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Subjective circularity performance analysis of adaptive heritage reuse practices in the Netherlands

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ABSTRACT

Adaptive reuse of built heritage is a driver for the circular economy. This paper examines Dutch adaptive reuse practices regarding their functional, operational and financial models, and assesses their circularity performance by evaluating cultural values preservation, circularity of reuse intervention, and outcomes from use. Primary data was collected through an online survey of stakeholders representing 53 cases. We employed Multiple Correspondence Analysis (MCA) to summarize the relationships among variables and Partial Least Square-Structural Equation Model (PLS-SEM) analysis to assess the weights of the active variables and their causal relationships. We then conducted a factorial mapping and hierarchical cluster analysis to investigate further the correlations between certain characteristics, individual cases, and active circularity variables. The findings indicate that there has been a major trend towards more private sector involvement, stimulation for pro-active engagement of local actors, and better dialogue among stakeholders. In addition, stakeholders acknowledge that adaptive reuse strongly contributes to conserving cultural values. However, stakeholders only weakly recognize its correlation to the circularity framework in the limited context of the physical built environment. This study provides essential insights regarding emerging adaptive reuse trends and circularity performance, which can be further incorporated into circular economy strategies and roadmaps for the built environment. The framework established in this paper for analyzing circularity performance of adaptive reuse practices is transferable, and can be replicated in empirical studies worldwide.

1. Introduction

Cultural heritage plays an important role in cities as economic and cultural assets. Creating unique cultural attraction points, heritage can draw investments and boost economic growth (Ikiz Kaya, 2020). Its cultural and social values promote cultural diversity and social well-being while also contributing to environmental adaptability and sustainability (Vardopoulos, 2019). The reuse of underused or abandoned built heritage is a practical substitute to demolition as it avoids wasteful processes of demolition and new construction while prolonging the cultural heritage lifespan (Bullen and Love, 2011; Leadbeter, 2013; Rodrigues and Freire, 2017).

Adaptive reuse is thus widely recognised as a driver for circularity by helping to reduce raw material use, energy consumption, waste, and environmental costs while curbing air pollutants and carbon emissions (Gravagnuolo et al., 2019). Yet, the incorporation of adaptive reuse as a regenerative practice into the circular economy framework is still new (Foster, 2020). Adaptive reuse can still be regarded unviable by various decision-makers due to economic constraints, limitations in regulatory frameworks and lack of knowledge (Pintossi et al., 2021). To tackle these challenges, this study aims to strengthen the link between adaptive reuse and circular economy goals by elaborating and testing a framework for assessing the circularity performance of adaptive reuse practices through stakeholder engagement.

1.1. Adaptive reuse in the circular economy framework

The circular economy model is defined as a closed-loops system that is regenerative, focusing on minimizing the resource extraction and environmental impact through the recovery of all wastes as resources for new production cycles (Kirchherr et al., 2017). Circular economy is recognized as a new sustainability paradigm that can foster sustainable

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systems when coupled with a complementary socio-cultural focus (Geissdoerfer et al., 2017; Paiho et al., 2020). Building renovation is accepted as one of the flagships of the European Green Deal, and adaptive reuse of built heritage plays a significant role as a reusable resource in the transition towards the circular economy. Placing adaptive reuse of cultural heritage at the core of this framework, Fusco Girard and Nocca (2019) define a human-centered circular economy framework that emphasizes the integration of complex values attributed to natural ecosystems and cultural assets.

Over the past two decades, there has been a shift in mobilizing heritage from costly conservation-based development control measures towards stimulating change through the reuse of abandoned and underused historic buildings and sites (Misirlisoy and Gunce, 2016). Although experts worldwide accept the socio-economic and environmental benefits of adaptive reuse, local administrators, developers, and building owners may still regard built heritage adaptive reuse as unviable due to relatively high operation-maintenance costs and the poorer environmental performance of existing building stock (Conejos et al., 2016). National planning and building regulations can also hamper decision-making in favor of adaptive reuse as current legislative and regulatory frameworks do not always support effective and operative dialogue among relevant parties and the participation of citizens (Aigwi et al., 2019; Ikiz Kaya et al., 2021). Thus, it is important that the Leeuwarden Declaration calls for a smart and quality-based heritage transformation process that ensures flexible regulatory frameworks, participation, inclusion and multi-disciplinarity in decision-making structures, innovation, quality-based procurement, and sustainable financial and business models for successful adaptive reuse projects in the long run (Europa Nostra, 2018).Yet, the adoption of the circular economy framework into the building sector is still quite new (Leising et al., 2018). Given the challenges and limitations of embedding circularity in adaptive reuse practices, the human-centred circular economy approach and supporting policies need to be better implemented into practice-based actions and strategies. Therefore, it is important to assess the performance of adaptive reuse practices based on the circularity principles to inform future policy and decision making about characteristics, models and strategies that accelerate and alleviate circularity performances. This paper aims to fulfil this gap with the elaboration and testing of an evaluation framework to assess the circularity performance of adaptive reuse practices from the perspective of involved stakeholders, and to identify the emerging trends, characteristics and instruments that support better performance.

1.2. Circularity goals and adaptive reuse practices in the Netherlands

The Netherlands is one of the first countries to adopt a government-wide circular economy programme with the target of making the economy fully circular by 2050. To reach this target, the Dutch government aims to become at least 50 % circular in the building and construction industry by 2030 (Circular Economy, 2019). The City of Amsterdam was also one of the pioneers in adopting circular strategies to become a circular city with a set of roadmaps for circular built environment (SGS Research, 2017). Building renovation and reuse were defined as one of the main strategies to achieve circularity in the built environment, and policy-based adjustments were introduced to embed circularity better into adaptive reuse strategies and practices, specifically after the economic recession (Veldpaus et al., 2019).

The economic recession of 2008–2014 catalyzed a slow shift from state investments in cultural heritage to financially independent models of private and civic investments across Europe (Veldpaus et al., 2019). The real estate market recession, decrease in global and domestic tourism, less public and private funding, cuts in heritage-related government programs all adversely impacted the cultural heritage sector. Substantial measures and initiatives were taken to mitigate these adverse impacts on heritage conservation, which also triggered attribution of additional economic and functional values to cultural heritage (Ost, 2018). The substantial changes in heritage financing and management practices following the economic recession have stimulated growing interest in adaptive reuse as an economically, functionally, and culturally viable solution to heritage protection. This has also been one of the drivers for a stronger focus on adaptive reuse as an architectural solution to promote circularity in the built environment.

In the Netherlands, reuse policy relies on vacant building stock and the local administrators are responsible for producing land use plans that designates the use and the function of areas (Remoy and van der Voordt, 2014). The 'crisis and recovery act' of 2010 allows temporary use of buildings and sites regardless of their pre-designated functions and incorporates consideration of *cultural history,* standing for the tangible and intangible heritage assets of the area, into land use plans (Janssen et al., 2017). At an administrative level, Dutch local authorities have shifted from being direct investors and partners in architectural and urban development projects towards being facilitators and drivers of development, promoting new means of public-private financing and partnerships (Veldpaus et al., 2019). Nationally, a new 'adaptive reuse program' was initiated with the central government committed to more investment as part of its 'heritage counts' 2018−21 policy program (Van Engelshoven, 2018). Public participation in heritage-related decision-making has also gained importance with the new national initiative to adopt the European Faro Convention, which highlights the value of cultural heritage for the society (European Commission, 2005). As a result of these financial incentives, supportive legislation, and participatory policy programs, adaptive reuse has become the most viable option for spatial development amid the economic crisis.

Given these improvements in administrative, regulatory and economic structures supporting adaptive reuse practices towards circularity, the Netherlands sets a good example to learn from. This study analyses the relationship between circularity performance and the emerging trends, policies and strategies of adaptive reuse adopted in the Netherlands. The findings can be transferable across-borders and contribute to better alignment of adaptive reuse policies and practices with the circular economy framework worldwide.

1.3. Scope and aim of the study

Given the limitations of embedding circularity in the built environment, it is important to assess the circularity performance of adaptive reuse practices in terms of their economic, environmental, cultural, and operational contexts to identify emerging trends and characteristics. The circular financial, administrative, and business models and tools employed in such cases can be fundamental to improve the circularity performance of adaptive reuse practices worldwide that a circular built environment will comply with. Their assessments will function as role models for stakeholders and policy-makers involved in building sector knowledge, planning and decision-making to orient adaptive reuse and regeneration practices towards circularity. Accordingly, this paper examines adaptive reuse of built heritage practices implemented in the Netherlands after the economic recession as an exemplary case study in terms of their administrative, functional, operational, business, and financial models within a circular economy framework. Defined as *subjective circularity performance analysis,* this study assesses their circularity performance from the perspectives of stakeholders and identifies the circular tools that improve their performance assessment, based on a set of circularity indicators adopted for adaptive reuse. Stakeholders increasingly contribute to the transition towards circular economy, and their experiences and reflections play an important role in enhancing accountable, representative and transparent decision making (Soma et al., 2018). This circularity assessment improves our understanding of the correlation between certain trends in adaptive reuse practices and circularity variables, which can then be incorporated into circular economy strategies and roadmaps for the built environment.

For this purpose, the first step was to produce an inventory of Dutch adaptive reuse cases, which were then examined for their cultural,

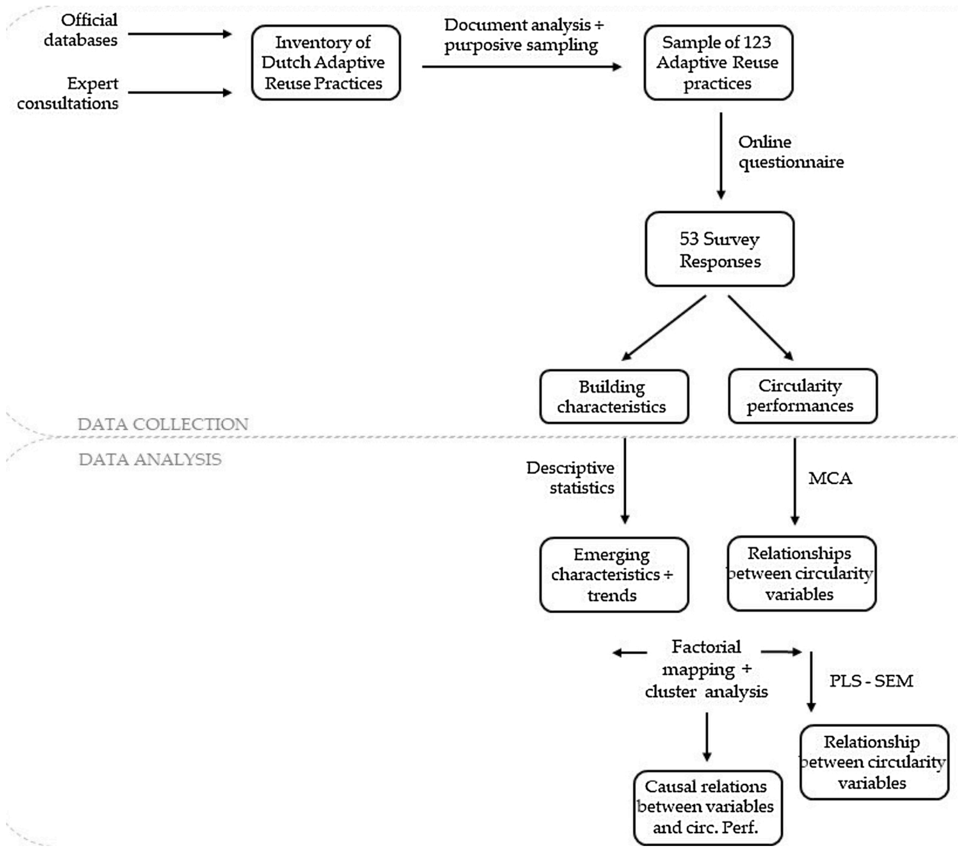

Fig. 1. The multistep research methodology.

operational, and financial attributes, and for shifts in their ownership status, managing bodies, business models, and stakeholder and public involvement in their administrative structures. Secondly, the relevant stakeholder(s) of each practice assessed their specific case based on a set of circularity evaluation criteria. This assessment used an evaluation framework derived from the criteria to assess the impact of adaptive heritage reuse within the circular economy (Gravagnuolo et al., 2017). These criteria examine multidimensional productivity and performance in terms of economic (i.e. decoupling growth, optimization of resources), environmental (i.e. energy efficiency, waste reduction and management), social (i.e. labor market, social network) and cultural dimensions (i.e. education, local skills and craftsmanship, identity building) with the added intrinsic value of cultural heritage in the urban/spatial context. This evaluation framework thus examines cultural values preservation (CVP), circularity of conservation intervention (CC), and circularity of outcomes from use (CO), using a multidimensional approach and longitudinal timeframe based the subjective analysis by the relevant stakeholders.

The data collected was then analysed using a multistep approach to investigate the weights and relationships between different circularity variables for adaptive reuse, and to conduct a relational analysis to identify the common characteristics of recent practices in the Netherlands in relation to the evaluated circularity variables. Thus, this paper addresses two research questions: Which specific characteristics and models of adaptive reuse that emerged after the economic recession contribute to better circularity performance? How are these circularity performance variables related?

This study elaborated and validated a framework for subjective circularity performance analysis of adaptive reuse practices using an empirical approach with evidence from real-life practices, which can be replicated for case studies across the globe. It is also the first to examine such practices in the Netherlands within the circularity performance context.

2. Materials and methods

The multiple steps of data collection and analysis are defined in this section (Fig. 1). We also describe the sample of 53 adaptive reuse practices through descriptive statistical analysis in Section 2.2.

2.1. Data collection

The first data collection step was to develop an inventory of adaptive reuse of heritage practices implemented in the Netherlands after the financial recession (2008–2014). Data for the inventory was gathered from the official databases of national and regional administrative bodies, knowledge institutions and professional non-profit organizations, such as the Dutch Cultural Heritage Agency (RCE), the National Restoration Fund (NRF), the National Society for Restoration and Reuse of Cultural Heritage (BOEi), and non-profit organizations, such as Future of Religious Heritage (TRE). Experts from these institutions were also consulted to produce a list of current adaptive reuse practices initiated since 2014, the year economic recession shifted towards recovery.

Document analysis was then conducted to identify the sample set of adaptive reuse practices and their characteristics by exploration and verification of content (O'Leary, 2014). These multiple resources were consulted for triangulation and corroboration of the datasets to reduce potential bias and enhance credibility (Bowen, 2009) The sample was selected based on functional change (in adaptive reuse practices, buildings and sites are converted to accommodate new uses), their location (regional distribution), starting period of the projects (from 2014 onwards) and the existence of relevant data about the projects. These criteria were then employed for the sampling strategy, and purposive sampling was used for the selection of information-rich

Fig. 2. Geographic distribution of the adaptive reuse projects examined in the Netherlands.

representative cases (Etikan and Bala, 2017). The purposive sampling thus identified 123 adaptive reuse projects. For these projects, data concerning the location, functional change, ownership, management bodies, and project implementation processes were collected from the relevant secondary sources listed above. Contact details of different stakeholder groups for each project, including local administrators, property owners, project developers, builders, designers and users, were also collected from these sources.

The second data collection step was enabled via a two-part online questionnaire. The survey instrument was developed and administered using the Limesurvey software. For each of the 123 projects, every accessible stakeholder was contacted in October 2019 via email with a link to access the online questionnaire and an information sheet explaining the context, objectives and voluntary participation guidelines to participate. In November 2019, the non-respondents and those who only partially completed the questionnaire were reminded one more time with an additional one-month period. In sum, we received full responses from 53 out of 123 practices. The partially completed responses that did not answer the second part of the questionnaire focusing on the circularity responses were removed from the dataset.

The first part of the questionnaire focused on the characteristics of buildings in terms of age, heritage typology, function and change in use, ownership and administrative status, financing mechanisms, and business and management models. One-line descriptions were added for the terminologies used to define the financial and business models, and the heritage typologies. These data were collected to characterize the practices of adaptive reuse to examine which financing and managerial arrangements contribute to certain circularity variables. Shifts in ownership status, managing bodies, and economic and business models play a significant role in defining the emerging trends. The data collected in the first part of the survey enabled descriptive statistical analysis to orient the relational analysis in the second phase.

The second part of the questionnaire assessed circularity performance of buildings based on the multidimensional evaluation criteria introduced in Section 2.2.2 This assessment aimed to produce empirical evidence from the relational analysis between characteristics and emerging models in adaptive reuse practices and the cultural, environmental, economic and social aspects of circularity. The respondents were asked to evaluate the adaptive reuse practices that they were involved in, based on a Likert scale from 1 to 7 (1: do not agree, 7: fully agree), to indicate how closely they thought the practices met the circularity performance indicators. The reason of using a 7-point Likert scale was to provide sufficient response options to respondents and therefore increase the reliability in the responses (Colman et al., 1997).

2.2. Descriptive statistics and sample description

Table A1 (in appendix) shows the descriptive results per case. The 53 projects are well balanced geographically across Dutch provinces (see Fig. 2). The respondents were also balanced across various stakeholder groups: 27 % were building/site owners, 26 % were project owners or developers, 19 % were current users, 15 % were local administrators,

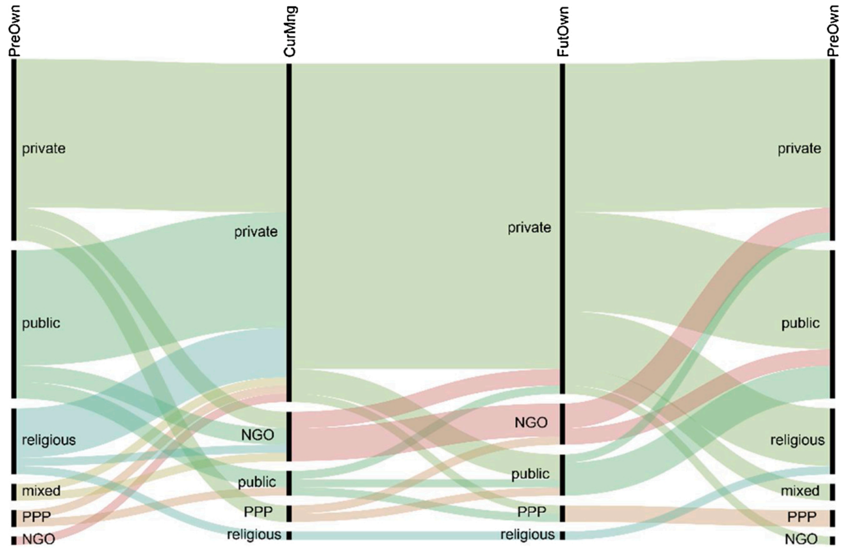

Fig. 3. Depiction of relations between two target variables: change in ownership and managing body.
Note: "PreOwn" indicates the category owning the heritage prior to adaptive reuse; "FutOwn" indicates the one currently owning it; "CurMng" indicates the one currently managing the reused heritage.

and 13 % were designers, advisors or real estate agents. For three adaptive reuse projects, responses were collected from two different stakeholder group representatives.

2.2.1. Ownership of adaptive reuse cases

The dataset defining the sample is considered complex based on the its volume, the data structure and relationships between variables, the variety and abstraction of data (Spacey, 2017). Even though the sample size is not too large in this study, the heterogeneity of data with diverse values (both qualitative and quantitative), the large number of relationships between diverse variables (current and former states of the cases), and the indirect links among certain variables make the data complex. Due to the complexity of the dataset, multivariate statistics were preferred for the characterization of the selected attributes. This helped to identify emerging trends in adaptive reuse processes since the recession ended, i.e. between 2014 and 2019. This also shed light upon the correlations between such characteristics and the circularity performance items.

For further descriptive analysis, as the questionnaire included a large set of variables, this multivariate dataset was first reduced to principal components (Khattree and Naik, 2003). Characterizing a principal component by means of the categories of explanatory variables allows selection of the most relevant categories of the explanatory variables represented in the categories of the variable to characterize. It is based on comparing the percentages of the subjects/objects in a certain response of the explanatory variable with the percentage of subjects/objects in the same category of the target variable for the entire sample.

The characterization of variables was carried out for the principal component variable, namely shifts in ownership status for the cases (before and after the reuse practices) (see Fig. 3, Table A1). The reason for selecting change in ownership as the principle component was its direct impact on follow-up changes in administrative, financial and managerial structures operating for the cases. For this variable, there were five recorded categories of current ownership after reuse: private (n = 40; 75,47 %), public (n = 5; 9,43 %), non-governmental organization (NGO) (n = 5; 9,43 %), public-private partnership (PPP) (n = 2; 3,77 %), and religious (n = 1; 1,89 %).

Most cases that are currently publicly owned were also previously owned by the public institutions (80.38 %, while the percentage in the set is 34.54 %). All five publicly owned cases are currently used for commercial purposes (the percentage in the set is 81.13 %), while three were formerly production facilities and two were public buildings. Their current managing bodies are either private companies (60 %) or PPPs (40 %), and all pay rent to the building owners. Regarding the financing of the reuse projects, public funding paid a major role in the financial models supported by funds provided by national (60 %), regional (80 %); and municipal authorities (60 %). In three of these five cases, the managing bodies also invested in the projects.

Among the private-owned cases, which make up the largest group of projects, only 47.5 % were formerly owned by private entities while 35 % formerly belonged to public bodies, 22.5 % to religious organizations, and only one to an NGO. For almost all the private-owned cases, the managing bodies are private entities, with only two administered by public institutions. Regarding functional change, 80 % of the buildings were converted into commercial uses: of which, 25 % were formerly production units, 27.5 % were religious buildings and 7.5 % were residential units. In addition, 15 % were production facilities turned into residential units, 10 % were commercial buildings that are now multifunctional, and one sanatorium was converted into a residential building. In 75 % of the private ownership cases, the managing body pays rent to the owner while in 40 % of such cases, the manager is also the owner. Finally, the financial resources supporting the reuse projects for these cases were mainly owner/manager investments (65 %), public funding (57.5 %) and private foundations (25 %), with 10 % supported through crowdfunding initiatives.

For the two cases owned through public-private partnerships, the ownership did not change but the manager is a public body for one and a private entity for the other. In both cases, they retained their commercial uses while the regeneration projects were financed directly by owner/manager investments.

Regarding public participation, NGO-owned all allow public involvement in decision making compared to 58.49 % average for this set. Public participation is always anticipated at the initial idea development stage while 40 % of the projects also engage local communities in the design, project implementation and monitoring stages. As for the public participation methods, the most frequently employed tool is public consultation (100 %) whereas workshops and digital tools are less frequently applied (20 %). Most NGO-owned buildings (80 %) followed the trend for introducing commercial functions while their original use differed for each case (residential - 20 %, production - 60 %, public - 20 %).

Table 1
Data summary of the 23 active variables grouped by latent variable: 53 individual cases.

Variable code	Active variable	Categories (number and percentage of individuals per category)					
		Agree		Neutral		Disagree	
Cultural values preservation (CVP):							
CVP	cultural values preservation	51	96 %	1	2 %	1	2 %
Circularity of conservation intervention (CC):							
CC1	use local skills/techniques/knowledge	39	74 %	9	17 %	5	9 %
CC2	improved service life of the building	47	89 %	4	8 %	2	4 %
CC3	Use energy efficiency measures	39	74 %	9	17 %	5	9 %
CC4	contributed to ecosystems preservation and regeneration	15	28%	21	40 %	17	32 %
CC5	contributed to reducing construction/management waste and landfill	17	32 %	23	43 %	13	25 %
CC6	contributed to halting/reversing biodiversity loss	14	26 %	19	36 %	20	38 %
CC7	optimized the use of existing energy resources	21	40 %	21	40 %	11	21 %
CC8	took into consideration the building's long-term performances	42	79%	7	13 %	4	8%
CC9	enhanced new innovative models for financing, business, and governance	20	38 %	25	47 %	8	15 %
CC10	contributed to higher and long-term local return on investment	34	64 %	16	30 %	3	6 %
CC11	contributed to increased long-term employment	34	64 %	15	28 %	4	8 %
Circularity of outcomes from the use (CO):							
CO1	increased the number of cultural visitors	27	51 %	16	30 %	10	19 %
CO2	provided common goods to the local community	38	72 %	13	25 %	2	4 %
CO4	Increased the building's future flexibility and adaptability	32	60 %	14	26 %	7	13 %
CO5	improved local awareness of heritage in the real estate market	41	77 %	11	21 %	1	2 %
CO6	provided circular economy processes in the real estate market	10	19 %	28	53 %	15	28 %
CO7	contributed to higher productivity (fewer inputs for more output)	14	26 %	34	64 %	5	9 %
CO8	enhanced creativity and innovation	43	81%	10	19 %	0	0%
CO9	generated long-term free use concession	6	11 %	17	32 %	30	57 %
CO10	improved local health/wellbeing	18	34 %	24	45 %	11	21 %
CO11	contributed to the creation/regeneration of micro communities	27	51 %	18	34 %	8	15 %
CO12	contributed to enhancing civic pride, identities, and sense of the place	41	77 %	11	21 %	1	2 %

Lastly, the only case owned by a religious entity was a former publicly owned complex integrating residential, public, and religious functions. Without changing its ownership or management, it was converted into a residential unit with financial support from a private foundation and the owner's investment.

2.2.2. *Subjective circularity performance variables*

In addition to the characterizing variables, the distribution of the 53 cases was based on 23 variables relating to the subjective analysis of circularity performance (see Table 1). These variables are grouped in three sets, each corresponding to a latent variable: Cultural values preservation (CVP), circularity of conservation intervention (CC), and circularity of outcomes from the use (CO). Each active variable can assume three categorical values (variable categories): agreement (A), disagreement (D), and neutral (N). Table 1 summarizes the frequency of variable categories for each active variable.

Cronbach's alpha values were calculated (see Eq. A1 in Appendix) in order to assess the internal consistency for each set of latent subjective circularity variables. Forcircularity of outcomes from the use (CO), the value was acceptable, at 0.842, between the lower limit (0.6−0.7) and the upper limit indicating redundancies (0.9) (Hulin et al., 2001; Tavakol and Dennick, 2011). For circularity of conservation intervention (CC), as the value was 0.601, which was considered acceptable due to moderate internal consistency despite falling below 0.7. The value for cultural value preservation (CVP) could not be computed because it included only one variable. In sum, the Cronbach's alpha values computed for the sets of active variables were within an acceptable range, showing internal consistency of each set of items. Thus, we can say that the statements in the survey are useful to assess the latent subjective circularity variables (i.e. CC, CO) and can be considered in the analysis.

2.3. *Methods*

For analyzing the dataset, this study followed the consequent multistep approach, including Multiple Correspondence Analysis (MCA), Factorial Mapping and Cluster Analysis, and Partial Least Square-Structural Equation Model (PLS_SEM). This multistep data analysis methodology was applied because of the structure and complexity of the data. MCA method is used to reduce the multivariate data to increase its interpretability (Abdi & Valentin, 2007). MCA and the following cluster analysis were applied as explorative methods to summarize and visualize the multiple categorical variables. Thus, similarly assessed adaptive reuse cases can be identified and the association between variable categories can be deduced. Additionally, PLS-SEM was used to investigate the relations between latent subjective circularity variables (namely CC, CVP and CO) and test the circularity performance assessment framework.

2.3.1. *Multiple Correspondence Analysis (MCA)*

After the descriptive analysis of the sample, a combined Multiple Correspondence Analysis (MCA) and cluster analysis was performed to extract the main factors of the survey variables so as, to group the characteristics related to each variable.

MCA is a multivariate statistical method for analyzing all the interactions between the multiple categorical variables gathered from the survey. It provides, "a summary of the relations existing between" such variables (Di Franco, 2016: 1301). This type of factorial analysis technique identifies the dimensions capable of reproducing the relevant associations between the analyzed variables with fewer factors. In this study, the MCA expressed synthetically the links between the series of variables and the factors, the circularity performance evaluation criteria, and the adaptive reuse characteristics. A further explanation of MCA methodology and its formula can be found in Abdi & Valentin (2007).

The MCA dimensions distinguish cases based on response categories that differentiate extremely from the sample average. Hence, MCA uses the frequency distribution to allocate categories at each dimension. In each dimension, the categories with the high degree of similarity are represented as closest to each other (in terms of distance). A code in R is employed to calculate the Cronbach's alpha value, and perform and visualize the MCA, using the R-packages ltm and FactoMineR (Lê et al., 2008), and Factoextra (Kassambara & Mundt, 2020). Before conducting the MCA, outliers were removed from the sample.

For the MCA, the 23 variables relating to the assessment of the circularity performance were considered as the 'active variables', as

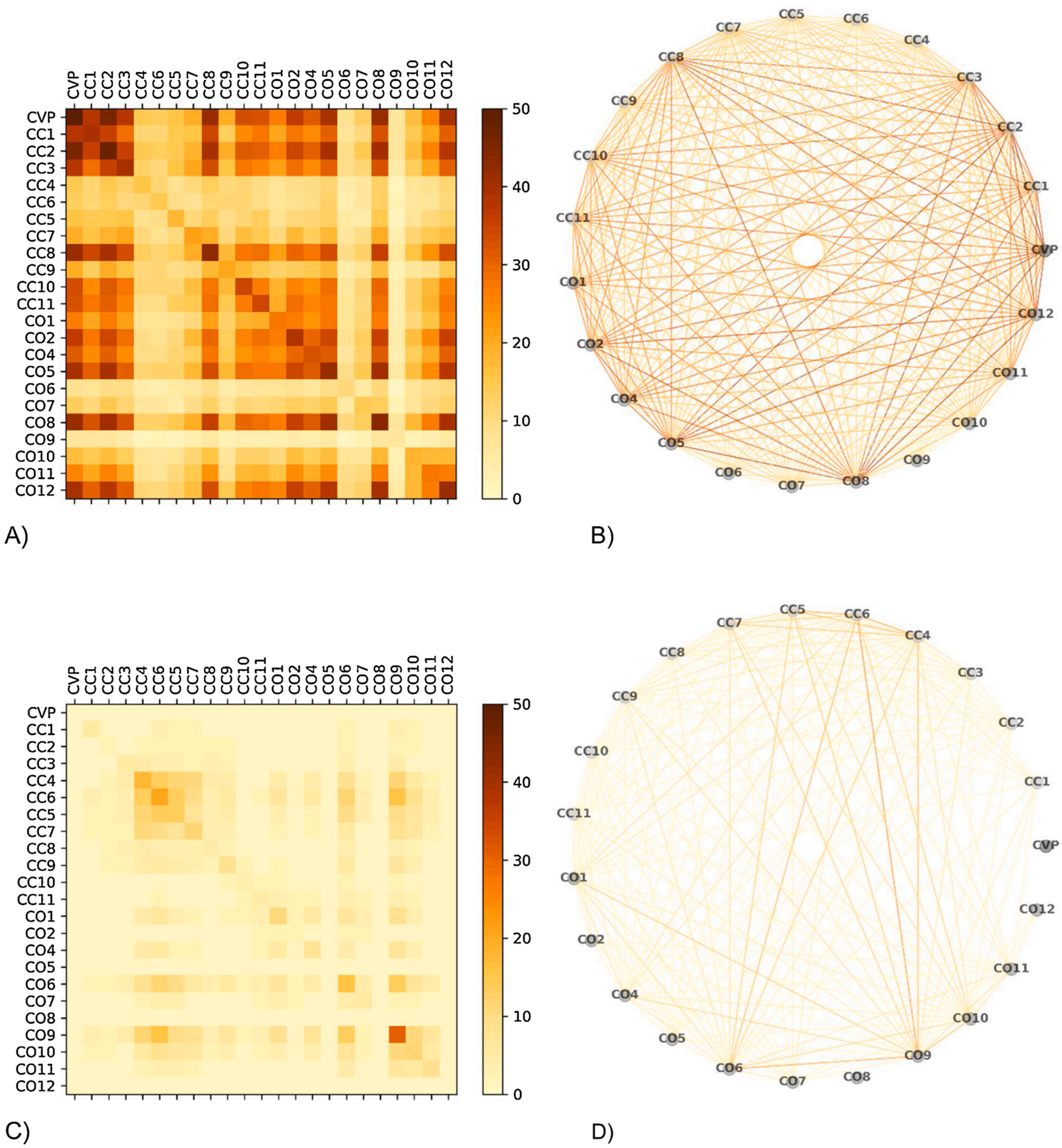

Fig. 4. Frequency of categorical variables in pairs for the circularity assessment. A) Hheatmap for the agreement categories; and B) corresponding co-occurrence network; C) heatmap for the disagreement categories; D) corresponding co-occurrence network.

listed in Table 1. The 19 variables reporting the characteristics of the cases constitute the supplementary qualitative variables. The year of conclusion of the reuse intervention, a quantitative variable, was excluded from the analysis.

2.3.2. Factorial mapping and cluster analysis

The MCA led to analysis of the associations between the characteristics of the adaptive reuse practices derived from the survey and expressed their causal relationships with the three categories of circularity performance variables. The independence of the factors extracted from the MCA in the form of linear combinations of active variables further allowed the construction of two-dimensional and multi-dimensional factorials maps. Factorial mapping offers a more detailed expression of results, presented as the sum of the percentages of information captured by each individual factor. To reveal the co-occurrence of the variable categories "agreement" and "disagreement", the relations between variable categories were mapped within the active variables of MCA. This mapping was visualized in a network and heat map based on the frequency of the pairs of variable categories. The analysis is performed using the Python-packages Matplotlib (Caswell et al., 2020), NetworkX (Hagberg et al., 2008), Numpy (Oliphant, 2006), and Pandas (McKinney, 2010).

Reading maps built from factor categories and project characteristic coordinates relies on the distance of the points representing the variables or factors and their position in respect to the center of the axes. If two factors related to different variables lie close together, then this represents an association between them and an interdependence of the categories they refer to. This mapping also takes into account the frequency of co-occurrence of the variable category within the active variables, visualized as interactions between each variable. The size of the interactions is represented by the varying thickness of the lines in the network map.

Following the factorial network and heat mapping, hierarchical cluster analysis was used to analyze these relationships and group the f

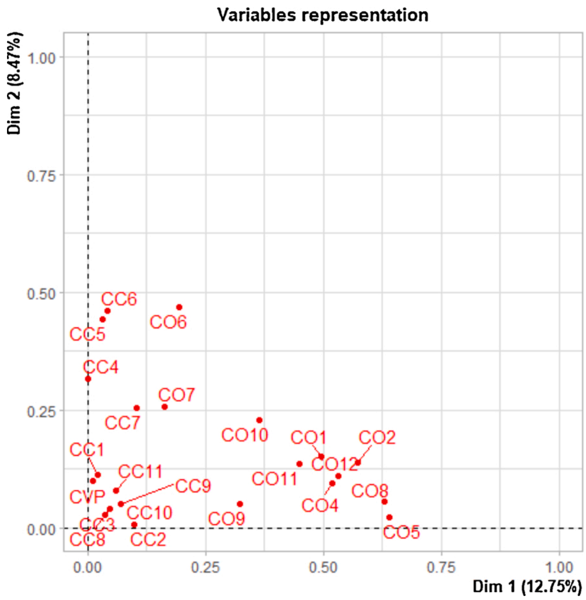

Fig. 5. Correlations between active variables and dimension.

variables into a smaller number of differentiated homogenous groups. This created three clusters of interdependent variables.

2.3.3. Partial Least Square-Structural Equation Model (PLS_SEM)

Structural Equation Modeling (SEM) is a multivariate data analysis method for testing theoretically supported linear and additive casual models (Chin, 1998; Haenlein & Kaplan, 2004). It combines factor analysis and multiple regression analysis to analyze the structural relationships between measured and latent variables. PLS-SEM, which is a soft modeling approach to SEM, is an appropriate methodology under the following two conditions (Bacon, 1999; Wong, 2010): small sample size ($N < 200$), and little available theory for the applications. PLS_SEM is also used to predict phenomena when the model is somewhat complex (Hair et al., 2012).

Since we had 53 cases in our sample and no available theory on the circularity performance of adaptive reuse cases, we chose PLS-SEM to follow the MCA. According to Marcoulides and Saunders (2006), a sample size between 52 and 59 is required for PLS-SEM with three latent variables, so this methodology is feasible for this dataset. PLS-SEM improved our understanding of the relationship between the three latent variables (CVP, CCI and CO) as part of the assessment of the circularity performance variables.

3. Results

We followed three steps to analyze the dataset. First, we assessed the relationships between the categorical variables of circularity performance (CVP, CC and CO) through MCA. Second, we conducted cluster analysis based on the factorial maps of the latent and qualitative variables to investigate and better understand the causal relations between the active variables and the qualitative characteristics of heritage reuse practices. Third, we used PLS-SEM to examine the relationship between the latent variables with path coefficients and t-values.

3.1. Subjective circularity performance variables and MCA

Overall, stakeholders mostly assessed circularity performance positively answers, i.e. a value of "agreement" for the categorical variables. This is highlighted by the main diagonals of the heatmaps in Fig. 4A and C which present the number of agreements or disagreements for each active variable.

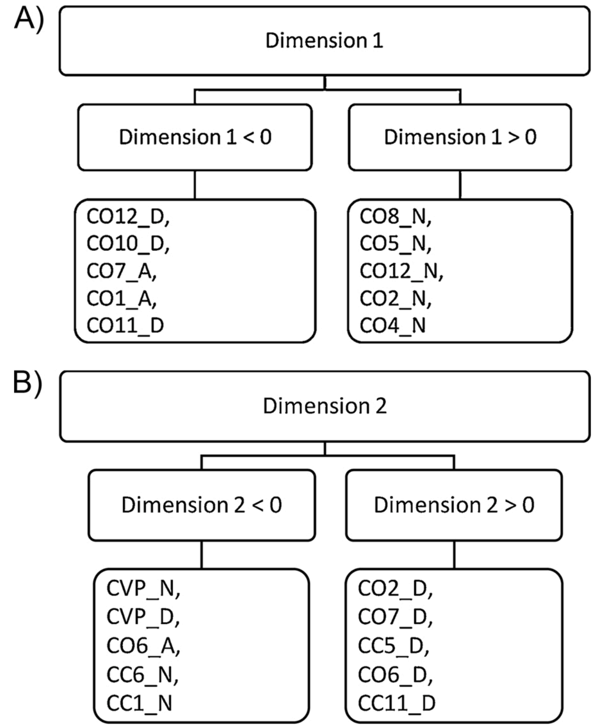

Fig. 6. A) Dimension 1: positive and negative coordinates. B) Dimension 2: positive and negative coordinates.
Note: A = "agreement", N ="neutrality"; D = "disagreement".

A solution was then explored with two MCA dimensions as they facilitated interpretation of the solution (Costa et al., 2013; Yokota et al., 2017) and are easily plotted (Richards & van der Ark, 2013). Dimension

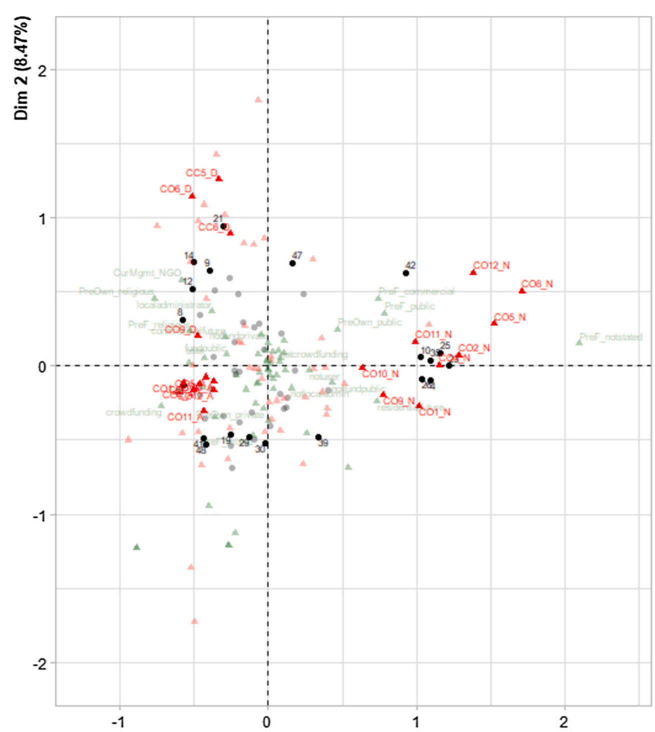

Fig. 7. MCA factor map. The 20 variables (in red), 20 individuals (in black) and 20 supplementary variables (in green) were better represented considering Dimension 1 and Dimension 2 appear with their label reported and filled with a bold and vivid colour.

Table 2
Description of the three cluster of categories of active variables.

Cluster	Active variables	Project no.	Emerging characteristics
Cluster A	CO2_N, CO4_N, and CO11_N	4, 10, 23, 25, 26, 35, 42	PreF_public, PreF_commercial, PreOwn_public, FutF_residential, FutF_mixed, Fund_nocrowdfunding
Cluster B	CC5_D and CO6_D	9, 11, 12, 14, 20, 28, 47	PreF_religious, PreF_production, FutOwn_private, Fund_public, Fund_nocrowdfunding
Cluster C	CO1_A, CO2_A, CO4_A, CO5_A, CO8_A, CO11_A, and CO12_A	8, 14,19, 22, 30, 37, 38, 41, 46, 48	FutF_mixed, FutF_commercial, Public involvement_yes

Note: The categories of active variables included in the clusters were among the 20 best represented in the MCA factor map– see Fig. 6. The individuals listed are those presenting a circularity performance as the one reported by all categories of active variable of each cluster.

Table 3
Summary of the reflective outer models.

Latent Variable	Final Indicators	Loadings	t-values	Composite Reliability	AVE
CVP	CVP1	1.000	NA	1.000	1.000
CC	CC2	0.487	2.204	0.850	0.500
	CC3	0.490	2.819		
	CC4	0.839	13.115		
	CC5	0.772	9.942		
	CC6	0.775	9.675		
	CC7	0.775	9.786		
CO	CO5	0.795	8.301	0.813	0.525
	CO6	0.561	3.836		
	CO9	0.762	5.536		
	CO10	0.757	6.048		

1 explained 12.69 % of the variance (eigenvalue = 0.248) while Dimension 2 explained 10.90 % (eigenvalue = 0.213); hence, this solution explained 23.59 % of the total variance. This solution, however, revealed two outliers (Table A2), defined as individual cases that are ''at least one standard deviation away from the barycentre as well as contributing significantly to the interpretation to one pole of an axis" (Bendixen, 1996, p. 12). These outliers were *Polygonale loods* (case 2 in Fig. 7) and one of the two inputs about *Watertoren* (input 1, case 39 in Fig. 7). After these outliers were removed, the MCA was reconducted on a reduced sample of 51 individuals.

This second iteration was also a two-dimension solution. Dimension 1 accounted for 12.75 % of the variance (eigenvalue = 0.238) while Dimension 2 accounted for 8.47 % (eigenvalue = 0.158), explaining 21.22 % of the total variance. In Dimension 1, five variables had a correlation higher than 0.5 (Costa et al., 2013): CO5 ($R^2 = 0.64$), CO8 ($R^2 = 0.63$), CO2 ($R^2 = 0.57$), CO12 ($R^2 = 0.53$), and CO4 ($R^2 = 0.52$) as shown in Fig. 5. For Dimension 2, all variables had correlations lower than 0.5 (Fig. 5 and Table A3) with the highest correlations for CO6 ($R^2 = 0.47$), CC6 ($R^2 = 0.46$), and CC5 ($R^2 = 0.44$). In sum, the discriminant variables represented the CO category for Dimension 1 and almost evenly represented the CC and CO categories for Dimension 2. For Dimension 1, the positive coordinates represented neutral assessments of the variables relating to the CO variables, whereas the negative coordinates represented both negative and positive assessments of these variables (Fig. 6A). Dimension 2 presented neutral assessments for the categories associated with its positive coordinates and mainly neutral assessments for the negative coordinates (Fig. 6B).

The MCA indicated that 51 out of 53 cases rated CVP positively, highlighting the significance of heritage protection for these practices. We then further evaluated the MCA results with factorial mapping and cluster analysis, identifying three clusters of active variables. We then associated these clusters and categories with individual cases and their emerging characteristics, as discussed in Section 3.2.

3.2. Cluster analysis of active variables and emerging characteristics

Following the MCA, a hierarchical cluster analysis was conducted based on the distance of active variable points from each other. After a number of trials, we decided on three clusters (Fig. 7, Table 2). We first tested clustering with individual cases but later opted to cluster based on the association between variable categories to better reflect the performance of circularity. These clusters were then linked with the individuals and descriptive supplementary variables.

Cluster A included categories corresponding to a neutral assessment of circularity performance, characterized by positive coordinates for Dimension 1. Cluster B included categories corresponding to a negative assessment of circularity performance. These categories had negative coordinates for Dimension 1 and positive for Dimension 2. Finally, Cluster C mainly included categories corresponding to a positive assessment of circularity performance. This cluster included the categories having negative coordinates for both Dimension 1 and Dimension 2.

We further elaborated these clusters to include individual cases (shown in black in Fig. 6), emerging characteristics (in green) of adaptive reuse practices, and to reflect upon their association with the categories of active variables (Table 2). Cluster A thus represents a neutral assessment of three active variables: "provided common goods to the local community" (CO2); "increased future flexibility and adaptability of the building" (CO4); and "contributed to the creation/regeneration of micro communities" (CO11). This also indicates that there had been a neutral approach towards the impact on communities and regeneration of the buildings and their surrounding environments. As for the projects included within this cluster, their emerging descriptive characteristics involve a high percentage of formerly publicly owned buildings (71 %) converted into residential and mixed used units that were mostly funded by the owner/manager.

Cluster B represents a negative assessment of two variables: "contributed to reduce construction/management waste and landfill" (CC5); and "providing circular economy processes in real estate markets" (CO6). The projects grouped under this cluster previously functioned as either religious or production facilities before conversion into commercial or mixed-used complexes. These buildings were mainly appropriated by private companies while their reuse was supported by public subsidies.

Cluster C represents a positive assessment of seven active variables: CO1, CO2, CO4, CO5, CO8, CO11, and CO12. In addition, CVP and CC2 do not appear in the MCA factor map for this cluster but in the individuals that have that profile of categories.

Regarding the supplementary variables, all these individuals reported the involvement of local stakeholders in decision-making processes. Considering that half of these practices are currently managed by NGOs or public-private partnerships, the involvement of citizens in decision making to a certain extent is not surprising. In terms of circularity, case 14 matched the performance profiles of both Clusters B and C.

The cluster analysis results show that stakeholders of former publicly owned practices transformed into residential or mixed-use buildings were mainly neutral in their subjective performance assessment of adaptive reuse practices in terms of communal good and adaptability of heritage. In contrast, stakeholders of former religious or production facilities appropriated by private bodies tended to make negative evaluations regarding project performance in waste reduction and its impact on the real estate market. Finally, stakeholders of reused buildings

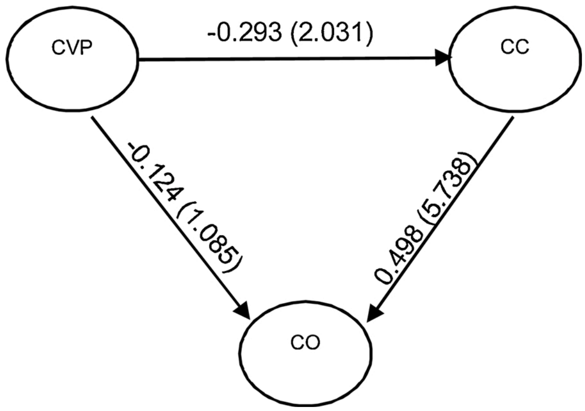

Fig. 8. Final PLS-SEM model showing the relationship between the latent variables with path coefficients and t-values (in brackets). Note: t-value >1.96 is accepted as statistically significant.

functioning as commercial or mixed-use facilities generally made more positive assessments of the circularity of the project outcomes.

3.3. PLS-SEM analysis

For the PLS-SEM analysis, we used the SMARTPLS software, with 300 iterations for estimating the model, as suggested by Ringle et al. (2005). Firstly, all combinations for the relations between latent variables were tested and the best fitting model was adopted. Initially, all the indicators were used to explain the latent variables. However, this resulted in low indicator reliability and low model fit. Therefore, we adopted a stepwise approach and removed indicators with low performance. Table 3 summarizes the reflective outer models, showing the final indicators, composite reliability and AVE (Average Variance Extracted). The final model with the remaining indicators has an acceptable goodness of fit (SRMR = 0.106), (Hu & Bentler, 1998). Table 3 also shows that the final model has high internal composite reliability (> = 0.6) and convergent validity (AVE) (> = 0.5).

As Fig. 8 shows, CC has a strong and statistically significant positive effect on CO; CVP has a non-significant weak negative effect on CO. Moreover, the hypothesized path relationship between CVP and CC is found to be statistically significant and negative. Thus, CVP is a predictor of CC while CC is a predictor of CO whereas CVP does not predict CO directly.

When the cultural value of the historic building or site is preserved through the reuse practice, then the circularity of conservation intervention receives less importance. This indicates that cultural value preservation is still considered traditionally without being linked with the concept of circularity. Furthermore, when circularity of conservation intervention is considered important, this has a strong positive influence on the circularity outcomes, as expected. These results also contribute to the better understanding of the circularity perception of relevant stakeholders, as discussed in Section 4.

Another interesting finding is that the CC indicators included in the final model are all related to circularity of materials and the physical building whereas the model excludes circularity of business, management, and local people/knowledge. This might mean that the respondents have a consistent understanding of circularity at the physical and building level, but that this did not always extend to cover the socio-economic aspects. A similar finding applies to the CO indicators. Respondents were consistent about more concrete outcomes of circularity such as its effect on real estate market and wellbeing rather than community and people-related outcomes.

4. Discussion

In this paper, we examined practices of adaptive reuse implemented in the Netherlands starting from 2014, hence after the recovery from the 2008 financial recession, in terms of their administrative, functional, operational, and financial models. We assessed their circularity performance based on a set of indicators evaluating cultural values preservation, circularity of reuse intervention, and circularity of outcomes from the use. For this purpose, we first employed MCA to summarize the relationships among the variables. We then conducted factorial mapping and hierarchical cluster analysis to investigate further the correlations between certain trends and characteristics in adaptive reuse practices, as well as individual cases, and the active variables of circularity. Finally, we used PLS-SEM analysis to assess the weight of the active variables (circularity performance indicators) and their causal relationships.

In the Netherlands, the 2008 financial recession stimulated a more liberal and flexible attitude towards adaptive reuse of built heritage, complemented with supportive policy agendas and legislations. As for the 53 cases examined in this research, it is clear that there has been a major trend towards involving private companies in investments, ownership and business models for adaptive heritage reuse practices through private ownership, management and PPPs. Private involvement in ownership of facilities in reuse projects has almost doubled, from 45 % to 89 %. Regarding functional changes, commercial usage of the buildings almost tripled, followed by a high increase in residential use to address the Netherland's housing shortage. In addition, the results indicated an increase in public funding and central government and the local municipality subsidies supporting private investments and reuse activities. Public funding and foundations made up 52 % of the financial instruments for the reuse projects, although it is important to note that despite 52 % of cases having public funding, only 8 relied solely on this whereas 24 had a mixed (public-private) funding scheme.

The combined efforts of Dutch policy documents, regulations, and campaigns focusing on the integration of *cultural history values* into the wider planning context also contributed to greater appreciation by a wide range of heritage-related stakeholders of heritage values and awareness of heritage protection. As the MCA demonstrates, there is a high awareness and affirmative response towards acknowledging adaptive heritage reuse as a means of protecting cultural values (96 % in the analysis). However, the PLS-SEM assessment of the correlations between active circularity variables shows that when cultural values are preserved, stakeholders give the circularity performance of the conservation intervention less importance (negative path coefficient). The strong positive influence of the circularity performance of a conservation intervention over the outcomes of the use emphasizes the strong relationship between these circularity variables, which are not directly correlated with the heritage protection indicator. This clearly shows that there is still a weak connection and awareness among relevant stakeholders regarding adaptive heritage reuse and the circularity framework. In addition, considering the weightings of CC and CO indicators, the stakeholders' circularity conceptions and perceptions are mostly limited to the physical and building level, without always extending to cover the relevant socio-economic aspects and consequences.

Another important finding concerns the increased public involvement and participatory practices that support decision-making and reuse processes at different stages. The 'heritage act' of 2016, coupled with national programs and activities favoring citizen participation in the heritage field, placed greater emphasis on engaging different stakeholders and citizens through participatory processes in reuse practices (Nadin and Stead, 2013). This is specifically true for reused buildings and complexes owned by NGOs, which mostly likely to have public involvement. Overall, 65 % of the examined cases reported public involvement in the reuse process through public consultation and workshops, mostly in the early stages of idea development and design process.

In conclusion, the economic and regulatory initiatives adopted in the Netherlands after the economic recession provided space for more private sector involvement, stimulated pro-active engagement of local actors, and produced better dialogue among stakeholders. The new regulations and policy programs also promoted an integrated heritage and landscape approach that capitalizes on the cultural value intrinsic to the built heritage alongside its economic value. Regarding the government's circular economy goals, however, stronger ties should be built between heritage appreciation and conservation, and the circularity aspirations of the various stakeholders involved in heritage reuse. Circularity performance is still understood within the limited context of the physical built environment, so a wider approach integrating urban social and economic parameters is also needed.

5. Conclusions

This study aims to strengthen the position of adaptive reuse of built heritage in the transition towards circular economy through elaborating and testing an evaluation framework for adaptive reuse practices to assess their circularity performance, and identifying building characteristics, reuse strategies and instruments that have direct correlations with circularity performance variables. The findings indicate that there has been a major trend towards more private sector involvement, stimulation for pro-active engagement of local actors, and better dialogue among stakeholders. Stakeholders also acknowledge that adaptive reuse strongly contributes to conserving cultural heritage values. However, stakeholders only weakly recognize its correlation to the circularity framework in the limited context of the physical built environment. This proves that an evaluation framework to evaluate the circularity performance of adaptive reuse practices, complemented with a set of practice- and policy-based instruments and roadmaps are essential to better embed circularity into the building and renovation/reuse sector. This study fills this gap and provides essential insights by analyzing the relationships between emerging adaptive reuse trends and circularity performance, which can be further incorporated into circular economy strategies and roadmaps for the built environment.

This study advances our understanding and assessment of adaptive heritage reuse practices in the Netherlands within the wider context of circular economy goals for the built environment. The Netherlands is exemplary with its adaptive reuse policies, strategies and trends for facilitating and accelerating the transition towards circular economy. While the study presents nation-wide findings, the framework established in this paper for analyzing circularity performance of adaptive reuse practices is transferable and can be replicated for other empirical studies worldwide. It thus complements recent studies on building a theoretical framework that places adaptive reuse of cultural heritage at the core of circular economy with empirical findings from real-life practice (Fusco Girard, 2020; Foster, 2020; Gravagnuolo et al., 2019).

Given that our findings and conclusions are limited to the cases that we identified and collected data from, further investigations could be carried out for other geographic contexts and building scales. The different analysis (MCA, cluster analysis and PLS-SEM) show that the framework and its indicators are useful for the assessment of circularity of adaptive reuse cases. Especially, by utilizing the framework and its analysis with PLS-SEM, other countries could assess the subjective circularity of their adaptive reuse cases. With MCA and cluster analysis, the performance status of each adaptive reuse case could be checked. Moreover, future studies could refine the indicators and collect more data to provide deeper insights. The varying perspectives of the responding stakeholders could also be further examined to identify changes in perception and approaches. Moreover, a more balanced representation of different stakeholders should be ensured while collecting data. Overall, this study provided essential insights regarding circularity performance and supplementary emerging trends of built heritage adaptive reuse, which can be further incorporated into circular economy strategies and roadmaps for the built environment.

Ethical approval

All participants provided their informed consents prior to their participation in the study.

Author contributions

D.I.K. – conceptualization, research design, methodology, data collection, data analysis, writing. G.D. – methodology, data analysis, writing – review & editing. N.P. - data processing and analysis, writing – review & editing. C.A.M.K. - data collection.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A

Equation A.1 – Cronbach's alpha formula can be seen in the equation below:

$$\alpha = \left(\frac{k}{k-1}\right)\left(1 - \frac{\sum_{i=1}^{k}\sigma_{y_i}^2}{\sigma_x^2}\right) \quad \text{(A1)}$$

where: k refers to the number of scale items

$\sigma_{y_i}^2$ refers to the variance associated with item i

σ_x^2 refers to the variance associated with the observed total scores

Table A1
Description of samples per case.

Case ID	Current Ownership (FutOwn)	Former Function (PreF)	Current Function (FutF)	Current Manag-ing Body (CurMgmt)	Management Model			Funding source				CVP	CC			CO		
					The owner is the mana-ger (MgmtModel1)	Rent for use (MgmtModel2)	Con-ces-sion charge free (MgmtModel3)	Public funding (Fund-Public)	Private funding (Fund-Private)	Owner's invest-ment (FundOwn)	Crowd-funding (FundCrowdfunding)	Value	Mean	SD	Median	Mean	SD	Median
12	NGO	production	commercial	NGO	no	yes	no	yes	no	yes	no	6	3.7	1.4	4	4.9	1.4	6
18	NGO	production	mixed	NGO	yes	yes	yes	yes	yes	yes	yes	3	6.2	1.1	7	6.2	1.2	7
23	NGO	public	commercial	NGO	no	yes	no	yes	no	no	no	7	4.3	2.5	4	5.1	2.4	7
38	NGO	mixed	public	PPP	no	yes	no	yes	no	no	no	6	5.2	1.3	5	4.2	2.7	5
45	NGO	production	commercial	NGO	no	yes	no	no	no	no	no	7	4.2	1.9	4	5.2	1.8	6
2	PPP	commercial	commercial	private	yes	no	no	no	no	yes	no	7	2.8	2.3	1	4.8	2.4	5
30	PPP	mixed	mixed	public	no	yes	no	no	no	yes	no	7	3.5	2.0	4	4.7	2.0	5
1	private	residential	commercial	private	no	yes	no	no	no	yes	no	6	5.8	0.9	6	4.3	1.3	5
3	private	residential	commercial	private	no	yes	no	no	no	yes	no	7	4.8	1.4	5	3.5	1.6	4
4	private	production	commercial	private	no	yes	no	yes	yes	no	yes	7	5.7	1.5	7	4.1	1.7	4
5	private	production	mixed	private	yes	yes	no	no	yes	yes	no	7	5.3	1.3	5	4.0	0.0	4
6	private	religious	mixed	private	no	yes	no	yes	no	yes	no	4	5.3	1.2	5	4.7	1.1	5
7	private	mixed	commercial	private	no	yes	no	yes	no	yes	no	7	5.4	1.4	6	5.5	2.0	6
8	private	mixed	commercial	private	no	yes	no	yes	no	yes	no	6	5.5	1.0	5	4.4	1.4	4
9	private	mixed	commercial	private	yes	no	no	yes	no	no	no	7	4.3	2.7	6	5.4	2.1	6
10	private	religious	commercial	private	yes	no	no	yes	yes	no	no	7	4.5	2.9	7	4.8	2.7	7
11	private	not stated	residential	private	yes	no	no	no	no	yes	no	7	5.5	1.1	6	4.0	0.0	4
13	private	production	commercial	private	no	yes	no	yes	no	yes	no	7	5.1	2.2	6	4.1	2.1	5
14	private	mixed	mixed	private	no	yes	no	yes	yes	yes	no	7	6.0	1.7	7	5.0	1.8	5
15	private	religious	mixed	NGO	no	yes	no	yes	no	no	no	7	4.0	1.9	4	4.7	2.0	5
16	private	production	mixed	private	no	yes	no	yes	no	yes	no	7	5.5	0.8	6	4.9	1.9	5
17	private	mixed	residential	private	no	yes	no	yes	no	yes	no	7	5.6	1.6	7	5.0	2.4	6
19	private	residential	commercial	private	yes	yes	no	no	no	yes	no	7	5.1	2.0	4	5.1	1.2	5
20	private	commercial	mixed	private	no	yes	no	yes	no	yes	no	7	5.3	1.2	5	6.1	1.3	7
21	private	production	commercial	private	no	yes	no	yes	no	no	no	7	3.6	1.6	4	4.5	1.5	4
22	private	commercial	mixed	private	yes	yes	no	no	no	yes	no	7	5.7	1.1	6	2.9	1.4	3
24	private	mixed	residential	public	yes	no	no	no	no	no	no	6	4.3	1.3	4	4.0	0.0	4
25	private	production	residential	private	no	yes	no	no	no	yes	no	7	5.5	1.5	6	4.9	1.5	4
26	private	public	commercial	private	no	yes	no	no	no	no	no	6	4.8	1.3	5	4.0	0.0	4
27	private	commercial	mixed	private	no	yes	no	no	no	yes	no	7	5.1	1.3	5	4.0	0.0	4
28	private	religious	mixed	private	yes	no	no	no	no	yes	no	1	1.0	0.0	1	1.0	0.0	1
29	private	religious	mixed	private	no	yes	no	yes	no	yes	no	6	4.7	2.4	5	4.7	1.8	5
32	private	commercial	mixed	private	no	yes	no	yes	no	no	no	6	4.4	0.8	4	5.7	1.3	6
33	private	mixed	mixed	private	yes	no	no	yes	no	no	no	7	4.5	1.8	4	3.5	2.0	4
34	private	religious	mixed	private	no	yes	no	yes	no	no	no	7	5.7	1.4	6	5.5	1.1	6
35	private	religious	mixed	NGO	yes	yes	yes	yes	yes	no	yes	7	6.5	1.2	7	5.1	2.0	4
36	private	commercial	mixed	private	no	yes	no	yes	yes	yes	no	7	4.8	2.1	6	5.7	1.5	7
37	private	production	commercial	private	yes	no	no	yes	no	yes	yes	7	5.0	1.8	5	4.0	0.0	4
40	private	religious	mixed	private	no	yes	no	yes	yes	no	no	7	1.7	1.1	1	2.9	1.8	3
41	private	production	residential	private	yes	no	no	no	yes	no	no	6	4.9	1.4	5	5.4	1.7	6
42	private	mixed	mixed	private	no	yes	no	yes	no	yes	no	5	4.3	0.6	4	4.6	0.8	4
46	private	production	residential	private	yes	no	no	no	no	yes	no	6	4.3	1.6	4	4.7	1.7	5
47	private	religious	residential	private	no	yes	no	no	no	yes	no	6	4.5	1.4	5	4.1	2.7	4
48	private	religious	mixed	private	no	yes	no	yes	yes	no	yes	7	5.4	2.0	6	6.0	1.8	7
49	private	religious	commercial	private	yes	yes	no	yes	no	yes	no	7	4.7	2.6	6	3.7	2.5	4
50	private	religious	commercial	private	yes	no	no	no	no	yes	no	6	5.0	0.8	5	6.0	1.0	6
52	private	production	residential	private	yes	no	no	no	no	yes	no	6	4.5	2.0	4	4.3	1.7	4
31	public	production	commercial	PPP	no	yes	no	yes	yes	yes	no	7	5.5	1.2	6	5.8	1.3	6
39	public	commercial	commercial	private	no	yes	no	yes	no	yes	no	7	4.3	1.1	4	5.5	1.6	6
44	public	public	mixed	private	no	yes	no	yes	yes	no	no	7	5.5	0.9	6	6.2	1.0	6
51	public	religious	commercial	public	no	yes	no	no	yes	no	no	6	6.0	1.5	7	5.9	2.0	7
53	public	public	mixed	private	no	yes	no	yes	yes	no	no	7	4.6	1.0	4	5.7	1.2	6
43	religious	mixed	mixed	religious	yes	no	no	no	yes	yes	no	7	4.7	1.7	6	4.5	1.8	5

Table A2
Description of outliers in terms of coordinates and contribution to the MCA solution.

Case	Coordinates		Contribution	
	Dim 1	Dim 2	Dim 1	Dim 2
Polygonale loods	1.070	0.599	8.700	3.178
Watertoren (input 1)	1.633	1.747	20.255	26.987

Table A3
MCA dimensions discrimination measures.

Variable	MCA dimension		Mean
	1	2	
CVP	0.011	0.099	0.055
CC1	0.021	0.113	0.067
CC2	0.100	0.007	0.053
CC3	0.038	0.028	0.033
CC4	0.001	0.316	0.159
CC6	0.043	0.460	0.251
CC5	0.031	0.441	0.236
CC7	0.103	0.255	0.179
CC8	0.048	0.040	0.044
CC9	0.070	0.051	0.061
CC10	0.071	0.049	0.060
CC11	0.061	0.079	0.070
CO1	0.495	0.151	0.323
CO2	0.573	0.138	0.355
CO4	0.520	0.094	0.307
CO5	0.640	0.022	0.331
CO6	0.195	0.467	0.331
CO7	0.163	0.256	0.210
CO8	0.629	0.055	0.342
CO9	0.324	0.051	0.187
CO10	0.365	0.228	0.297
CO11	0.450	0.135	0.292
CO12	0.532	0.110	0.321
Active total	5.482	3.642	4.562
% of variance	12.749	8.469	10.609

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