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The cost of green roofs disposal in a life cycle perspective: Covering the gap

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ABSTRACT

This study is aimed at providing a contribution in overcoming the current gap, especially in Life Cycle Costing (LCC) and Benefit – Cost (BCA) analyses, due to the lack concerning the green roof disposal costs. Therefore, we have applied to an actual extensive green roof the LCC methodology suggested by D. G. Woodward (that appears like one of the most formalized and generalizable), but we have extended the analysis to the disposal phase. This will allow a complete and proper application of the LCC methodology in order of achieving an economic accounting of this component through its life cycle. In this way, it is possible to achieve the complete evaluation of the "green roof" performance by a life cycle perspective (the environmental performances, in fact, are assessed by means of the classical Life Cycle Assessment approach). Needed steps for accomplishing the cost analysis of the disposal phase of this building component have been applied and discussed. These steps help to formalize the procedure, so attributing it an approach which may be generalized. The relative contribution of production, maintenance and end of life phases to the whole cost of this extensive green roof has been illustrated as well.

1. Introduction

The best value of green roofs is that they not only can improve the esthetical appearance of an urban context but, as it has been shown in several research works available in literature (for example in studies carried out by Takebayashi et al. [1], Lazzarin et al. [2], Onmura et al. [3], Wong et al. [4], Niachou et al. [5] and Takakura et al. [6]), they can provide many environmental and economic benefits, either to the private building owners and to the public at large.

Table 1 tends to clarify how the presence of a green roof in a building leads to economic benefits for the building owner.

Even if the environmental assessment of such building component by a life cycle perspective appears relevant, so it is also the economic analysis of green roofs.

By the way, since green roofs are able to provide several economic benefits to the building owner, such as lower energy consumption especially for cooling, stormwater utility fee credit (they are able to retain stormwater for small events) and NO_x emissions credits (they are able to improve air quality), in predicting the total cost associated with a green roof over its intended service life, costs such as avoided expenses due to reduced energy consumption, avoided cost due to reduced runoff to the stormwater system might be actually included in their economic analysis.

However, it seems relevant to note that so far, little research has been done to evaluate the economic performance of green roof systems for urban applications. A short review regarding what has been already done from this standpoint and mainly reported in proceedings, has been carried out by Carter and Keeler [7].

In the following, journal papers currently available on this topic, are briefly described.

2. State of the art for the economic analysis of green coverings

Carter and Keeler [7] use data collected from an experimental green roof plot to develop a benefit – cost analysis (BCA) for the life cycle of extensive (thin layer) green roof systems in an urban watershed. Clark et al. [8] apply a cost-benefit analysis at the building scale in order to quantitatively integrate the range of stormwater, energy, and air pollution benefits of green roofs into an economic model that captures the building-specific scale. Hao Niu et al. [9] aim at quantifying and scaling the environmental benefits of green roofs from individual buildings to the city scale and at incorporating them into an economic framework (Net Present Value) model to calculate the range of breakeven points. Wong et al. [4] develop a Life Cycle Costs Analysis (LCC) and an LCC where the

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Nomenclature

LCC	life cycle costing
BCA	benefit − cost analysis
LCA	life cycle assessment
HDPE	high density polyethylene
PP	polypropylene
PET	polyethylene terephthalate
NPV	net present value
m,n	actualization years (years)
i,j	discount rate
a	actualized cost of 1 Euro (Euro)

energy costs are included as well, with the aim of comparing the cost of green roofs with respect to other roof alternatives, in order to understand which one is the best option. More in detail, they examine the initial cost implications of having a green roof as compared to a conventional roof; compute and compare the life cycle costs of roof gardens and average roofs; incorporate economic benefits by embodying energy costs into life cycle costs.

All of these studies apply either a Benefit−Cost Analysis (BCA) methodology or a Life Cycle Cost approach (LCC) in order to compare the performance of conventional roof systems and green roofs. However, it seems relevant to note, that with respect to the part referring to the evaluation of the costs, none of the aforementioned studies take into consideration the disposal cost of green roofs.

Table 2, which reports synthetically the state of the art regarding the assessment of the economic performance of green roofs, briefly described above, makes clearly evident this gap.

This short review justifies the attempt to provide a contribution in covering this gap related to economic analyses of green roofs, for a more complete and proper evaluation of the costs of green roofs, whatever is the methodology applied (BCA, LCC, etc [10–12]).

On the other hand, since there are many commercially available green roof systems, whose product cost can vary according to design and function (e.g., intensive green roof or extensive), we have here chosen to approach the problem by analysing an actual extensive green roof, built up in Sicily.

It also needs to be outlined that, even the maintenance costs of green roofs can vary significantly based on the specific type of green coverings; in fact, accessible green roofs (intensive) with more demanding plantings would require obviously higher maintenance costs than those of inaccessible green roofs (extensive). However, it should be considered that future maintenance and replacement costs of green roofs are supposed to be lower than those of traditional roofs; in fact, green roofs, as it has been said earlier and as several authors [13–16] claim, generally have longer lives than exposed roofs because of the presence of additional layers of substrate and vegetation which act as a protection for the roof membrane. A longer service life of roofing systems would mean fewer roof replacements during the life of the building, thereby reducing the maintenance cost.

This application also allowed us to present some data concerning the hypothesized disposal phase of extensive green roofs.

Furthermore, we have applied the LCC approach to the green roof under analysis. For doing this, we have selected to apply the procedure reported by D. G. Woodward in his work "*Life cycle costing − theory, information acquisition and application*" [17].

The LCC methodology is basically a compilation and assessment of all costs related to a given product, over its entire life cycle, from production to use, maintenance and disposal, that are directly covered by any actors of the chain. A product, in fact, in its life cycle has to pass the phases of product development, manufacturing, distribution, usage, and disposal/recycling. In each of these phases, costs are incurred which are to be borne by manufacturer or/and user. Society also bears some kind of costs due to pollution, depletion of natural resources and health damages [18].

The LCC approach identifies all future costs and benefits and reduces them to their present value by the use of the discounting techniques [17].

However, it has to be reminded that still an ISO standard does not exist for LCC method, unlike life cycle assessment methodology (LCA) [19,20]. By the way, even from the environmental point of view, several constraints do exist. It seems relevant to note that, despite several researches have been addressed to green roofs in the last years, in the international scientific literature, there are only a few papers regarding also the environmental performance assessment of their life cycle, so far.

Furthermore, also as far as the environmental life cycle assessment (LCA) of green roofs is concerned, it seems relevant to remark that the only two works, currently available in journal papers on these topics seem, for different reasons, to be only partially complete.

Table 1
Where do the economic benefits for the building owner come from in a building with a green roof?

Environmental and energy benefits	Economic benefits
Lower indoor temperature in the building [32].	Energy cost savings due to reduced cooling loads.
Shielding of roofing materials from direct exposure of solar radiation and not exposition to extreme temperature fluctuations [25].	Maintenance and replacement costs savings due to a longer service life of roofing system.
Better aesthetic appeal, supply of added amenity space for the occupants [4].	Increased property values, increased marketability of a property.
Stormwater retention [7].	Reduced stormwater utility fee.
Potential rainwater harvesting to provide a partial supply to meet domestic needs. Alternatively rainwater can be used as toilet flushing water [4,33,34].	Water cost savings.

Table 2
State of the art regarding the economic evaluation of green roofs (only journal papers are here included).

Authors	Assessment methods used	Initial costs		Operating and maintenance cost	Disposal cost
		Components purchase costs	Installation costs		
Carter and Keeler (2008) [7].	Cost − Benefit analysis + NPV analysis	Yes	Yes	Yes	No
Corrie Clark et al. (2008) [8].	Cost − Benefit analysis + NPV analysis	Yes	Yes	No	No
Hao Niu et al. (2010) [9].	Cost − Benefit analysis + NPV analysis	Yes	Yes	No	No
Wong et al. (2003) [4].	Initial cost analysis + Life cycle costing + Life cycle costing embedding the energy savings due to the presence of green roofs	Yes	Yes	Yes	No