A decision support tool for the adaptive reuse or demolition and reconstruction of existing buildings

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Abstract: A large number of old and abandoned buildings are under restoration with a view to accommodate new functions, while some others have already been consolidated and reconstructed. The decision whether to interfere and to what extent to an existing building is a complex issue which should take into consideration the broad range of all sustainability concerns. This means that the decision should examine not only a number of environmental factors but also social and economic indicators as well as maintenance in terms of cost, time, quality and performance within an acceptable range. This paper explores the relationships between financial, environmental and social parameters associated with building adaptive reuse or demolition and reconstruction. A weighted decision support tool (WDST) has been developed and discussed in this context. This tool can assist in the transformation of the traditional empirical decision-making processes of building stakeholders, towards more sustainable, profitable and cultural respectful practices.

Keywords: adaptive reuse; demolition; decision support tool; eco-costs; building value.

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1 Building stock in Europe and Greece

Sustainability is a concept that has been widely spread when the Bruntland Report 'Our Common Future' was published in 1987. Since then, it has been generally acknowledged that sustainable development has three pillars: environment, society and economics. The role of construction is important in the international economy, with considerable impact on the environment. Buildings use resources in many different ways such as through the manufacturing process in which the building components are produced, through transportation of materials to the construction site and through operation when the building is occupied (Retzlaff, 2009). Naturally, resources are also employed when a building is demolished in which case recycling or disposing of materials is required (UNEP, 2007). It is therefore only rational to link the construction sector with the concept of sustainability, considering the environmental impacts arising from the energy consumption during the use and the processing of the natural resources during all stages of the building life cycle.

The building industry started to recognise the impact of their activities on the environment in the 1990s. A shift in thinking was required to reduce the impact of construction on the environment. It was essential to rethink how the buildings were initially designed and subsequently built and operated. In order to improve the sustainability of a building, all the sustainable dimensions right at the early design phases of the building project need to be considered. In this respect, it is important to consider the entire life cycle of a building when evaluating its sustainability and in some cases, it may be environmentally better to re-use buildings instead of constructing new ones. Most developed countries have a substantial stock of existing buildings in many different states of repair and utility. Unfortunately, it is quite common, when the useful life of buildings expires, to remain abandoned without any use. Usually the older the stock is, the poorest the physical condition. The maintenance therefore and refurbishment of existing buildings are critical issues for sustainable building construction as Kohler and Moffatt (2003) argue.

It is indicative that in the EU-25, the number of dwellings is about 196 million. Half of the existing residential buildings were built before 1970 and about 1/3 of the dwellings were built during the 1970 to 1990 (Norris and Shiels, 2004). The annual rate of construction of new dwellings represented as a percentage of the size of existing stock ranges from 0.3% in Sweden to 3.5% in Ireland and 3.9% in Greece, with an average of 1.1%, while the estimated annual replacement rate (ratio of the annual demolition rate to the size of existing stock) for dwellings in Europe is only 0.07% (Hartless, 2003). About

70% of the residential buildings are over 30 years old and about 35% are more than 50 years old. This is an important observation showing that most of buildings in Europe have been constructed based on obsolete national building regulations for construction, energy consumption and installations for disabled persons. It is expected that the emphasis in Western Europe will shift even more towards renovation and maintenance of existing housing stock, instead of new constructions, with the economic recession. Sleight (2005) had already forecasted that growth in European construction will slow down, with new housing construction expected to be 0.7% in 2011 compared to 4.4% in 2004.

In the case of Greece, there is a large number of abandoned buildings as indicated by the Hellenic Statistical Authority in 2000. Indeed, the observations are that in 1991, 31.91% of the existing buildings in Greece were abandoned, while 10 years later, the percentage had increased to 33.29%. It is remarkable that this result once translated into real numbers, it refers to approximately 2,500,000 abandoned building cells without any use. Clearly, this is a considerable amount of the built environment in Greece and it affects not only cities but regions also.

It can be argued that one reason for such result is urbanism; however, it is only a 20% to 25% of abandoned buildings that lies in small towns of North and South Greece. Remarkably enough and beyond the concept of urbanism, 38.5% of abandoned dwellings are in the centre and suburbs of Athens, capital of Greece, which retains the problem of the large number of abandoned buildings. Table 1 illustrates the number of buildings in different time periods and their age in national level. It is also noticeable that a significant number of dwellings in Greece were constructed between 1960 and 1980, when Greece faced a great boost in construction sector. Since then, a decrease in the number of building constructed is observed.

Table 1 Existing buildings in different time periods and their age

Years	*Number*	*Age*
Before 1919	199,510	> 92
1919–1945	406,633	91–66
1946–1960	665,315	65–51
1961–1970	761,182	50–41
1971–1980	737,575	40–31
1981–1985	404,303	30–26
1986–1990	297,348	25–21
1991–1995	241,615	20–16
After 1996	191,739	< 16
Under construction	57,430	< 16
Not subscribed	28,320	-
Total number of buildings	*7,896,190*	-

Source: National Statistical Service of Greece – Inventory (2002)

Irrespective of a country having a large or small number of abandoned buildings, a solution is necessary. The question is which type of intervention should be attempted to old buildings which following the term of sustainability will be environmentally wise and economical and socially accepted. Should we attempt to give new life to these buildings? Or would it be better in an environmentally friendly way to demolish and start a new building following all the new and modern regulations? The decision whether to interfere and to what extent to an existing building could not be clearly a one way decision. There are many alternative ways to interfere to an existing cell depending on the case and the situation of the building. The pertinent options are described in the following section.

2 Re-use or demolish

There is no doubt that buildings are major assets and although it can be argued that they last for long, they also require maintenance during their life cycle. Eventually, buildings may become inappropriate for their original purpose due to obsolescence, or can become redundant due to change of the demand for their service. In this case a change may be required and the question posed often is to demolish to make a new construction or to refurbish or adaptively reuse it (Langston et al., 2008). Either decision affects environmental, financial and social parameters which should be taken into account before finally deciding about the future of the building.

According to Thomsen and van der Flier (2008), the construction of new residences is declining below 1% of the existing stock annually to date. Consequently, the ageing stock is growing and as such the knowledge about old buildings, although new construction is still the dominant approach for developers. The authors however argue that knowledge on demolitions is very limited since the volume of demolitions is very low. For example, in the Netherlands less than 0.2% of the existing residential stock is demolished and in most other EU countries the percentage is even lower. As it is argued, besides the technological aspects of demolitions, the decision to demolish is first of all a managerial decision dependent largely on the owner.

Demolition is an intervention with potentially severe social effects, on individuals as well as on society. Demolition implies, in practical terms, loss of living and working space and in economic terms, destruction of capital. In environmental terms, the demolition waste together with the use of the new building materials is undisputed a substantial environmental load. More specifically, the environmental impacts from this phase arise, amongst others, from the manufacturing of materials and the energy consumption during this process, the energy required for the disposal of demolished parts and materials, not to mention the transportation and construction needs while recycling. It is believed that demolition plus replacement is most likely less sustainable than life cycle extension of the existing building (Thomsen and van der Flier, 2008). In the European housing market where the stock is ageing, there is growing debate about the future of this stock and whether demolition followed by new construction or life cycle extension is the solution.

Langston et al. (2008) further argue that existing buildings that are obsolete or towards the disuse stage and potential demolition are a very good source of raw materials for new projects. However, they also argue that it is more effective instead of extracting these materials during demolition and either using them to new projects, or even trying to find means for recycling them, to leave the basic structure of the building intact and change its use. This is what is called according to Langston et al. (2008) ‘adaptive reuse’ and besides the new life that breathes into the existing building, it also brings benefits in environmental and social terms and at the same time helps to retain national heritage.

Bullen (2007) in a slightly different interpretation states that adaptive reuse is "rehabilitation, renovation or restoration works that do not necessarily involve a change of use", and supports that adaptive reuse 'extends the useful life and sustainability in a combination of improvement and conversion'. Douglas (2006) however felt that adaptive reuse involves conversion to change of use required by new and existing owners' and this is a view held by others (see for example, Davidson and Dolnick, 2004). Despite the different readings of the same term, the bottom line that is adequate for the present research is that the term of adaptive re-use refers to a building that is not demolished; on the contrary it is re-used following the necessary works irrespective of keeping the same use or changing it.

According to Roders (2006), there are seven scales of intervention on an existing building cell starting with the lower scale – deprivation (scale one), preservation (scale two), conservation (scale three) and restoration (scale four); to superior scale – reconstruction (scale six) and demolition (scale seven). Feilden (1982) sustained that the best way to preserve a building is to keep it in use and emphasised that the adaptive re-use of buildings is perhaps the only way to save in an economic manner historic and aesthetical values and at the same time bring up to contemporary standards historic buildings. Adaptive reuse although is a challenge in many respects, for example design and permitting, it offers economic, environmental and social benefits making it an attractive solution to developers.

Considering that the present research poses the question to demolish or re-use a building, an important tool in the present analysis is the life cycle of a building. The life cycle of a building, 'from cradle to grave', refers to the view of a building during its entire life and is divided into phases to enable comparisons of the buildings' performances. The traditional approach presents the different phases of the building's life cycle with a linear relation. The sequential life cycle (SLC) of a physical construction can be divided in different activities such as materials extraction, manufacture of components, transportation, construction, use, refurbishment, use and adaptive reuse of the existing physical construction. In SLC, the refurbishment stage refers to operation and maintenance as a continuous process while after the adaptive reuse of the building the life cycle starts from scratch.

Before however a decision is reached, it is important to discuss how the building's performance is usually evaluated. Many tools have been developed attempting to provide an objective evaluation measuring amongst others, resource use, ecological loadings and energy consumption. A description of these tools follows on the following section.

3 Building assessment systems

Cole (1998) argues that it is difficult to precisely define what 'building performance' is, since there are several different parties with different interests and requirements in the building sector. For example, renters and lodgers are interested in luxury and comfort whereas developers focus more on equity and financial performance in general, (Haapio and Viitaniemi, 2008). In order to address the needs of the different groups of interest, a common set of criteria were developed the scope of which was to assess the environmental impact of buildings, to collect information on the building and its operation, to assist in the design of buildings in a sustainable way, and to monitor the impacts of construction on the environment (Cole, 1998). In this way, the concept of the building assessment system was developed which is a tool that rates how well a building is performing or is expected to perform according to the specified set of criteria (Cole, 2005).

According to Retzlaff (2009), building assessment systems were adopted initially in the US on a voluntarily basis. The first approach widely known that addressed a large range of issues in a single tool was the Building Research Establishment Environmental Assessment Method (BREEAM) in 1990 in the UK (Crawley and Aho, 1999). Since then, a large number of methods has been developed such as ATHENA Environmental Impact Estimator, Building Environmental Assessment Tool (BEAT) 2002, BeCost, Building for Environment and Economic Sustainability (BEES) 4.0, BREEAM, EcoEffect, Envest 2, and Leadership in Energy and Design (LEED), (for a broad discussion see for example, Larsson and Cole, 2001, DOE, 1996/2006; IEA Annex 31, 2001; Reijnders and Roekel, 1999).

As Wallhagen and Glaumann (2011) explain, the majority of the assessment tools assembles a large number of environmental issues, then weights and aggregates the various aspects into overall judgements. Cole (2005) argues that environmental assessment tools can broadly be divided into two categories, those that are based on life cycle assessment (LCA) principles and those that are not. Most LCA-based environmental assessment tools such as the Athena Environmental Impact Estimator and Envest are used as the basis of evaluating materials or other strategic design options. Other types of methodologies applied in assessment techniques relate to scoring performance (e.g., aggregation of points; eco-efficiency-based) and to the derivation of weightings (e.g., expert consensus, analytic hierarchy process, etc.) (Cole, 2005). Although the methods developed vary to a great extent, they aim to assist some common purposes: to motivate owners and developers to improve the performance of their buildings, to notify all pertinent parties on the level of impact of buildings in consideration, and to measure in an objective manner the impact of buildings in question (Brochner et al., 1999; Cole, 1999). Some of these methods such as ATHENA and BEES also provide the option of costing which will be further examined below.

More integrated approaches have also been developed in the past which further illustrate the importance of assessment methods. For example, de Jonge (2005) based on the theory of Vogtländer (2001a, 2001b) related sustainable investments such as building costs and operational costs to eco-costs. The aim of the research was to develop a tool which provides information on the environmental burden of housing projects, related to the design characteristics with the scope to be used at various stages in the design and development process, both new construction, redevelopment and renovation projects. The tool ultimately provides the decision maker with assistance whether to renovate or to redevelop. In the same context, Itard et al. (2006) examined the challenge of large-scale urban restructuring and urban renewal of post-war neighbourhoods. The research adopted an LCA-based tool (EcoQuantum) and in order to take into consideration the dynamic, and not static, behaviour of buildings adapted calculations to the dynamic aspects of a building for the aspects of energy use. De Jonge (2006) explains that the possibilities of improving the energy performance of existing housing are limited. This raises the question how to balance energy use of old buildings against that effects of emissions and materials depletions of new construction.

Although there are many tools to assess existing buildings, new buildings, etc., the focus of the present study is on existing buildings and the research hypothesis is whether it is worth maintaining an old building or demolishing it. In the prism of sustainable buildings, a number of requirements are set for the assessment tools in addition to the environmental aspect, which concern the economical and the social aspects that need to be considered and included in the assessments. In addition to the fact that despite the large number of building assessment systems, there has not yet emerged a single system that is widely accepted; all these set the benchmarks for the development of a new decision-making tool for the evaluation of existing buildings.

4 The decision support tool

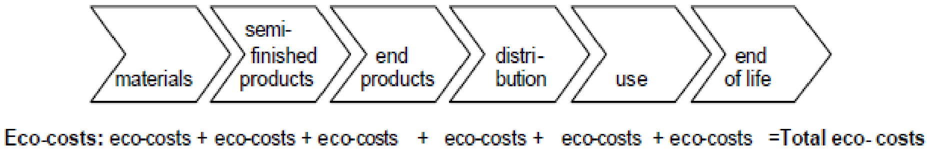
The concept of sustainability concerns not only environmental but also economic and social factors. As Bragança et al. (2010) explains, a building in order to be sustainable, it must obey a number of factors besides the respect for the environment which are social integration and social economy, maintenance in terms of cost, time, quality and performance within an acceptable range. This is further verified by a number of studies (such as Power, 2008) which investigate the feasibility of an intervention to an existing building cell. Most of the studies indicate that, the factors arising from the dilemma whether to adopt and reuse a building or demolish and reconstruct, can be divided into three main categories: environmental-ecological factors, economical-financial factors and Sentimental-social factors. In this respect, the present research develops a decision support tool for the assessment of potential adaptive reuse of buildings and discusses how this potential can be validated based on a triple bottom line (financial, environmental, and social) philosophy.

4.1 Environmental – ecological factor

In the case of the building's environmental evaluation, a significant number of models that assess its performance have been developed as illustrated in Section 3. The present research has adopted for the environmental factor the basic principles of the eco-costs and the eco-costs value ratio (EVR) model developed by Delft University of Technology (Vogtländer, 2001a), which expresses ecological burden in economic terms. The theoretical framework of the eco-costs model is described in Figure 1. Eco-costs are based on the concept of 'marginal prevention cost', or else the costs that are required to bring back the environmental burden to a sustainable level. Eco-costs are a single life cycle analysis-based indicator for environmental burden and are a measure to express the amount of environmental burden of a product or a building on the basis of prevention of that burden. Vogtländer (2001b) tried to handle the following dilemma; the growing economy seems to be one of the major reasons for the deterioration of the environment however stopping the growth seems unrealistic. He therefore developed his theory on the concept of better eco-efficiency of systems for production and consumption.

More analytically, the EVR model links the 'value chain' to the ecological 'product chain'. In the value chain, the added value in terms of money and the added costs are defined for each step of the product (from cradle to grave). In the same respect, the ecological impacts of each step in the product chain are expressed in monetary terms which are called eco-costs. It should be mentioned that eco-costs are not real costs but virtual.

Figure 1 The eco-cost chain combined by the ecological product chain



Source: Vogtländer (2001b)

The outcome of the implementation of this theory, for each process, product or service is the ratio of the value and the eco-costs. This eco-costs/value ratio can be defined at any aggregation level of the chain based on equation (1):

$$EVR = \frac{Eco-Costs}{Value} \tag{1}$$

where a low EVR indicates that the product is appropriate for use in the sustainable society. Conversely, high EVR indicates that the value/costs ratio of a product might become 'less than one' in the future, since 'external' costs will become part of the 'internal' cost-structure. In this respect, the EVR serves as an indicator for sustainability in LCA in case where the quality of products differs. In the decision making process of an intervention to an existing building, the quality of the initial product is the same. For this purpose, the value factor is omitted, while the actual target of this phase is to predict just the environmental burden of the decision or otherwise the energy consumption of the intervention expressed in financial terms.

The calculation model includes 'direct' as well as 'indirect' eco-costs. The first category includes costs such as costs required to reduce the emissions in the product chain to a sustainable level, eco-costs of energy which is the price for sustainable energy sources and eco-costs of materials depletion. In the latter case, costs are the eco-costs of depreciation such as the eco-costs related to the use of equipment, buildings, etc., eco-costs of labour are the eco-costs related to commuting and the use of the office (building, heating, lighting, electricity, etc.). All the elements calculated in the eco-cost model, are calculated according to the LCA method as defined in ISO 14041. The eco-cost model is applied in the context of the life cycle of a building presented in Section 3. For each stage of the buildings life cycle (L), reference is made to the different kinds of embodied and cumulative energy of the building.

The advantages of the proposed model besides it being available for use at no cost, is that it provides a platform for comparisons since results are interpreted in monetary terms enabling the actual costs of construction (demolition or re-use) to be embed in a unified system. It is a method to express the amount of environmental burden of a product or a building on the basis of prevention of that burden. The advantage of this method is the flexibility of the calculations. Even if it is not based on a special software and belongs to the basic calculation method of LCA, conducted in an excel spreadsheet, the outcome of the method gives advanced results for the environmental impact of a product or service easily explainable to non-experts and transparent for specialists. Once the eco-cost method is applied aiming to calculate building energy, the export data in Euro even if the import data is energy units measured in KJ/Kg. Consequently, the analysis of the energy concludes in equation (2):

$$\begin{aligned} Eco\text{-}cost_i &= Eco\text{-}costs(initial) + Eco\text{-}costs(intervention)_i \\ &= TotalEnvironmentalIndicator(TEI) \end{aligned} \quad (2)$$

where i = 1, 2, 3, …, 7 (types of intervention based on Table 2).

Table 2 Type and scale of intervention

Scale of intervention	*i*	*Type of intervention*
Scale one	1	Deprivation
Scale two	2	Preservation
Scale three	3	Conservation
Scale four	4	Restoration
Scale five	5	Rehabilitation
Scale six	6	Reconstruction
Scale seven	7	Demolition

Source: Roders (2006)

4.2 Financial factor

Besides the actual calculations for the assessment of the environmental impact of a building intervention (demolish or re-use) interpreted in terms of energy consumption, the actual costs associated with its potential investment (demolish or re-use) during the building's life cycle should not be overlooked. The purpose of this analysis is the prediction of the total cost for the stakeholder in each type of intervention to the existing building. Life cycle costing (LCC) analysis is used by the present research as an analysis over the whole life cycle of a building. There is a large number of economic evaluation methods for LCC analysis, the most commonly used are presented in Table 3 together with their advantages and disadvantages.

According to Schade (2007), the most suitable approach for LCC in the construction industry is the net present value (NPV) method. NPV is the result of the application of discount factors, based on a required rate of return to each year's projected cash flow, both in and out, so that the cash flows are discounted to present value (PV). According to Kishk et al. (2003), the NPV is what is needed in terms of cost to be invested at present, to meet future financial requirements throughout the life of the project and in this respect the lesser the NPV of an alternative the better. The important contribution of the NPV method is that it takes into account the time value of money.

Table 3 Economic evaluation methods for LCC

Method	*What does it calculate*	*Advantage*	*Disadvantage*	*Usable for*
Simple payback	Calculate the time required to return the initial investment. The investment with the shortest pay-back time is the most profitable one.	Quick and easy calculation. Result easy to interpret.	Does not take inflation, interest or cash flow into account.	Rough estimation if the investment is profitable.
Discount payback method (DPP)	Basically the same as the simple payback method, it just takes the time value into account.	Takes the time value of money into account.	Ignores all cash flow outside the payback period.	Should be only used as a screening devise not as a decision advice.
Net present value (NPV)	NPV is the result of the application of discount factors, based on a required rate of return to each year's projected cash flow, both in and out, so that the cash flows are discounted to present value. In general if the NPV is positive it is worth while investing. But as in LCC the focuses is one cost rather than on income the usual practice is to treat cost as positive and income as negative. Consequently the best choice between two competing alternatives is the one with minimum NPV.	Takes the time value of money into account. Generates the return equal to the market rate of interest. It use all available data.	Not usable when the comparing alternatives have different life length. not easy to interpret.	Most LCC models utilise the NPV method Not usable if the alternatives have different life length.
Equivalent annual cost	This method express the onetime NPV of an alternative as a uniform equivalent annual cost, for that it take the factor present worth of annuity into account.	Different alternatives with different life's length can be compared.	Just gives an average number. It does not indicate the actual coast during each year of the LCC.	Comparing different alternatives with different life's length.
Internal rate of return (IRR)	The IRR is a discounted cash flow criterion which determines an average rate of return by reference to the condition that the values be reduced to zero at the initial point of time. It is possible to calculate the test discount rate that will generate an NPV of zero. The alternative with the highest IRR is the best alternative.	Results get presented in percent which gives an obvious interpretation.	Calculations need a trial and error procedure. IRR can be just calculated if the investments will generate an income.	Can be only use if the investments will generate an income which is not always the case in the construction industry.
Net saving (NS)	The NS is calculated as the difference between the present worth of the income generated by an investment and the amounted invested. The alternative with the highest net saving is the best.	Easily understood investment appraisal technique.	NS can be only use if the investment generates an income.	Can be used to compare investment.

Source: Smullen and Hand (2005)

However, this method compares alternative ways of intervention but with the restriction of the same life length of building for both alternatives. This renders the existence of a predefined period of study mandatory. In this respect, this method cannot be used when the alternatives being compared have different life lengths since in this case the interpretation is very difficult with disputed outcomes. This obstacle is overcome when, for the basis of comparison, there is a pre-defined limited time period. As such, using the NPV method, all costs by year are initially identified and quantified and subsequently are discounted to PV. They are finally added to calculate the sum of life cycle cost for each of the possible alternative type of intervention. Based on the above and according to Sieglinde (2010), the LCC of the building under consideration based on NPV and pertinent the analysis concludes to equation (3):

$$LCC_i = I + Repl\text{-}\mathrm{Re}\,s_i + E_i + W_i + OM\ \&\ R_i + O_i = TotalCostIndicator(TCI) \quad (3)$$

where:

I PV of investment costs

Repl PV of capital replacement costs

Res PV residual value (resale value, salvage value) less disposal costs

E PV of energy costs

W PV of water costs

OM&R PV of non-fuel operating, maintenance and repair costs

O PV of other costs

i 1, 2, 3, …, 7 (type of intervention based on Table 2).

The present research for the purposes of comparison has predefined the period of study to 50 year as a good perspective for the useful life of construction projects. For both alternatives (demolish or re-use), it is assumed that the initial costs (I), such as capital investment costs for land acquisition, construction and necessary equipment for the operation of the facility, are equal. Furthermore, for the basis of comparison, it is also assumed that the capital replacements (Repl) of a building system remains the same since the number and the timing of capital replacements of building systems depend on the estimated life of the system and the length of the study period. The residual value of a system (Res), components or materials is its remaining value at the end of the study period, or at the time it is replaced during the study period. Residual values can be based on value in place, resale value, salvage value, or scrap value, net of any selling, conversion, or disposal costs. Components or materials in the case of demolition considered to reach the initial cost, because of a total displacement or destroy of the component or the system. In this case, the difference between the capital replacement costs (Repl) and the residual value is equal to 0, ($\mathrm{Repl} - \mathrm{Res}_{(i)} = 0$, where $i = 7$).

4.3 Sentimental – social factor

The last factor that is included in the proposed tool concerns the sentimental factor that should be part of any sustainable approach. When building values are examined, the decision to demolish or reuse an existing building has a sentimental dimension which in the case of the present research is interpreted as the social factor. It is worth to compare a building to a monument with a view to distinguish the different kinds of value accumulated in its cell. This interpretation has been based on Riegl's research (1982), first published in 1930, which argues that the built up environment could be seen as a collection of monuments from the existence of a community. The study distinguished monuments to two kinds, intentional and unintentional. An intentional monument is "a human creation, erected for the specific purpose of keeping single human needs or events (or a combination thereof) alive in the minds of future generations" (Allen, 2009) whereas unintentional monuments, which are much more numerous, are remains whose meaning is determined not by their makers, but by the modern perceptions of these monuments. An argument however to the latter is that in modern age all monuments (buildings) could be seen as intentional to a certain extent, since they were built for a specific purpose and their meaning is not yet determined by their makers, but by their users or by our perception of these monuments.

Based on Riegl's (1982) theory, different ages encourage the cult of different values and our attitude towards conservation depends upon which values are attributed to the monument. The distinction has been established not with a purpose to overlap one value over another, but in an effort to identify the processes of valuation that determine different approaches to conservation. More specifically, Riegl developed five different kinds of values namely the memory value, age value, historical value, use value and art value.

Quantifying building values is not a straight forward process. Conversely to the previous two factors (environmental and financial), the sentimental factor, as a non-tangible parameter, is much harder to measure and eventually conclude to a single equation as in cases of equations (2) and (3) expressing outcomes in monetary terms. To overcome this difficulty, a ranking table, based on Riegl's theory (1982), is introduced aiming to measure the sentimental factor as illustrated in Table 4. In this way, stakeholders (x) have the opportunity to rank the five building values with a grade that varies from [0.1–0.3] where grade 0.3 could be interpreted as the building value that is not significant at all, while value with grade 0.1 is the most significant for the stakeholder.

Table 4 Ranking table for the sentimental factor

Values	*Ranking range*
Use value	
Memory value	
Historical value	0.1–0.3
Age value	
Architectural value	

$$R(x)_i = \sum \left(UseValue_i + MemoryValue_i + HistoricalValue_i + AgeValue_i + ArchitecturalValue_i \right) \quad (4)$$

where i = 1, 2, 3, …, 7 (type of intervention based on Table 2), and $x = a, b, c$…. (different stakeholder).

The outcome of Table 4 defines the cumulative value of an existing building, expressed with a ranking factor $R(x)_i$ which could vary from 0.5–1.5 based on the ranking table where the lowest grade is 0.1 and the greatest 0.3. In the cases of demolition and reconstruction, the values of this category are omitted. The final calculation of the value indicator is based on the average of the results of equations (2) and (3) multiplied with the ranking factor $R(x)_i$ as illustrated in equation (5). In this respect, we produce a more comparable and less sensitive basis for comparisons.

$$Value_i = \frac{\left(Eco\text{-}\cos t_i + LCC_i \right)}{2} \times R(x)_i = TotalValueIndicator(TVI) \quad (5)$$

where i = 1, 2, 3, …, 7 (type of intervention based on Table 2).

It is important to emphasise that the outcomes of all equations (2), (3) and (5) are expressed in monetary terms (Euros) providing a common basis for comparisons.

4.4 The weighted decision support tool

The scope of the present research is twofold; to identify and establish the triple bottom line of the environmental, economic and social indicators that affect the assessment of potential adaptive reuse, and to weigh the importance of the evaluation outcomes based on the opinion of experts and potentially other stakeholders involved. In this respect, therefore, once the alternatives have been identified and the different categories have been evaluated, the final step is to develop a weighting scheme w aiming to accommodate the comparisons of alternatives. In the present research, these are obtained from an experts' opinion survey[1], and are the following:

$$w_E = 0.34,\ w_C = 0.30 \text{ and } w_S = 0.36$$

Subsequently, the following composite index, CI*(A), is computed for each alternative, where:

$$CI(A) = w_E \times TEI + w_C \times TCI + w_S \times TVI \quad (6)$$

The composite index produced for each alternative assists in the decision making since it allows for comparisons of different alternatives of environmental, economic and social factors and reflects values in monetary terms which are weighted according to the importance of each category. Naturally, the best alternative is the one with lowest score. The lower the score is, the more environmental, economic and social respectful, the alternative under consideration is. The weighted decision support tool (WDST) is illustrated in Table 5.

Table 5 Weighted decision support tool (see online version for colours)

					Alternative 1	*Alternative 2*
Decision support tool for demolition or adaptive reuse of existing buildings	Eco-costs	Eco-costs (initial)	Con/tion phase	Eco-costs (materials)		
				Eco-costs (assembling semi/finished materials)		
			Operating phase	Eco-costs (heating)		
				Eco-costs (cooling)		
				Eco-costs (ventilation)		
				Eco-costs (lighting)		
				Eco-costs (equipment and appliances)		
		Eco-costs of alternatives	Intervention phase	Eco-costs (partial demolition)		
				Eco-costs (restoration)		
				Eco-costs (demolition)		
				Eco-costs (reconstruction)		
	Total environmental indicator (TEI)					
	Weighted factor W_E					
	Weighted total environmental indicator ($We \times$ TEI)					
	Life cycle cost	LCC		Investment costs (I)		
				Capital replacement costs (Repl)		
				Residual value (Res)		
				Energy costs (E)		
				Water costs (W)		
				Non-fuel operating, maintenance and repair costs (OM&R)		
				Other costs (O)		
	Total cost indicator (TCI)					
	Weighted factor W_C					
	Weighted total cost indicator ($W_C \times$ TCI)					
	Social value	Ranking range 0,1–0,3		Use value		
				Memory value		
				Historical value		
				Age value		
				Architectural value		
		Total ranking (R)				
	Total value indicator (TVI) = (Total environmental indicator + Total cost indicator) / 2 × R					
	Weighted factor W_V					
	Weighted total value indicator					
	Composite index (CI)					

5 Applying the WDST for a housing project

The final stage of the methodology proposed is the actual implementation to a real-project case study. To emphasise the applicability initially of the tool proposed and subsequently the accuracy of results and ease of use, it was preferred to use the initial cost calculations from a case study already examined (Bowie and Jahn, 2002). More specifically, the case study concerns a complex of approximately 200 apartments, built in the 1960s, owned by a Dutch housing association which is planning to start an intervention project. The characteristic approach of such a project would be to conduct a feasibility study concerning various options in order to support a final project definition. Apart from selling the apartments, the seven types of possible interventions are presented in Table 2. To retain focus, only the alternatives of extensive renovation and redevelopment will be examined. For these strategies, investment costs (traditional and eco-costs) have been estimated on an apartment basis.

Let us assume that extensive renovation is considered as Alternative 1 ($i = 1$) and new construction is considered as Alternative 2 ($i = 2$). The assumptions made are illustrated below:

- The eco-costs during the operation phase are not calculated and are omitted from the tool because in both alternatives the initial eco-costs that occur during the operating phase are the same and will not influence the final result.

- The energy, water, operating and maintenance costs are also the same and are omitted in the total calculation of the cost section. The life cycle cost of the building is the same in both alternatives until the time of intervention. The difference in the total costs commences after the intervention phase. For this purpose, the costs that will be calculated are the costs of demolition and reconstruction.

- In order to calculate the ranking for the social section, two scenarios have been used. The first scenario refers to the ranking of one stakeholder (a) who is fond of the renovation alternative while in the second scenario the same stakeholder examines also the alternative of demolition and reconstruction.

  The stakeholder defines the social-cumulative-value of the existing building in the case that the decision is to adopt and reuse it even if the use value of the building may not exist yet. In this case, the responsibility to retain the memory, historical, architectural and age value of the building is of high importance. As such the ranking factor $R(a)_1$ is formed as follows:

$$R(a)_1 = \sum \big(UseValue_1 + MemoryValue_1 + HistoricalValue_1 + AgeValue_1 + ArchitecturalValue_1 \big) = 0.7$$

  On the other hand, the same stakeholder due to functional, technological, social and legal obsolescence decides to demolish and reconstruct the existing cell considering that it is more important the ability of the building to fulfil all the user needs in the future more than the preservation of the cultural heritage. During studying this alternative the ranking factor $R(a)_2$ adjusted as follows:

$$R(a)_2 = \sum \left(UseValue_2 + MemoryValue_2 + HistoricalValue_2 + AgeValue_2 + ArchitecturalValue_2 \right) = 1.3$$

Subsequently, the following composite index, CI*(A), is computed for each alternative, and presented in the WDST.

Table 6 Weighted decision support tool for a housing project (see online version for colours)

					Alternative 1	*Alternative 2*
Weighted decision support tool	Eco-costs	Eco-costs of alternatives	Intervention phase	Eco-costs (partial demolition)	1.200,00	
				Eco-costs (restoration)	25.700,00	
				Eco-costs (demolition)		3.000,00
				Eco-costs (reconstruction)		67.800,00
	Total environmental indicator (TEI)				26.900,00	70.800,00
	Weighted factor W_E				0,34	0,34
	Weighted total environmental indicator (We × TEI)				9.146,00	24.072,00
	Life cycle cost	LCC		Cost of partial demolition	2.800,00	
				Cost of restoration	105.000,00	
				Costa of demolition		12.500,00
				Cost of reconstruction		135.000,00
				Other costs (O)	17.000,00	19.500,00
	Total cost indicator (TCI)				124.800,00	167.000,00
	Weighted factor W_C				0,30	0,30
	Weighted total cost indicator (W_C × TCI)				37.440,00	50.100,00
	Social value	Ranking range 0,1–0,3		Use value	0,30	0,10
				Memory value	0,10	0,30
				Historical value	0,10	0,30
				Age value	0,10	0,30
				Architectural value	0,10	0,30
		Total ranking (R)			0,70	1,30
	Total value indicator (TVI) = (Total environmental indicator + Total cost indicator) / 2 × R				53.095,00	154.570,00
	Weighted factor W_V				0,36	0,36
	Weighted total value indicator (WC × TVI)				19.114,20	55.645,20
	Composite index (CI)				65.700,20	129.817,20

The results of the WDST demonstrate that Alternative 1 (extensive renovation) has the lowest score and thus it is the most environmental, economic and social respectful proposal. In fact, extensive renovation is approximately 50% lower than the demolition alternative.

Naturally, the outcomes of this application should be further tested to the sensitivity of the weighted scheme applied. However is should be noted that in the specific case study, the results of the different indicators are so dramatically different that even the use of a very different weighting scheme could not have altered the final outcome of

Alternative 1 being more favourable under the criteria set. This finding throws some light to the discussion of the results and demonstrates that there are cases where the results are not sensitive to the application of weights.

6 Conclusions

The building sector has been constantly evolving towards a sustainable built environment. In this respect, it is clear that there is need for a tool that will take into consideration the sustainability of buildings using three main areas: the environment, the society and the economy. The number of abandoned buildings in Europe and in Greece in particular is large making the need for intervention almost self-evident. The question that rises in these cases is the type of intervention and the hypothesis set in this research is whether re-use is a preferred option as opposed to demolition and reconstruction of these buildings. This issue needs serious consideration since there are a series of social, cultural, economical, and environmental reasons to be reserved about demolition on a wide scale. Adaptive reuse of old buildings has brought long and short-term benefits to cut the environmental, social and economic costs of urban development and expansion in a sustainable manner.

The decision-making tool that has been presented in this paper examines not only environmental issues but economic and social factors aiming to embrace all three sections of sustainable development. A number of methods and case studies have been examined that fed and assisted the development of the WDST. Ultimately, its aim is to assist the decision-making process for the pertinent parties enabling comparisons of different indicators in common monetary units. This allows a quick and easy comparison between alternatives and options as demonstrated herein. The tool at present stage is by no means exhaustive and more thorough and in-depth examination of the impacts of environmental, social and economic indicators on the level of intervention on a building is required. The next stage should also include more applications of the tool to real projects enabling the testing, monitoring and auditing of the outcomes and fine tuning of the tool.

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Notes

1 68 Greek experts (i.e., designers, engineers developers and building users) participated in a survey undertaken by the authors. 39% of the respondents are engineers (17% architects, 22% civil engineers) each of which had a minimum of five year work experience being involved in more than three restoration projects; 29% are developers and 32% building users (20% building owners and 12% building occupants).