase before the implementation of a certain project (ex-ante evaluation).

Heink and Kowarik [62] propose the following definition of indicator as a "measure or component from which conclusion on the phenomenon of interest (the indicandum) can be inferred". They underline the necessity of avoiding failure in defining technical

terms, proposing a systemic overview of existing definitions of the term indicator, with a special focus on ecology and environmental planning. According to Hockings et al. [63], indicators are "measurable entities that are used to assess the status and trend of a range of site values. A given value, objective, or additional information need can have multiple indicators. A good indicator meets the criteria of being measurable, precise, consistent and sensitive". Indicators represent also essential tools to synthesise complex information on the territorial functions, as they are able to monitor the state and the functioning of urban areas and to verify the achievement of predetermined goals [64]. Still, Zhang et al. [65] state that "indicators and measurement systems are an essential tool for ensuring management targets are reached [...]" and this was also confirmed by Stanners and Bordeau [66], who consider indicators as vital elements for developing awareness on urban issues.

Elaborating good indicators facilitates the decision-making phase, identifying limits and opportunities and thus reducing risks or costs. Through indicators, emerging issues and impacts can be envisaged, allowing corrective actions when necessary. Experts involved in the indicators elaboration are entrusted with the task of providing information that is comprehensible and credible by all for their correct use in the decision-making process [67].

Despite a huge quantity of definitions is available, in the present study we adopted the description of an indicator as «a quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect changes connected to an intervention, or to help assess the performance of a development actor» [68]. Indicators must always be clearly defined in theoretical and operational terms and they must be simple and understandable according to their scope.

2.2. Analysing and Systematising Heritage Indicators

After defining what is an indicator and for which scopes it may be used, the relevant literature on heritage indicators was collected and analysed. The methodology applied was based on two main phases, articulated into diverse steps:

- Phase 1: existing studies on indicators for cultural heritage impacts assessment were collected, analysed and classified following four main steps, to assess how indicators are currently used in research and practice.
- Phase 2: the conceptual framework of "Circular CHAR (Cultural Heritage Adaptive Reuse)" was built based on the analysis of previous studies on circular economy models in cultural heritage conservation and adaptive reuse; previous studies were collected, analysed and synthesised to propose a comprehensive framework of circularity criteria for CHAR impacts assessment in the perspective of the circular economy and circular city model; finally, circularity criteria were compared with existing heritage indicators sources, identifying knowledge gaps for further research.

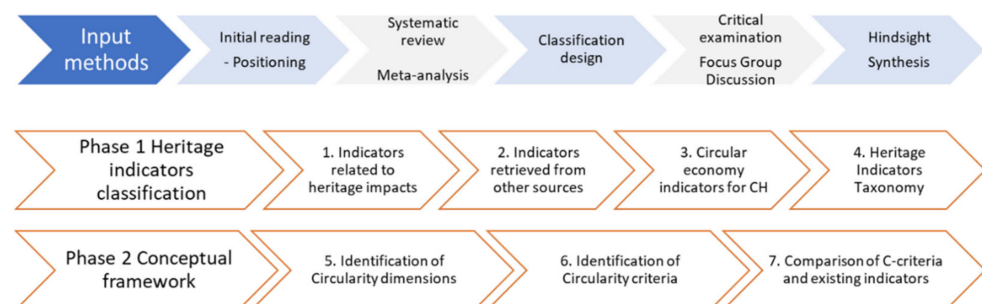Figure 1 summarises the methodological process highlighting the main phases and steps.

Figure 1. Methodological process to select, synthesise, analyse and systematise heritage indicators and build the Circular Cultural Heritage Adaptive Reuse (CHAR) impacts assessment framework.

2.2.1. Phase 1: Analysis and Classification of Existing Heritage Indicators

"Heritage indicators" are here meant as indicators directly or indirectly related to cultural heritage impacts. They were selected from existing studies, including scientific articles retrieved from Scopus/WoS, Google scholar and Italian scientific journals indexed by the national agency for research quality evaluation (ANVUR). Additionally, "grey" literature was collected from institutional sources, including both policy-related documents and practice-based guidelines. Some examples are documents by ICOMOS, UNESCO, European Commission, Historic England, as well as international organisations focused on circular economy such as Ellen MacArthur Foundation, ARUP, Club of Rome, and others. The selection process consisted of using specific keywords within the "Science Direct" database (up to the year 2020) to facilitate the search, such as: "cultural heritage adaptive reuse" (1.621 initial results), "cultural heritage sustainability indicators" (9.754 initial results) and "cultural heritage indicators" (16.170 initial results). To narrow the focus of our search, literature sources were selected giving priority to the most recent (years 2017–2020). Sources that did not present indicators and were not strictly related to impacts assessment were immediately excluded. An in-depth analysis of the identified literature sources was then performed, reading the abstracts and selecting the most relevant documents for further analysis. Subsequently, titles, abstracts and keywords were carefully read in order to select the relevant literature to be analysed in-depth. Starting from this initial sample of about 20 documents, the references of these sources were analysed to identify further documents that could be useful for our purpose and adding also grey reports retrieved from the web.

Initial reading was processed by selecting papers and studies that focused on the evaluation of impacts of cultural heritage conservation, presenting a set of evaluation tools, methods, criteria and/or indicators. As existing reviews of indicators were included, this study has the characteristics of a systematic review integrated with a meta-analysis of diverse sources, where the meta-analysis specifically refers to "the statistical analysis of the data from independent primary studies focused on the same question, which aims to generate a quantitative estimate of the studied phenomenon" [69].

The methodological process in Phase 1 is described below, with reference to Figure 1 and to the three steps indicated.

Step 1: Selection and analysis of studies specifically focused on cultural heritage impacts, including existing reviews of indicators. This first screening allowed to select 23 papers and studies focused on cultural heritage impacts. A comprehensive overview of the literature sources analysed in this step is presented in Appendix A. In analogy with the results of previous studies [25,26], a database of literature sources and indicators classifications was built.

Step 2: Selection and analysis of studies related to urban development and urban regeneration which include heritage indicators. Using the same procedure described in step 1, literature sources indirectly linked to cultural heritage or to some of its most relevant domains (for example cultural tourism or the creative and cultural sectors) were collected and analysed. These domains have been identified on the basis of the first screening of analysed sources. Only a sub-set of indicators linked to cultural heritage was retrieved and classified from the studies included in Step 2. These indicators can be adapted to assess relevant impacts related to cultural heritage adaptive reuse, such as cultural vibrancy in a certain area where a reused cultural building is located. A number of 48 literature sources was collected in Step 2 (see Appendix B).

Step 3: Selection and analysis of specific studies focusing on circular economy and circular city that include heritage aspects and indicators. Circular economy literature was analysed, particularly related to circularity in the built environment and building construction sector, circular city model, and the few specific studies available on "circular adaptive reuse of cultural heritage". According to this analysis, additional 5 sources and 54 indicators were retrieved (see Appendix C).

All the selected documents were thus classified based on the year of publication, type of source, and sector of implementation to provide a general overview of the studies regarding cultural heritage indicators and the indicators related to its impact sectors.

Step 4: Construction of a taxonomy of indicators. Existing heritage indicators were classified based on the taxonomy categories. A first tentative taxonomy of indicators was structured according to the objectives of the study and based on other taxonomies found in previous studies. In particular, Saidani et al. [26] proposed, between other categories, to classify indicators based on the "level" or "scale", "usage", "sustainability dimension", "transversality of the implementation sectors" and "type of sources". Additionally, Gravagnuolo et al. [12] proposed to identify relevant indicators of "circular adaptive reuse of cultural heritage", according to the "sustainability dimension", "typology" (quantitative or qualitative) and "scale of implementation". According to these reference studies and taking into account the specific objectives of this analysis, the final taxonomy was built.

The existing indicators included in these selected studies were analysed and classified according to the following categories (see Appendices A–C):

- Geographical scale (level): "macro" scale was assumed for indicators addressed at the national scale (NUTS 0) or regional scale (NUTS 2), "meso" scale for indicators at city level and "micro" scale for indicators at the scale of the heritage building or site.
- Evaluation phase (usage): "ex-ante evaluation indicators", when the assessment is performed before a specific project or reuse design is realised, in order to take informed choices between diverse alternatives, "monitoring indicators" when the assessment is performed during the implementation of a specific project and "ex-post evaluation indicators" used to examine the results of actions or activities and to compare the programmed measures with the actual results.
- Typology: qualitative, if based on perceptions or subjective and unquantifiable aspects (soft); and quantitative, if based on precisely measurable aspects (hard).
- Sustainability dimensions addressed: economic; social; cultural; and environmental—according to the "four pillars" approach proposed by "Cultural Heritage Counts for Europe" research [56].

The classification of existing indicators was performed based on the classification of the original studies. For example, some studies proposed a list of indicators in each sustainability dimension, which was useful to classify the specific indicators within the proposed taxonomy. Additionally, some studies focused on the urban dimension, therefore the related indicators were classified in the "meso" scale according to the proposed taxonomy. Where the classification in original studies was uncertain, indicators were compared with similar ones included in other studies expressing a clear classification with regard to the proposed taxonomy, which helped to identify a thorough and robust classification. Following this process, each indicator selected was classified according to all taxonomy categories.

2.2.2. Phase 2: Circular CHAR Impacts Assessment Framework Based on Criteria and Indicators

Phase 2 is aimed at building a conceptual and operational framework to assess the impacts of cultural heritage adaptive reuse in the circular economy perspective. This phase was focused on the identification of circularity dimensions based on previous literature (theoretical level), as well as evaluation criteria (operational level). The potential for implementation of the resulting "Circular CHAR" impacts assessment framework was finally assessed comparing the proposed criteria with the existing heritage indicators analysed in Phase 1, in order to identify robust domains of implementation and knowledge gaps for further research.

The methodological process in Phase 2 is described below, with reference to Figure 1.

Step 5: in-depth reading of the selected studies on circular economy/circular city/circular buildings was performed, including both a thematic-analysis and a content-analysis. This process led to the identification of the "Circularity dimensions", representing

the basis of the impact assessment framework for "Circular Cultural Heritage Adaptive Reuse" (Circular CHAR). The "Tripod model" (see Section 3.2) developed within the Horizon 2020 research project "CLIC: Circular models Leveraging Investments in Cultural heritage adaptive reuse" [11,70,71] was the main reference for the "Circular CHAR" framework developed in this study at the theoretical level.

Step 6: based on the mentioned "Tripod model" adopted, as well as previous literature on circular adaptive reuse of cultural heritage, a structured set of circularity criteria was identified, resulting in the "Circular CHAR" impacts assessment framework. The evaluation criteria proposed in the literature were synthesised and discussed during a series of 5 Focus group sessions conducted with an interdisciplinary group of 14 experts in heritage conservation, heritage economics, evaluation methods, circular economy, sustainable finance, economic spillovers of development projects and social impacts, including CLIC project researchers. Focus groups were conducted through in-person and online meetings between January and July 2020. During each focus group, an initial long list of proposed evaluation categories and related indicators retrieved from literature sources was discussed. Each expert was provided with preparatory documents and was asked to provide comments in written form for the next experts' meeting. During the five focus group sessions, the list of criteria was refined and synthesised to avoid overlapping and specify descriptions and definitions.

Step 7: the circularity criteria identified in Step 6 were compared with the existing studies and available heritage indicators analysed and classified in Phase 1, to assess the level of potential operationalisation of the Circular CHAR framework.

The following section describes in detail the results of each phase of the study.

3. Results

3.1. Results of Phase 1: Building the Heritage Indicators Literature Database

The analysed literature sources were classified according to the following criteria:

- Year of publication.
- Typology: institutional reports (i.e., report provided by Institutions), scientific articles, research reports, working papers, websites, handbooks and books.
- Scope: ranging from the sources strictly focused on cultural heritage impacts (cultural heritage), to sources addressing other sectors indirectly associated to cultural heritage impacts ("other topics") and, finally, to sources linked to the concept of circular economy applied to cultural and built heritage.
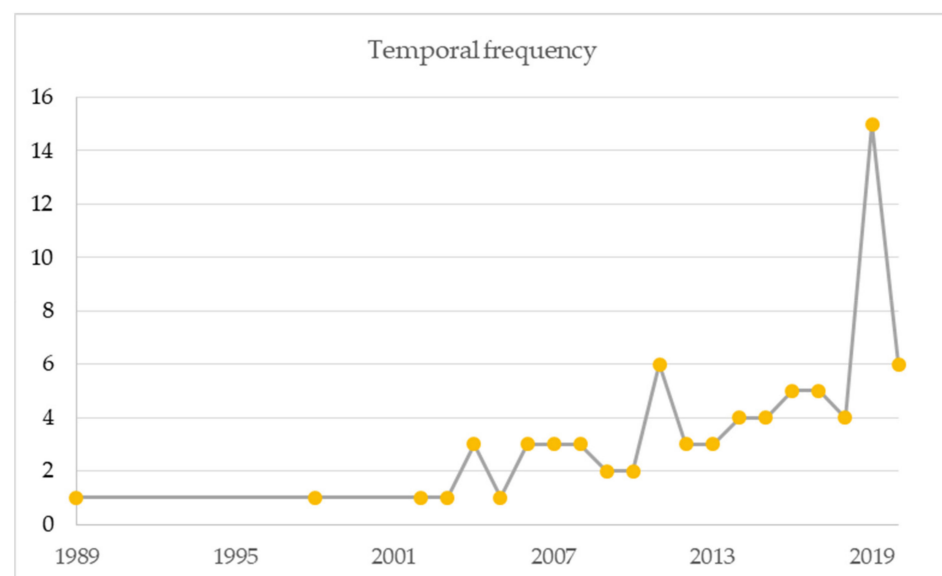

Figure 2. Temporal frequency of the analysed sources.

A total of 76 literature sources was analysed. Figure 2 shows the temporal frequency of publications from the 80s to 2020. It can be recognised an increasing attention to heritage indicators over time, with the highest frequency in the last ten years. This attention is growing, with a peak in the more recent years (2014–2020).

The typology of literature sources analysed showed a significant prevalence of institutional reports (about 35.5%) and scientific articles (32.9%). Research technical reports represented about the 22.3% of the total sources collected, while working papers, books and websites were present only for a small percentage (between 2.6 and 1.3%). In particular, websites were used as a source from which analysed indicators were directly deduced. These are online information and monitoring platforms used by international associations and organisations to assess and support cultural heritage strategies.

The "Compendium of Cultural Policies & Trends" [72] is an online database with in-depth information on cultural policies, statistics and trends. It shows two monitoring categories, "Statistics" and "Comparison", each of which is subdivided into sub-categories from which the indicators have been derived directly.

The Eurostat "Circular Economy Indicators" [73] is a monitoring framework set up by the European Commission. The framework consists of ten indicators, some of which are broken down in sub-indicators, for a total of 16 indicators. Compared to the four categories suggested in the framework ("Production and Consumption", "Waste Management", "Secondary Raw Materials" and "Competitiveness and Innovation") the indicators were reorganised and adapted to the four dimensions proposed in this research.

Academic and practice literature was included, so that the database is representative of theoretical and practical knowledge (Figure 3a).
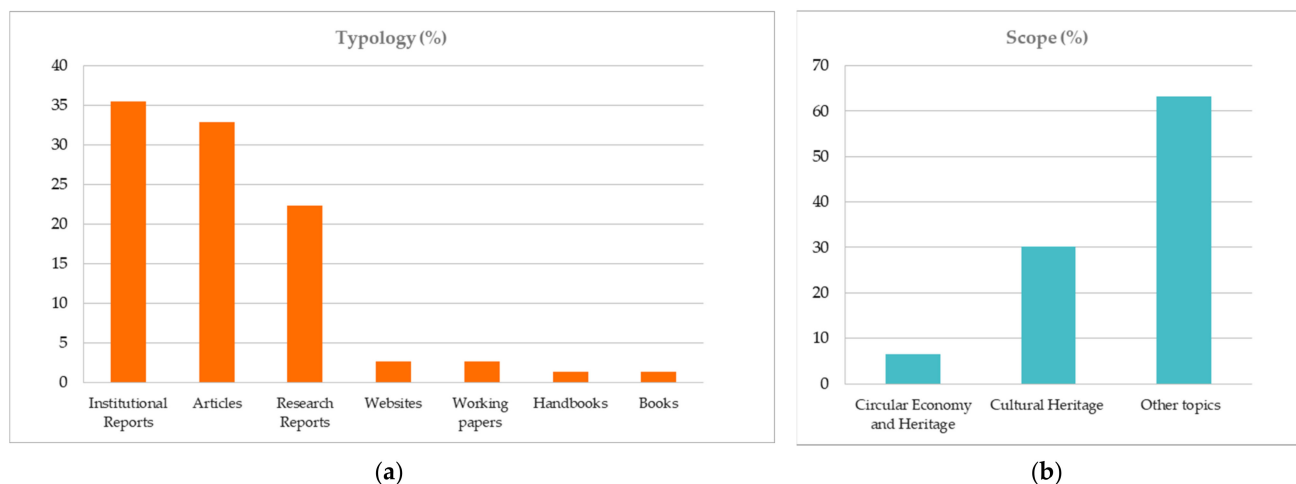

(**a**)   (**b**)

Figure 3. Classification of the analysed sources according to (**a**) Typology; (**b**) Scope.

Literature sources were classified according to their scope. The first group was made of 23 sources specifically related to "Cultural heritage" (30%). The second groups included 48 sources not specifically related to cultural heritage, but in which heritage-related indicators are present, classified as "Other topics" (63%). As already specified, for those sources, only a sub-set of indicators was analysed. Indeed, indicators were selected both from sources strictly linked to cultural heritage, and from sources linked to broader sectors, such as circular built environment. In this last case, studies and indicators that are very far from our scope could also be found. Therefore, only those indicators useful to evaluate the circularity of cultural heritage adaptive reuse have been selected, according to the boundaries of the investigation as set out in the methodology section. Finally, a number of 5 sources related to "Circular economy & cultural heritage", as well as built environment was identified (7%), in which all indicators were considered for the successive analysis (Figure 3b).

A number of 3543 relevant indicators was collected and classified according to the proposed taxonomy: geographical scale, evaluation phase, typology and sustainability dimension addressed.

Figure 4 shows how the indicators are distributed and classified. In particular, Figure 4a shows that most of the indicators are applied at the macro scale of the region or state (52.6%), followed by indicators applied at the meso scale of the city and urban areas (34.2%) and a smaller percentage applied at the micro scale of the building or site (13.2%). While the adaptive reuse interventions on cultural heritage are mostly realised in specific buildings or sites, there is evidence of a lack of indicators supporting the evaluation of impacts at the "micro" scale. Regarding the evaluation phase, it has been identified according to the scope of the evaluation in the original sources. Figure 4b shows that most indicators are applied in the ex-post evaluation phase (94.6%), highlighting a particular focus of existing policies and practices in the post-realisation phase, according to the literature sources selected. Clearly, it is important to assess the impacts of heritage conservation, reuse and valorisation projects after their realisation. The ex-post assessment should also represent a starting point for future practices, learning from the past to take better choices. However, the scarce attention in the ex-ante and ongoing/monitoring evaluation seems to highlight that evidence-based evaluations are poorly adopted in the planning and design stages. The classification of indicators was conducted based on clear information retrieved from the reference sources, as well as comparison with other similar indicators used in other studies. However, in some cases the classification was uncertain, due to the unclear definition of the fields of application of the reference documents analysed. Therefore, some indicators were exclusively classifiable as "ex-post", while in other cases the classification of indicators usage was flexible and could be applied in different phases of the evaluation. It should also be noted that, in order to build effective decision-support tools, evidence-based data should be collected on extensive scale and following structured, harmonised and agreed approaches, building datasets that can support as far as possible the estimation of key indicators in the ex-ante design and planning phase. Quantitative indicators are needed in this sense and represent the 66.3% of all indicators included in the database, as showed in Figure 4c, while 33.7% are qualitative indicators based on "soft" data mostly represented by citizens and stakeholders' perceptions, as well as spatial or visual representations. Observing the sustainability dimensions addressed, it is possible to note that indicators related to the social dimension represent the majority (33.4%), economic indicators are also well represented (28.7%), and indicators related to the cultural dimension represent the third group (25.1%). Indicators related to the environmental dimension of heritage conservation are limited (12.8%), which highlights that the environmental impact of heritage conservation has been quite disregarded in the heritage sector, not representing a particular focus for researchers and practice stakeholders. However, as stated by Fusco Girard et al. [11,12,42], a circular economy approach in heritage conservation could substantially contribute to achieve climate objectives and reduce the overall costs of conservation, turning it into an "investment".

Phase 1 of the analysis resulted in a better understanding of the actual use of indicators in the heritage field as well as in heritage-related additional sectors. The database of literature sources analysed in this study is available as Supplementary Materials. Between the literature sources scope groups, the circular economy was identified as an emergent issue for cultural heritage research, since many studies related to circular economy have been proposed in the most recent years. Therefore, a set of specific dimensions and criteria of circularity was identified in Phase 2 to build a comprehensive impacts assessment framework for Circular CHAR.

Figure 4. Classification of indicators according to (**a**) Geographical scale; (**b**) Evaluation phase; (**c**) Typology; and (**d**) Sustainability dimensions.

3.2. Results of Phase 2: Circular CHAR Structured Framework of Criteria and Indicators

According to the existing literature on cultural heritage adaptive reuse in the perspective of the circular economy and circular city model, a structured set of evaluation criteria was developed, aimed to reflect the circular economy perspective in CHAR.

In Step 5, the diverse general definitions of circular economy were explored [22], identifying a specific definition of circular economy for cultural heritage adaptive reuse based on recent literature. One of the key studies analysed was Gravagnuolo et al., which defines the circular economy in cultural heritage adaptive reuse as "a sustainable economy that enables a continuous positive development cycles that preserve and enhance the created values, in an indefinite time, of cultural and natural capital, optimises resource yields and minimises system risks by managing finite stocks and renewable flows" [12]. In the mentioned study, the main characteristics of the circular economy model for cultural heritage were identified, including diverse frameworks such as the 9 Rs approach (Reuse, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover) [74,75], and the ReSOLVE framework proposed by Ellen MacArthur Foundation (Regenerate, Share, Optimize, Loop, Virtualize, Exchange) [76–78]. Therefore, according to Gravagnuolo et al. and other relevant scientific articles [12,79,80], a first set of evaluation criteria for CHAR was developed, highlighting potential and actual impacts of CHAR projects in the eco-

nomic, social, cultural and environmental dimension. The following dimensions of circular economy implementation in CHAR were initially identified:

- Conservation and regeneration of cultural heritage values—linked to cultural capital regeneration, both tangible and intangible.
- Circular economy implementation in building/site recovery works—linked to natural capital regeneration through technologies for energy, water, wastes, materials, including nature-based solutions.
- Impacts in the local context—including jobs creation, attractiveness of the place for businesses, cultural tourism, residents, commercial and artisanal activities.
- Circular business, financing and governance models applied—linked to inclusiveness in the decision and management process engaging local communities, capacity of generating revenue flows able to cover investments and management costs, sustainability of financing sources.

According to the research conducted under the Horizon 2020 CLIC project, the conceptual framework of the "Tripod model" was analysed. A further study of Gravagnuolo, Fusco Girard, Kourtit and Nijkamp [70] specified the conceptual evaluation framework placing CHAR in the perspective of the circular city model, identifying three main critical drivers or "building blocks" of circularity:

- a "regenerative capacity" [70] linked to the self-regeneration of the cultural assets, as well as of the economic, environmental and social resources needed for its maintenance over time (in analogy with the circular economy principle of extending the use value of resources in the largest time horizon possible).
- a "generative capacity" [70], linked to the net positive economic, environmental and social externalities generated in the area/territory—which in part come back to the heritage asset.
- a "symbiotic capacity" [70], linked to the cooperation and collaboration approaches that enable a more efficient use of resources (such as those realized in "industrial symbioses"), as well as clustering processes in the territory (implementing an "economy of relationships").

Thus, the work conducted under the CLIC research project was integrated in the conceptual framework presented in this article. According to Luigi Fusco Girard, the auto-poietic model of nature regeneration is embedded in the theoretical framework of circular adaptive reuse of cultural heritage [11,71,81]. As natural systems, the heritage site can be interpreted as a "lively regenerative/auto-poietic system", able to self-generate the resources needed for its functioning and to use all wastes as resources for new productive cycles [71]. Through the circular economy approach applied, it is possible to interpret and evaluate the adaptive reuse process identifying diverse forms of capital that are regenerated: man-made capital, natural capital, social capital, human capital. The model of circular CHAR was initially tested through empirical evidence based on a large dataset of 126 projects in CHAR, identifying a set of "building blocks" of circularity through statistical methods: Cultural value, Management characteristics, Circular metabolism, Landscape quality, Social impact, Economic spillovers [82].

Based on the conceptual evaluation model of "Circular CHAR", and its initial implementation through case studies analysis, a structured set of evaluation criteria for circular adaptive reuse of cultural heritage was built. The "circularity dimensions" as proposed by Luigi Fusco Girard as the "Tripod model" and recalled in Gravagnuolo, Fusco Girard, Kourtit and Nijkamp [70] were considered:

- The "regenerative capacity"
- The "symbiotic capacity" and
- The "generative capacity".

Once defined the main circularity dimensions based on the "Tripod model", in Step 6, an initial long list of evaluation criteria was developed. Circularity criteria were thus

discussed during a series of 5 Focus group sessions conducted with an interdisciplinary group of 14 experts including CLIC project researchers.

A number of 40 resulting criteria resulted from different rounds of discussion. A description was provided for each criterion (Table 1). Finally, the circularity criteria were compared with existing indicators retrieved and classified in the first phase of the analysis. The level of operationalisation of the impact assessment framework was assessed based on three aspects considered:

- Criteria for which well-established evaluation methods and indicators are available, based on the meta-analysis of heritage impacts studies (visualized with symbol "O" in Table 1).
- Criteria for which evaluation methods and indicators could be available from existing sources but should be adapted to the circularity framework (visualised with symbol "Δ" in Table 1).
- Criteria for which well-established evaluation methods and indicators are currently not available, or only few studies could be detected in recent years, showing a knowledge and implementation gap with regard to existing heritage indicators potentially applicable. These criteria may actually represent a new field of study for circularity and cultural heritage, which can be further developed/enhanced within the Circular CHAR: Intrinsic value, Local circular economies, Heritage community, Circular metabolism, Smart Specialisation Strategies, Wellbeing and Health impacts (visualised with symbol "X" in Table 1).

Table 1. Evaluation framework of criteria for Circular Cultural Heritage Adaptive Reuse.

Circularity Dimension	Criteria	Sustainability Dimension	Description/Motivation	Comparison with Current Indicators
Regenerative capacity (auto-poietic capacity)	Authenticity and integrity	Cultural	Regeneration of cultural capital, tangible and intangible, through conservation of heritage authenticity and integrity as defined by UNESCO and ICOMOS	Δ
	Intrinsic value	Cultural	Re-generation and transmission of heritage values and meanings through the adaptive reuse intervention, also through hybridisation between historic and contemporary values integrated with cultural landscape and coherent with the intrinsic value of cultural heritage	X
	Financial self-sustainability	Economic	Self-generation of financial resources needed for heritage conservation and continuous maintenance, through diverse revenue flows from reuse activities; independence of financial sources from public sector	Δ
	Local circular economy	Economic	Circular re-use of profits in the local context for further adaptive reuse projects and/or activities in additional heritage buildings or sites, circular entrepreneurial activities, social and solidarity economy activities; Local resources such as food, craft, materials are valorised through the adaptive reuse; stimulation of local investments and economic activities linked to proximity	X
	Energy efficiency	Environmental	Self-generation of energy sources for the operational phase through renewables, also reducing energy consumption needs through heritage-compatible technologies	O
	Freshwater efficiency	Environmental	Self-generation of water resources for the operational phase through water capture, filtering and reuse systems	O
	Nature-Based Solutions	Environmental	Regeneration of natural resources through nature-based solutions aimed to enhance air quality, freshwater quality, green surfaces	O

Table 1. *Cont*

Circularity Dimension	Criteria	Sustainability Dimension	Description/Motivation	Comparison with Current Indicators
	Soil recovery	Environmental	Remediation of polluted soils and brownfields, land recovery through reuse interventions	O
	Heritage community	Social	Self-organisation capacity of active citizens to build a cohesive and pro-active Heritage Community for heritage conservation, valorisation and adaptive reuse	X
	Local community	Social	Enhancement of skills, education and learning opportunities for the local community	Δ
	Traditional skills	Cultural	Enhancement of traditional skills through the adaptive reuse, incl. rehabber approaches and training opportunities	Δ
	Local identity	Cultural	Contribution of the adaptive reuse intervention to local identity; enhanced access to the educational function of cultural heritage	Δ
	Mutual cooperation	Cultural	Attitude of stakeholders to mutual cooperation, sharing common resources, knowledge, assets; involvement of third sector actors and/or sharing economy actors in the adaptive reuse; Collaboration pacts/agreements between public, private and people are implemented	Δ
	Cultural and knowledge capital production	Cultural	Knowledge production and cultural production stimulated by the adaptive reuse intervention	Δ
Symbiotic capacity	Circular metabolism	Economic	Realisation of circular supply chains to reduce costs of energy, wastes, materials, water achieving circular metabolism of heritage buildings and sites	X
	Smart Specialisation Strategies	Economic	Contribution of the adaptive reuse intervention to regional development, through coherence of the reuse functions and processes with regional Smart Specialisation Strategies	X
	Construction & Demolition Wastes	Environmental	Avoided Construction & Demolition Wastes through the adaptive reuse intervention	O
	Materials extraction	Environmental	Avoided raw materials extraction through the adaptive reuse intervention	O
	Participation in decision-making	Social	Involvement of diverse stakeholders and citizens in the decision-making process for the adaptive reuse	Δ
	Social cohesion	Social	Increase of trust and awareness of present and future generations' needs and rights	Δ
	Civic pride	Social	Enhancement of civic pride, belonging and civic responsibility; shared values and bonds in the local community, openness of the local community	Δ
	Cultural vibrancy	Cultural	Enhancement of cultural activities and events as a result of the adaptive reuse; enhanced access to culture and cultural heritage	Δ
	Creativity and innovativeness	Cultural	Enhancement of creativity and innovativeness as a result of the adaptive reuse	O
Generative capacity	Jobs creation	Economic	Creation of long-term jobs, directly and indirectly linked to the adaptive reuse	O
	Economic spillovers	Economic	Indirect and induced economic impacts in the area incl. diverse sectors such as building construction, cultural and creative activities, tourism, education and training, technologies for sustainability, research and innovation, entrepreneurship, etc.	O

Table 1. *Cont*

Circularity Dimension	Criteria	Sustainability Dimension	Description/Motivation	Comparison with Current Indicators
	Public finance benefit	Economic	Avoided costs for public finance and direct and indirect benefits from adaptive reuse interventions	Δ
	Attractiveness for creative, cultural and innovative enterprises	Economic	Localisation of innovative entrepreneurs, cultural and creative industries, research and development activities	Δ
	Attractiveness for residents	Economic	Localisation of permanent or temporary residents as a result of the adaptive reuse	Δ
	Attractiveness for circular cultural tourism	Economic	Localisation of economic activities linked to circular cultural tourism and hospitality as a result of the adaptive reuse	Δ
	Soil consumption reduction	Environmental	Avoided natural and fertile soil consumed, incl. for new buildings construction	O
	Air quality and microclimate	Environmental	Contribution to air quality and microclimate quality in the heritage context area	O
	GHG emissions reduction	Environmental	Contribution to GHG emissions reduction, incl. embodied energy valorisation of buildings and sites	O
	Water quality	Environmental	Contribution to enhancement of water quality in urban and rural environment	O
	Biodiversity	Environmental	Contribution to biodiversity conservation and enhancement, incl. actions to halt and reverse biodiversity loss	O
	Landscape quality and atmosphere	Social	Contribution to beauty and harmony of the landscape, enhancement of "place atmosphere", place-making	Δ
	Safety of public spaces	Social	Contribution to safety and accessibility of public spaces "for all"	Δ
	Cleanliness and healthiness of public spaces	Social	Contribution to cleanliness and healthiness of public spaces	Δ
	Quality of life for residents	Social	Contribution to objective elements of quality of life of residents, incl. presence of proximity shops, avoidance of gentrification effects and "touristification" of heritage sites	Δ
	Health	Social	Contribution to health incl. healthy materials, green installations, indoor air quality, natural lighting, noise control, electromagnetic pollution, healthy productions (e.g., healthy food in rural landscapes), mental health	X
	Wellbeing	Social	Enhancement to self-perceived wellbeing for citizens and users, related to the adaptive reuse intervention	X

Figure 5 visualises circularity criteria structured into three groups: "Resources" linked to the re-generative capacity. "Circularity enabling factors" linked to the symbiotic capacity in the context area and "Outcomes" linked to the generative capacity of the heritage system.
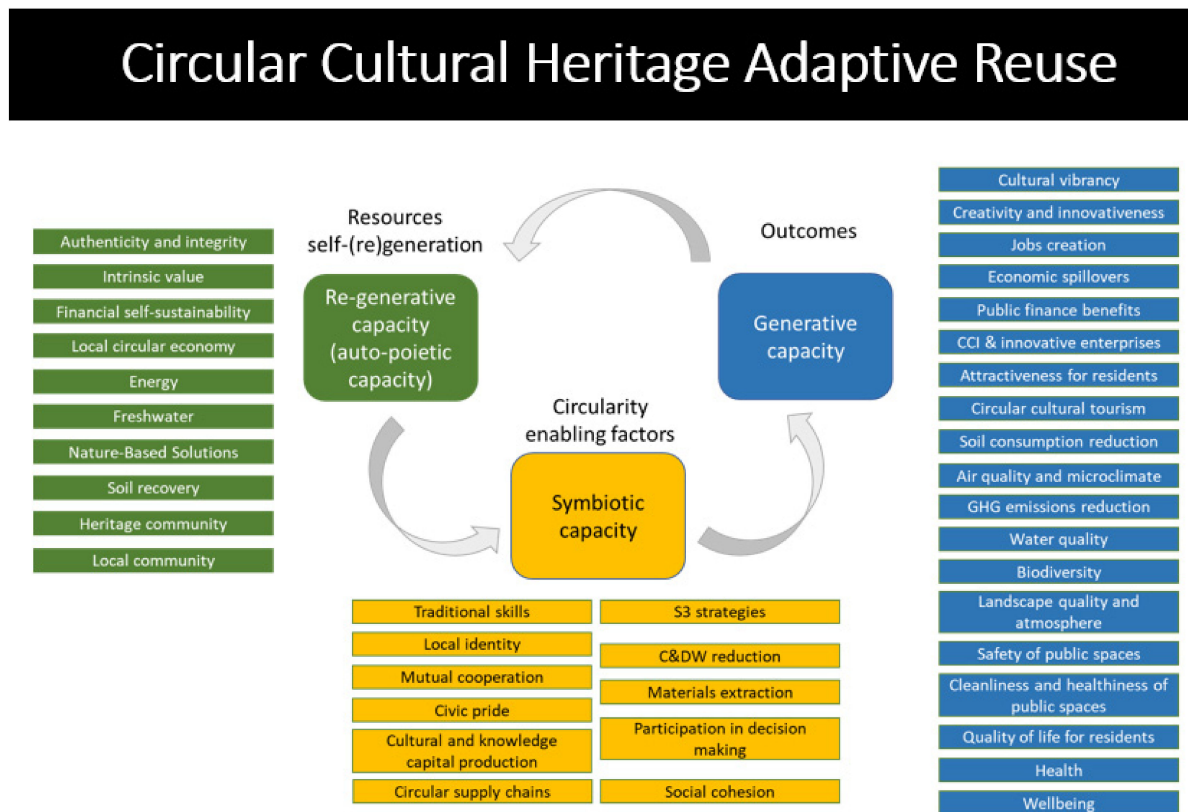
Figure 5. Visualisation of Circular CHAR database of criteria (Source: adapted from "Tripod model" by Luigi Fusco Girard, Horizon 2020 CLIC project).

4. Discussion

The performed literature structured review and meta-analysis has demonstrated that still many different interpretations of heritage indicators exist and there is still a lack of agreement in the scientific community to achieve a more uniform vision. Results showed that while some indicators for cultural heritage impacts assessment in the perspective of the circular economy are available, many relevant circularity aspects are not considered in current studies on cultural heritage impacts. Different indicators with a ranging degree of connections to cultural heritage have been developed over the years with a gaining attention especially in the most recent period. Yet, considerable effort is still necessary in order to reach a shared and harmonised vision on which is the most appropriate set of indicators to be used to assess the impact of cultural heritage adaptive reuse in a circular perspective.

From the point of view of the methodological approaches identified in the diverse sources analysed, a general confusion between criteria and indicators was observed, due to the lack of reference to a reliable and scientifically valid definition of indicators and how they should be used in heritage impacts research. The confusion present at the theoretical level is reflected at the practical level in the lack of a clearly defined and comprehensible structure that follows the methodological rigour of defining objectives, criteria and indicators. The result is a high variability of approaches in which, in the face of a declared and common need to identify an evaluation framework for heritage impacts assessment, each study approaches the subject from a diverse perspective. The lack of a clear methodology also impedes its replicability and could lead to slow down progress in this field.

This study proposed a structured review integrated with a meta-analysis of different kinds of sources, selected on the basis of the presence of indicators directly or indirectly linked to cultural heritage. More specifically, we proposed a classification of the sources

according to the typology and the impact sectors and our findings show that one of the most used typologies of sources is the Institutional Report on cultural and creative sectors, while the sources directly dealing with cultural heritage ranked second. Furthermore, the temporal frequency graph shows that attention to these issues is growing rapidly and it has undergone a significant increase especially in recent years. Secondly, we proposed a classification of the indicators based on the dimension, scale, evaluation phase and typology. Our findings show that most of the proposed ones are quantitative indicators belonging to the social dimension, referring to the macro scale and allowing to perform an ex-post evaluation. From the literature review conducted, it is evident that there is a lack of a defined and shared methodology for the evaluation of the multidimensional impacts of the adaptive reuse of cultural heritage in the perspective of the circular economy. This gap does not only concern an operational aspect, but rather originates from a sectorial "pillar" approach that hinders the reading of the relations and connections existing between different aspects that characterise the complex reality in which we live.

It is clear that, although the idea that cultural heritage contains both tangible and intangible values is now widely accepted, hard values, which are tangible and therefore measurable, are dominant because in decision-making processes they offer the possibility to choose on the basis of objective data. This means that soft, intangible and non-monetisable values are still neglected and this tendency was confirmed in our analysis by the predominance of quantitative over qualitative indicators. Proposing a multidimensional assessment of the impacts of the adaptive reuse of cultural heritage from the perspective of the circular economy model implies adopting a systemic perspective that is embedded in this model, capable of considering connections and interrelationships that exist between different systems. Despite the undeniable complexity, the evaluation tool can be interpreted as a means for simplification. It would not only orient the evaluation process towards an integration of the different values but would also favour a better management of the criticalities that the decision-making process itself poses at each stage of its development.

Analysing the specific scopes and domains of application of heritage indicators, the sources belonging to scopes "other than cultural heritage" have been taken into account to broaden the view and consider all the possible multidimensional impacts connected with the adaptive reuse. Among them, it can be highlighted that the cultural and creative sector domain includes specific indicators related to cultural heritage and to its potential impacts [25,67–69]. Another category of indicators that can be transferred to the cultural heritage sphere comes from the tourism sector, with a view on sustainability and culture. Indeed, Vecco and Srakar [83], while dealing with the difficult issue of building a sustainability index for cultural heritage, discovered that the biggest effort is generally dedicated to the relationship between sustainability and cultural heritage tourism. Among the additional analysed papers, many focus on sustainability in tourism, for example Asmelash and Kumar [84] try to link sustainable heritage tourism with tourist satisfaction, while Blancas et al. [85] deal with the construction of composite indicators for the sustainability assessment of a destination, including heritage-related indicators [85]. Moreover, Choi and Sirakaya [86] try to measure community tourism development, establishing a set of indicators according to five different dimensions (economic, social, cultural, ecological, political, and technological) and in the same way Lozano-Oyola et al. [87] build a sustainable tourism indicator system for cultural destinations. In this context, it is also worth mentioning the analysis of Ngamsomsuke et al. [88], who develop a set of indicators for sustainable cultural heritage development.

A further important correlation, when we deal with adaptive reuse as a means to implement circular economy, is represented by sustainability and circular economy in the built environment. Regenerating abandoned cultural heritage assets and landscapes determines the reduction of land consumption and the preservation of ecosystem services as well as the reduction of Construction and Demolition Waste (CDW) and the valorisation of embodied energy, i.e., the energy required in all the life cycle phases linked to the creation of the building [47]. Consequently, there is an urgent need of developing

environmental indicators able to quantitatively demonstrate how adaptive reuse has positive repercussions on the environment and reduces the input and output flows, from an Urban Metabolism (UM) perspective. Some initial studies focus on the benefits of adaptive reuse, underlining the significant reductions in energy consumption and in the emission of environmental carbon dioxide and other greenhouse gas, fossil fuel consumption, fresh water consumption, and materials use [42]. Foster and Krenin review the state of the art of the environmental indicators used for cultural heritage adaptive reuse [43]. From their analysis, it is clear that there are already many connections between the circular economy and the built environment and especially between cultural heritage adaptive reuse and the subsequent environmental advantages. As a matter of fact, "CE means using what is already there to maximise the use of embodied energy and materials in existing building stock. The challenge is that existing building stock, including cultural heritage buildings, must be refurbished and reused to meet the goals of a low-carbon economy" [43]. Despite this, the results of their research also underline that environmental indicators are rarely applied in cultural heritage adaptive reuse projects, pointing out the gap that exists between the indicators commonly used when we deal about circularity and the use of more specific indicators aimed at demonstrating the environmental advantages of cultural heritage adaptive reuse applications.

Finally, according to the results of the study conducted, interesting emerging fields of research intersecting circular economy and cultural heritage adaptive reuse are related to Intrinsic value, Local circular economies, Heritage community, Circular metabolism, Smart Specialisation Strategies, Wellbeing and Health impacts. For example, the concept of Intrinsic value of cultural heritage was proposed by Fusco Girard in 1987 [6] and further explored by Fusco Girard and Nijkamp in 1997 [8], but only recently the concept was developed by Fusco Girard and Vecco applying it to cultural heritage adaptive reuse [89,90], while operational tools and specific indicators for its assessment are still to be developed. On the same line, Gustafsson and Stanojev developed research on Smart Specialisation Strategies for cultural heritage adaptive reuse, pointing out the need of directing regional investments to achieve inter-sectorial synergic outcomes including cultural heritage adaptive reuse [91,92]. Moreover, the heritage community is another aspect related to a circular cultural heritage adaptive reuse as resulting from this study. However, indicators for assessing the role and contribution of the heritage community to cultural heritage adaptive reuse are still in their infancy and only few attempts have been made to structure robust evaluations [93]. Another important sector that can be in some way significant to associate to the adaptive reuse of cultural heritage is that related to wellbeing and health. Generally, there is not a direct correlation between cultural indicators and Societal Well-Being (SWB), with the exception of the Italian BES (equitable and sustainable well-being), while only few authors addressed the relationships between human health and heritage regeneration [94]. Therefore, considerable effort is still necessary to create this kind of correlation.

5. Conclusions

This paper provided a structured review and meta-analysis of literature sources on heritage impacts indicators, defining an impact assessment framework for cultural heritage adaptive reuse in the perspective of the emergent circular economy and circular city model (Circular CHAR impacts assessment framework). A classification of the selected sources and the indicators was performed, according to simple categorisations. The novelty of this paper consists in the attempt to link the concepts of cultural heritage, adaptive reuse and circular economy in an overall comprehensive impacts assessment framework that takes into account an enlarged definition of circular economy from a "human-centred" cultural perspective. This approach has been proposed within the Horizon 2020 CLIC research project and adopted as key reference for this study.

The main challenge with respect to the identification of a comprehensive impact assessment framework for circular adaptive reuse of cultural heritage is the definition of a common and recognised framework of criteria and indicators to assess quantitatively

and qualitatively the multidimensional impacts of cultural heritage adaptive reuse projects and their ability to "close the loops" of diverse resources flows in line with the circular economy principles. The analysis conducted in this paper allowed to build a first and preliminary matrix of Circularity dimensions and criteria for Circular CHAR, open to further developments. The "Circular CHAR" impact assessment framework was structured for ex-post evaluation. Assuming the systemic perspective of the circular economy model implies that the evaluation phase should not be limited only to the ex-post assessment, taking into account the potential of using a structured framework of criteria and indicators also in the ex-ante and monitoring stages of the CHAR process, supporting decision-making and strategic planning processes and allowing to intervene in a preventive way to orient choices towards sustainability. Therefore, the Circular CHAR developed in this paper can be an excellent monitoring tool for circularity that allows coherent intervention on cultural heritage.

Circularity criteria can be adopted for ex-ante evaluation linked to decision-support systems, however cautious attention should be put to adapt the indicators and evaluation methods, since some of the impacts may be hard to be estimated and would need the identification of proxies to be used within multi-criteria analysis methods. Additionally, in the case of ex-ante evaluation (decision-support oriented), the involvement of multiple stakeholders and "points of view" could be key for effective and shared decisions in the longer term. It is important to highlight that the number of criteria identified for a full circularity assessment in ex-post evaluation can be hardly used in ex-ante decision-support evaluations. As decisions require the involvement of decision-makers, it is important to ensure that a limited number of relevant criteria are identified. For ex-ante evaluations, the relevant criteria can be selected according to the scale, stage and data availability of indicators. A hierarchy of priority for criteria and indicators can be identified applying diverse multi-criteria decision aiding approaches. The exercise of reducing and prioritising criteria and indicators in ex-ante evaluation processes would benefit the effectiveness of decisions, including the point of view of multiple actors and interests. In this way, indicators can become a tool for discussion and sharing between community members, facilitated by open and deliberative laboratories such as policy labs [95,96].

Finally, there must be no time lag between the transition to a "circular" and "human-centred" model of sustainable development and the elaboration and implementation of multidimensional assessment processes: these two perspectives should be integrated from the outset into ongoing evaluation processes in order to bring about a real change in the definition of strategies and actions at both local, national and international level.

The possible limitations of the study can be linked to subjective interpretations of indicators that was noticed in the first phase of the analysis, establishing ad hoc rules in order to position correctly the indicators within the categorisation table. We see therefore a need for in-depth studies aimed at improving the definition of indicator and at proposing well-established matrixes, with a clear distinction between quantitative and qualitative variables. Indeed, one of the greatest difficulties encountered while conducting the study consisted in identifying the typology, scale and sustainability dimension of the indicators. For example, depending on the context, indicators can be placed in the economic rather than cultural or social dimension. Sometimes there is a very thin and blurred boundary between these dimensions, and it would be appropriate to present more exhaustive descriptions and clearly structured matrices in future analyses, in which all the attributes that characterise the proposed indicators are shown. With regard to the environmental dimension, this is more easily recognisable, but at the same time very rare and only few studies addressing the environmental advantages of CHAR have appeared in the international literature. This opens the ground for new analyses linked to the environmental implications of cultural heritage adaptive reuse at different scales, therefore not only the single building, but also the possible impacts on the circular city metabolic functioning.

Finally, it is worth to note that the contribution of cultural heritage to the implementation of the European Green Deal [97] has been recently highlighted by ICOMOS and Europa

Nostra to build an internationally agreed "cultural heritage green policy agenda" through the European Cultural Heritage Green Paper [81]. The present study aimed to contribute to the evolving international policies scenario for CHAR by providing a comprehensive framework that could be used at different levels for planning and design, as well as for the assessment of planned, ongoing and realised CHAR projects.

Appendix A

Table A1. Literature sources on cultural heritage impact sectors and indicators. Ec: Economic indicators, S: Social Indicators, En: Environmental Indicators, C: Cultural Indicators.

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
Nijkamp [55]	1989	Article	6	3			3	Meso	Ex-post	3	3
Pearson et al. [98]	1998	Institutional Report	139	19	9	36	75	Meso	Ex-post	137	2
Greffe [99]	2004	Article	4	4				Meso	Ex-post	4	
Hockings et al. [63]	2008	Institutional Report	17	2	7	5	3	Meso	Ex-post	17	
Labadi [59]	2011	Institutional Report	57	24	22	7	4	Meso	Ex-post	35	22
Rypkema and Cheong [60]	2011	Article	29	16	17	6		Meso	Ex-post	8	21
Licciardi and Amirtahmasebi [5]	2011	Institutional Report	13	4	7	2		Meso	Ex-post	7	6
Zancheti and Hidaka [100]	2011	Article	3				3	Meso	Ex-post		3

Table A1. *Cont.*

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
Elsorady [53]	2014	Article	16	1	3	3	9	Micro	Ex-ante		16
CHCfE Consortium [56]	2015	Research Report	54	18	13	9	14	Meso	Ex-post	32	22
Fusco Girard et al. 2015 [49]	2015	Article	124	77	14	15	18	Meso	Ex-post	121	3
James [101]	2015	Article	40	8	16	9	7	Meso	Ex-post	35	22
Sowińska-Świerkosz [50]	2017	Article	15	3	1	7	4	Meso	Ex-post	10	5
Guzmán et al. [52]	2017	Article	14		4	6	4	Meso	Ex-post	12	2
Nocca [48]	2017	Article	178	111	35	1	31	Meso	Ex-post	172	6
Stanik et al. [41]	2018	Article	6			2	4	Macro	Ex-post	3	3
Vecco and Srakar [83]	2018	Article	7	2	1	1	3	Macro	Ex-post	7	
Airaghi et al. [61]	2019	Research Report	13	12	1			Meso	Ex-post	13	
Historic England [102]	2019	Research Report	41	7	5	7	22	Macro	Ex-post	41	
Günçe and Mısırlısoy [17]	2019	Article	25	5	4	6	10	Micro	Ex-post		25
Della Spina [16]	2020	Article	11	6		4	1	Micro	Ex-ante	4	7
De Leão Dornelles et al [103]	2020	Article	1				1		Ex-post		1
Melloni et al. [104]	2020	Research Report	144	19	82	7	36	Meso	Ex-post	121	23

Appendix B

Table A2. Literature sources on other impact sectors and indicators. Ec: Economic indicators, S: Social Indicators, En: Environmental Indicators, C: Cultural Indicators.

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
Mercer [105]	2002	Institutional Report	373	56	204	21	92	Macro	Ex-post	181	192
WTO [67]	2004	Institutional Report	29	6	7	16		Macro	Ex-post	24	5
OCPA Task Force [106]		Institutional Report	64	15	21	2	26	Macro	Monitoring	21	43
Home Affairs Bureau [107]	2005	Institutional Report	27	7	10		10	Macro	Ex-post	12	15
Choi and Sirakaya [86]	2006	Article	98	16	42	30	10	Meso	Ex-post	35	63
OECD [108]	2006	Institutional Report	104	68	26		10	Macro	Ex-post	103	1
Jackson et al. [109]	2006	Research Report	53	16	9	1	27	Macro	Ex-post	46	7
UNESCO [110]	2007	Institutional Report	21	3	3		15	Meso	Ex-post	19	2

Table A2. *Cont.*

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
UNESCO [111]	2007	Institutional Report	23	11	8		4	Macro	Ex-post	23	
Institut de la statistique du Québec [112]	2007	Institutional Report	67	29	29		9	Macro	Ex-post	56	11
OECD [113]	2008	Institutional Report	31	20	3	1	7	Macro	Ex-post	21	10
Ministry for Culture and Heritage [114]	2009	Institutional Report	17	5	5		7	Macro	Ex-post	15	2
KEA European Affairs [115]	2009	Institutional Report	11	3	5		3	Macro	Ex-post	11	
NCCRS [116]	2010	Institutional Report	16	6	4		6	Macro	Ex-post	16	
UNESCO [117]	2010	Institutional Report	312	83	99	15	115	Macro	Ex-post	177	135
Ngamsomsuke et al. [88]	2011	Article	20	4	3	7	6	Macro	Ex-post		20
Daschko [118]	2011	Institutional Report	47	5	28	2	12	Macro	Ex-post	7	40
Ministry of Culture and Education of Finland [119]	2011	Institutional Report	116	54	33	3	26	Macro	Ex-post	105	11
ESSnet-CULTUR [120]	2012	Research Report	28	9	11		8	Macro	Ex-post	28	
Lozano Oyola et al. [85]	2012	Article	62	20	6	28	8	Meso	Ex-post	54	8
Montalto [121]	2012	Institutional Report	23	13	5	1	4	Meso	Ex-post	16	7
UNESCO and UNDP [122]	2013	Research Report	54	23	18	2	11	Macro	Ex-post	44	10
Columbia Basin Rural Development Institute [123]	2013	Research Report	164	48	36	6	74	Macro	Ex-post	94	70
Oxford Economics [124]	2013	Research Report	4	4				Macro	Ex-post	4	
UCLG [125]	2014	Institutional Report	57		34	5	18	Meso	Ex-post		57
ARTS COUNCIL ENGLAND [126]	2014	Institutional Report	59		51		8	Micro	Ex-post		59
UNESCO [127]	2014	Institutional Report	22	2	13		7	Macro	Ex-post	16	6
United Nations [128]	2015	Institutional Report	53	12	27	8	6	Macro	Ex-post	53	
Global network "Future we want includes culture" [129]	2015	Institutional Report	28	2	8	5	13	Macro	Ex-post	26	2
Kushner and Cohen [130]	2016	Research Report	17	15	2			Macro	Ex-post	28	
Council of Europe [131]	2016	Institutional Report	26	5	14		7	Macro	Ex-post	16	10
University of Baltimore [132]	2016	Institutional Report	56	6	27	18	5	Meso	Ex-post	53	3

Table A2. *Cont.*

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
Blancas et al. [85]	2016	Article	52	26	11	12	3	Macro	Ex-post	52	
European Commission [133]	2016	Research Report	43	14	10	18	1	Meso	Ex-post	41	2
UNESCO [134]	2017	Institutional Report	60	6	20	13	21	Macro	Ex-post	36	24
Ortega-Villa and Ley-Garcia [135]	2017	Article	19		12		7	Meso	Ex-post	4	15
Ren and Han [136]	2018	Article	67	14	18	24	11	Micro	Ex-post	41	26
ISTAT [137]	2018	Research Report	2	2				Macro	Ex-post	2	
EUROSTAT [138]	2019	Research Report	14	3	2		9	Macro	Ex-post	12	2
EUROSTAT [139]	2019	Research Report	9	1	4	4		Macro	Ex-post	9	
UNESCO [140]	2019	Research Report	21	7	6	1	7	Macro	Ex-post	1	8
Montalto et al. [141]	2019	Article	12	4	4		4	Meso	Ex-post	7	5
ISTAT [142]	2018	Research Report	11	2	3	6		Macro	Ex-post	9	2
Asmelash and Kumar [84]	2019	Article	61	10	31	12	8	Macro	Ex-post	14	47
European Commission [143]	2019	Website	16	8	2	6		Macro	Ex-post	14	2
European Commission [144]	2019	Institutional Report	29	3	21		5	Meso	Ex-post	23	6
OECD and ICOM [145]	2019	Institutional Report	8	2	6			Macro	Monitoring	2	6
Compendium of Cultural Policies & Trends [72]	2019	Website	26	8	11		7	Macro	Ex-post	18	8

Appendix C

Table A3. Literature sources on Circular Economy impact sectors and indicators. Ec: Economic indicators, S: Social Indicators, En: Environmental Indicators, C: Cultural Indicators.

Source	Year	Source Typology	Number of Indicators	Dimensions				Scale	Phase	Typology	
				Ec	S	En	C			Quant	Qualit
Gravagnuolo et al. [36]	2019	Article	17			17		Meso	Ex-post	17	
Historic England [146]	2019	Research Report	2			2		Micro	Ex-post	2	
Foster and Kreinin [43]	2020	Article	12			12		Micro	Ex-post	12	
Foster et al. [44]	2020	Article	20			20		Micro	Ex-post	20	
Heisel and Rau-Oberhuber [147]	2020	Article	3			3		Micro	Ex-post	3	

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