SOCIO-ECONOMIC FEASIBILITY OF GREENING ENTRECAMPOS RAIL STATION, LISBON

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ABSTRACT

Green roofs and living walls are considered effective solutions to improve the environmental integrity of urbanized areas. Nowadays, proposals arise not only for buildings but also for existent transport infrastructures which have needs/problems they can respond to. However, there are discussion about their feasibility, hence the need of cost-benefit analyses (CBA) for several scenarios. This study presents a methodological approach, supported by literature review, to discuss the feasibility of greening urban transport infrastructures by performing the CBA separately for financial (FA), economic (EA) and socioenvironmental (SA) analyses. Besides, infrastructure, user and environmental dimensions are assessed independently. Infrastructure dimension considers construction, maintenance and replacement/demolition costs and benefits as improvement of photovoltaic performance (FA), increase of aesthetics and recreation value (EA) and job creation (SA). User's value dimension includes well-being (EA), station's noise reduction and air pollution removal (SA). Environmental dimension reflects noise reduction and benefits related to storm water management (SA). The methodology is applied to one of the main stations in Lisbon, Portugal, Entrecampos Railway Station. Five different scenarios of green infrastructures are compared with station's current situation. The CBA demonstrated that all five greening scenarios are economically feasible. For 50 years and a 3.36% discount rate, the net present value (NPV) ranged between 734,700€ and 7,733,279€. A sensitivity analysis was performed to the CBA, showing the high influence of discount and inflation rates, recreation, aesthetics improvement, well-being and station's noise reduction on the NPV value, ranging from 1.5 to 9%.

Keywords:
Green roofs/walls
Cost-Benefit Analysis
Transport Infrastructures
Rail station

1. INTRODUCTION

1.1. Background and aim of the study

Several commission directives encourage national and local governments to rethink urban environments in order to minimize the unsustainable land occupation and improve citizens' quality of life. As integral parts of the cities and large under-exploited areas, transport infrastructures seek for adequate interventions. Moreover, they represent physical barriers inside the cities that blind citizens' visibility, resulting in a significant visual impact [1, 2]. Greening these infrastructures is a strategy to improve the environmental integrity of urbanized areas. Among other benefits, these systems increase permeability, improve air quality and reduce noise levels while responding to other multiple needs/problems such as aesthetic issues, discomfort, safety perception and non-use of several spaces [3, 4].

Even though there is an underlying assumption that green infrastructures enhance cities' value, there are few studies attempting to quantify their real economic impact [17–24]. In response to the lack of research on greening existent transport infrastructures, the present study proposes a methodological approach to perform life-cycle cost-benefit analysis with application to rail stations. The Entrecampos Rail Station, one of the main stations in Lisbon, Portugal, is chosen as a case study.

At the end, it is performed a sensitivity analysis to the studied parameters.

1.2. Transport infrastructures

The study focuses in rail transport infrastructures, particularly in heavy modes (train and subway). Typically, three circulation spaces are differentiated: decision spaces (entrances, ticket offices or corridor junctions where should exist clear signing), movement spaces (which connect decision spaces that should provide unobstructed routes) and opportunity spaces (utilities and retail with no interference on other adjacent areas) [5].

Rail transport users value pleasant journeys, clean spaces, efficiency, legibility of spaces and accesses [4]. The appropriate visibility and luminosity provide the required orientation (in space and time) and a sense of safety. However, interface stations are mostly robust constructions with vertical elements and raised floors which hinder the existence of ample spaces [6].

In urban areas, most passengers are commuters (daily use). A commuter's profile has low dwell times on stations and prefers paths with minimal journey times and less modal shifts [7, 8, 2]. Besides variance of dwell and journey times, other factors contribute to make journey's less attractive (e.g. walking distance and conditions, insecurity, climate, strain, social pressure, or inconvenience) [2, 8, 9]. In addition, users have increasingly valuing the availability of food and retail outlets [10].

1.3. *Green infrastructures*

Traditional green roofs systems are composed of a waterproofing membrane, root barrier, drainage and filter layers, and growing medium for the plants. Intensive green roofs can be accessible and handle larger plant species, usually with more need for water. Extensive green roofs are thin and therefore light, like traditional ones. This allows them to be sloped and often planted with sedum. Finally, intermediate solutions of semi-intensive green roofs include a wide variety of plant species, like native grasses and flowers [11–13].

Vertical greening systems are grouped in green facades or living walls. In the first group (green facades) plants climb along surfaces or are supported by systems that promote their uniform growth. Climbers grow either directly on the surface (direct system) or by climbing a support structure (indirect system). The second group (living walls) is divided in continue or modular systems, according to whether the plant species are scattered on permeable felt layers or in modular panels attached to a frame, respectively [14–16].

1.4. *Green urban transport infrastructures*

Several authors have performed cost-benefit analyses on the installation of green infrastructures in buildings [17–24]. Despite the results variability, these studies highlight relevant benefits in long-term permanence, air-conditioned buildings. However, not only railway stations are mostly strongly ventilated (given the openings to the outside), and not air-conditioned, but waiting times there are generally reduced. Therefore, conclusions based on literature review are unsuitable to the present study and reveal the need for quantifying the benefits relevant to this study. Green infrastructures costs and benefits can be distinguished from infrastructure, user or environmental dimensions, as it follows.

Infrastructure dimension

Generally, costs of vertical greening systems are higher than for green roofs [25], living walls costs are higher than for green facades [26] and green extensive roofs are less expensive than intensive ones. In addition, unit costs increase with height of construction and decrease with larger green areas [27]. Cost quantification is a complex process due to the diversity of systems, supports, installation's site, climate, local incentives, and others. Singular areas, trims or structural changes in infrastructures should be considered [28, 19].

Transport infrastructures with green roofs/walls tend to be valued due to benefits like aesthetics improvement and creation of new useful spaces [29, 3]. These benefits vary according to the infrastructures' visibility and accessibility [17].

Several authors also refer increases of the support's lifespan (e.g. waterproofing membrane, facades) given its lower exposure to environment insults [21, 30, 31, 17].

The growth of green infrastructures business also improves job creation (construction, maintenance, etc.) and generates new indirect jobs (new spaces, retail, services) [32, 13].

User dimension

Several studies conclude the reduction of anxiety and discomfort levels, mostly in urban environments, with greening presence [33–36]. Authors used to quantify these benefits according to the willingness to pay for urban green spaces improvement or installation [37–39]. Furthermore, users' well-being provides more tolerance, social interaction and health [40].

Green infrastructures insulation impact has been the aim of contradictory studies [41, 42, 28]. As stations are usually not insulated, the performance of green roofs/walls is highlighted. Although energetic efficiency is not a transports' related issue, green infrastructures have the potential to increase indoor thermal comfort [43, 28, 44].

Vegetation also enhances air quality and, thus, improves public health. The potential of living walls to remove air pollutants is almost half than that of green roofs [21]. Intensive roofs, which handle wide species, are more effective on air pollution mitigation [31]. In addition to filtering air pollutants and toxic gases, plants reduce urban temperatures and ozone formation [45, 31, 46].

Environmental dimension

Greening railway stations attenuates noise on surroundings (transmission). Besides this, plants can reduce noise levels indoors and at platform zones (diffraction) [21, 25]. In the long term, noise has consequences for public health [47]. This acoustic benefit is lower for thinner plant layers and discontinuous supports (vertical systems) [21]. On other hand, absorption in facades is effective due to multiple reflections [25].

Several authors do not include quantification of urban heat island's mitigation in their studies. This is assumed to be a marginal benefit, especially for applications in single buildings like station's case study, where it is influenced by local climate [21, 18, 20].

Green infrastructures can also recover and enhance local biodiversity [11, 48].

Water quality improvement and runoff management (rainwater retention and runoff delay) are also being studied for green roofs [49, 31, 46, 29].

2. METHODOLOGY

The proposed methodology (**Fig. 1**) aims to discuss the feasibility of greening urban transport infrastructures by performing a cost-benefit analysis (CBA) separately for financial, economic and socioenvironmental levels. Complementarily, infrastructure, user and environmental dimensions are assessed independently.

The relevant parameters are represented in **Fig. 1** as well (green coloured in particular for case study). The assumptions made are explained in section 2.3.

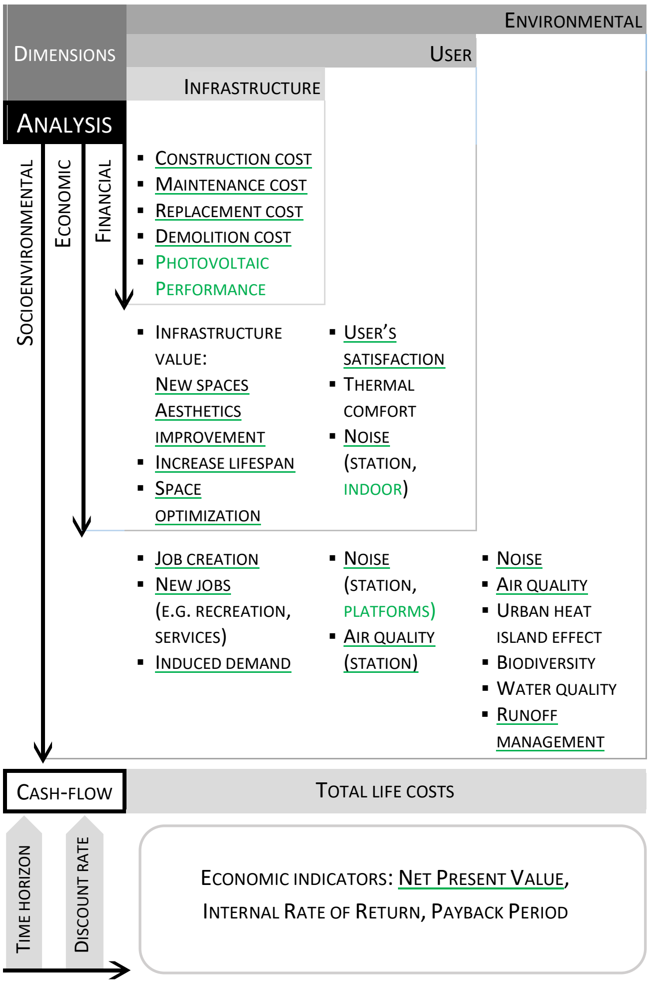


Fig. 1. Methodology proposal for cost-benefit analysis.

Methodology is adjusted to the parameters that are effectively analysed and quantified in the case study. Underlined benefits (see **Fig. 1**) are valued in the following CBA analysis because of their representativeness in Entrecampos Rail Station. The benefit of improved photovoltaic performance (coloured green in **Fig. 1**) is added to methodology because panels are already part of the station's reality.

The green infrastructures costs and benefits are considered over a time horizon that focuses on exploration period until residual costs. For vertical systems (green facade/living wall) it is admitted a 50 years' period of analysis and the extensive green roof is studied for 40 years. The discount rate is set at 3,36% (according to **Eq. 1**) to update de costs and benefits.

$$DR = (1 + r_{return})(1 + r_{risk})(1 + r_{inflation}) - 1 \qquad (1)$$

Where rate of return, rate risk and inflation rate are, respectively:

r_{return} – 0.234% according to German bund, benchmark in Eurozone (usually used risk free interest rate) [50];

r_{risk} – 2.5% for a medium risk investment (annual risk premium) [51];

$r_{inflation}$ – 0.6% (average for Portugal, 2016) for current prices cash-flow [52].

3. CASE STUDY

Entrecampos Rail Station (**Fig. 2**) is chosen as the case study of this paper. The station is one with the highest passengers' flow in Portugal. According to station's manager (Infrastructures of Portugal), there are about 679 000 monthly passengers (data from 2015). The infrastructure is an intermodal commuter rail station, with prevalence of suburban trains (more than 90%). It provides transfer to metro, local bus and taxis. Additionally, the station has mini generation photovoltaic panels installed on the roof and the generated energy is sold to the public grid.

Despite being a singular infrastructure with great value (located in the centre of the city), it reflects several problems of rail stations: poorly lighted areas, low visibility, sense of security, overcrowded at peak times, under-exploited areas, uncomfortable atmosphere, noise/vibrations (from the rail/users), visual pollution and infiltration of rainwater in the platform's zone. Surrounding areas also have high noise (from road/ rail traffic) and air pollution (from road traffic) levels.

Fig. 2. Entrecampos rail station: (a) aerial view, (b) south access and (c) north access.

3.1. Scenarios proposal

According to the station's performance and needs, five greening scenarios are suggested (described in **Table 1**). Scenarios proposal has a main purpose to enhance aesthetics, sense of comfort and use of spaces. Each vertical greening system (scenarios I, III, IV, V) is analysed for both green façade and living wall (see section **4**). Green roof scenario (II) considers a flat extensive one.

Scenarios are selected by the representativeness of their benefits in four intervention spaces – ground and raised floors in external environment, circulation and opportunity areas in internal environment – relatively to other potential scenarios.

3.2. *Scenarios costs and benefits*

Some assumptions are made to quantify the green infrastructures costs and benefits according to the proposed methodology. Foremost, in order to perform an optimal quantification of benefits, was conducted a local counting people' fieldwork in all accesses and stairs. The counts were performed at morning peak hour (critical hour) given its representativeness of the passengers' flow. The results (presented in **Fig. 3**) are useful for benefits for which it is important to consider the number of exposed passengers in each scenario.

Next, quantification assumptions are presented separately for infrastructure, user and environmental dimensions, according to the proposed methodology. **Table 2** combines all five scenarios with quantified costs and benefits.

Infrastructure dimension

Construction, maintenance, replacement and demolition costs are based on existing studies and on data provided by Neoturf (a company dedicated to green spaces and green roofs operating in Portugal).

Improvement on photovoltaic panels efficiency [53] is quantified by their annual power (140 000 kWh) and energy market prices in Portugal [54].

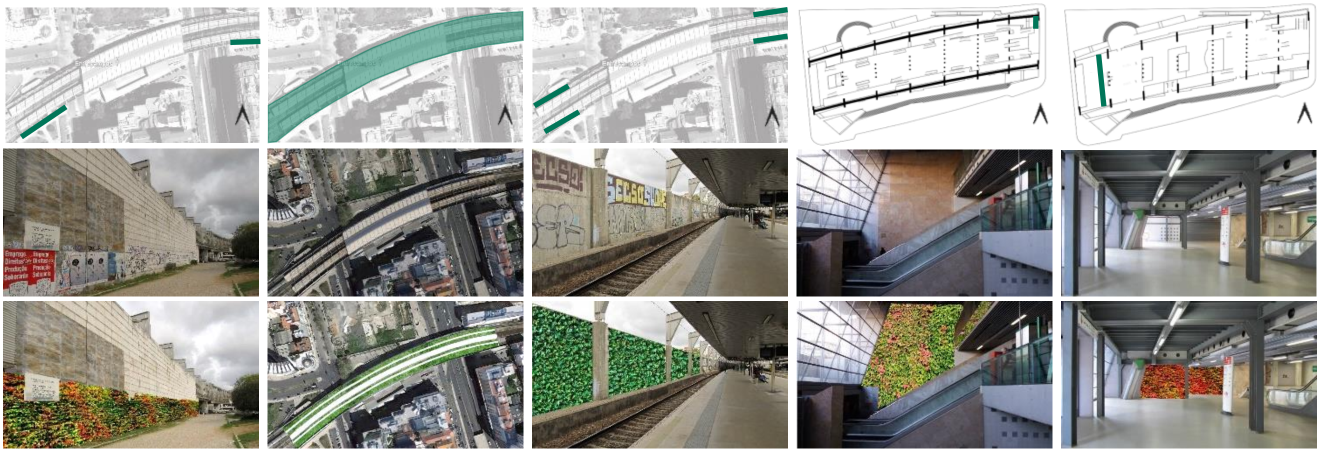
New space is only associated to scenario V given vegetation's potential to create new areas. For gain quantification, the renting stores' costs for case study are consulted [55].

Aesthetics is measured according to studies about the willingness to pay for visual improvements on stations [56]. In case study scenarios, greenness location (100%, 55% and 50% for external environment, platforms and station indoors, respectively), its visibility (100%, 55% and 5% for "good", "mean" and "bad", respectively) and exposed passengers (according to fieldwork) are considered. This quantification is not about the station's value since it is a public infrastructure.

Table 1
Analysed scenarios in the in socio-economic study.

Scenario I	*Scenario II*	*Scenario III*	*Scenario IV*	*Scenario V*

Location / Before / After



	External environment		Internal environment	
	Ground floor	Raised floor	Circulation areas	Opportunity areas
Benefits	Aesthetics improvement Air renewal Façade protection	Runoff management Noise reduction (outside) Sense of comfort	User's satisfaction Noise reduction (sound absorption) Legibility of spaces	Space for new initiatives Aesthetics improvement Sense of security

The increase of the building elements lifespan is not valued since the current station materials are durable not subject to maintenance (industrial roof type with steel structure and concrete walls with facing bricks).

Space optimization and induced demand are not valued too, due to the need of prediction/simulation models.

Job creation due to green infrastructures life cycle activities increases the local gross domestic product. New jobs are not considered given their dependence on the type of new spaces.

User dimension

Sense of satisfaction, or well-being, is an important benefit of greening transport infrastructures that is valued by users. Satisfaction value is measured based on literature review for first 10 analysed years, [37–39] given the complexity of using Entrecampos passengers' data. Then, exposed passengers and scenarios with benefits reflecting satisfaction (thermal comfort, less infiltration and noise, etc.) are considered (¼ weight for each benefit). Aesthetics brings a sense of comfort too, although it is not included in this quantification because it has been previously valued (also with user's perspective).

Railway associated noise is an externality of transport projects' economic evaluation. Decibel reduction in station (indoor) is valued according to local noise measurements and noise costs per exposed passenger in Portugal [57, 58]. Noise reduction at platforms' zone (outdoor area) is valued in "environmental dimension".

Pollutants removal benefits air quality during users' waiting times. The resulting gain is obtained through the equivalent carbon dioxide price in The European Union Emissions Trading Scheme (EU-ETS) defined by the Kyoto Protocol [50].

Environmental dimension

Noise emitted to the surrounding environmental is reduced by green roofs/walls at platform zones. That reduction is equivalent to avoid the investment in some intervention measures scheduled by the Lisbon city council [58].

Green roof scenario (II) prevents water inlet and leakage in the railway platform. Based on data about precipitation episodes in the case study area [52], the volume of water retention is obtained. That amount of water does not intercept drainage systems, reducing costs [59].

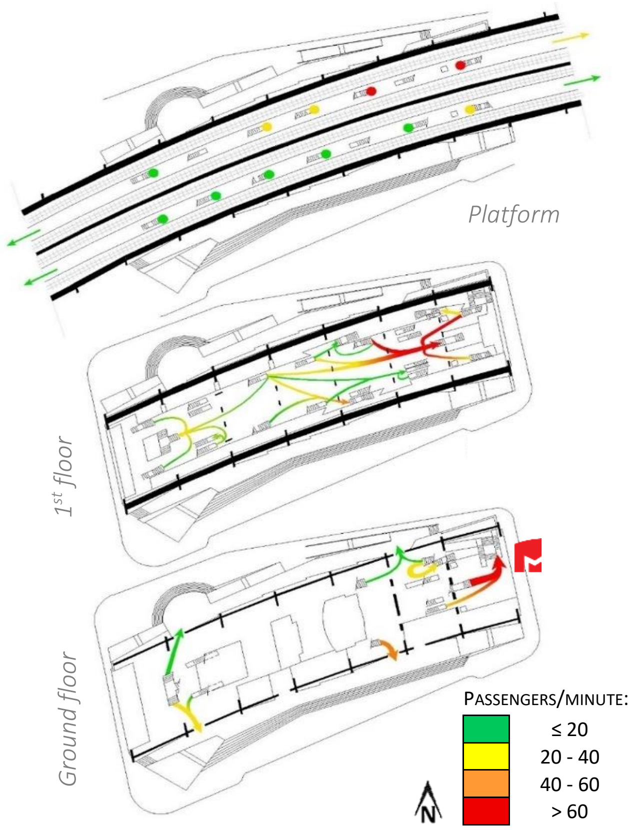
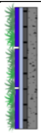
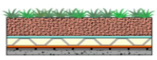
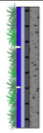
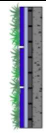
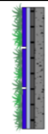


Fig. 3. Passengers flow at morning peak hour (8 am to 9:30 am).

Table 2
Summary table of the quantified costs and benefits for proposed scenarios.

		Scenario	*I*		*II*	*III*		*IV*		*V*	
		Proposal									
		Green area (m^2)	190		8,000	380		10		98	
		System (Continue/modular living walls; direct/indirect green facades; extensive green roofs)	Living wall 	Green 	 Extensive flat	Living wall 	Green 	Living wall 	Green 	Living wall 	Green 
Costs		Construction (€/m^2)	600	90	55	600	90	600	90	600	90
		Maintenance (€/m^2 year)	48	3	2,50	48	3	48	3	48	3
		Substitution (€/m^2)	500		50	500		500		500	
		Demolition (€/m^2)*	200	75	35	200	75	200	75	200	75
Benefits	Infrastructure	Photovoltaic panels (€/year)	---	---	708.97	---	---	---	---	---	---
		Photovoltaic panels (efficiency %)	---	---	+22.5%	---	---	---	---	---	---
		New spaces (€/month)	---	---	---	---	---	---	---	---	4309.20
		New spaces (m^2)	---	---	---	---	---	---	---	---	270
		Aesthetics (€/year)	72 429	50 700	---	308 096	215 667	18 132	12 692	4 369	3 058
		Aesthetics (improvement %)	5	3.5	---	5.5	4.2	0.83	0.58	0.65	0.46
		Job creation (€/m^2 year)	2.17								
		Job creation (employee/m^2)	1.251×10^{-4}								
	User	User's satisfaction (€/year)	---		462 960	15 432		3 704		1 852	
		User's satisfaction (base value %)	---		75	2.5		0.06		0.03	
		Station noise reduction (€/year)	---	---	---	---	---	33 343	13 361	10 260	4 112
		Station noise reduction (dB)	---	---	---	---	---	≈ 5	≈ 2	≈ 5	≈ 2
		Air quality (€/year)	136.80		5 760	273.60		7.208		70.56	
		Air quality (kg/m^2)	Annual absorption: 0.050 to 0.370 (NO_2); 0.378 to 6.470 (CO_2)								
	Env.	Environment noise reduction (€)	---	---	11 153	1 115		---	---	---	---
		Environment noise reduction (dB)	---	---	up to 5	up to 0.5		---	---	---	---
		Rain water retention (€/year)	---	---	820.38	---	---	---	---	---	---
		Rain water retention (%)	---	---	55	---	---	---	---	---	---

*Demolition costs are not considered in analysis. It is admitted total substitution of greening systems which cost (last year) includes components' demolition.

4. FEASIBILITY STUDY

A feasibility study is performed for financial, economic and socioenvironmental analysis. The analysis is presented separately for both types of vertical systems. Living wall's scenarios are named I, III, IV and V. Green façade scenarios, with climbers, are I_c, III_c, IV_c and V_c.

4.1. Financial analysis

Fig. 4 and **Fig. 5** show updated non-cumulative and cumulative cash flows, respectively.

As shown in the figures, all scenarios are financially unfeasible. These results are expected since the inputs are all negatives (except for green roof scenario), representing only costs. However, green roof scenario (II) benefits for the improvement of photovoltaic panels' efficiency, is not representative and does not reveal any trend of investment's recovery.

Green façade scenarios (I_c, III_c, IV_c and V_c) have lower initial and maintenance costs than living wall's (I, III, IV and V). Substitution costs are similar for both systems, resulting in end of life cycle significant costs.

Construction and maintenance costs for green facades have the same magnitude that for the green roof scenario. However, the proposed wide area of 8000 m^2 implies higher costs, making it the most expensive scenario.

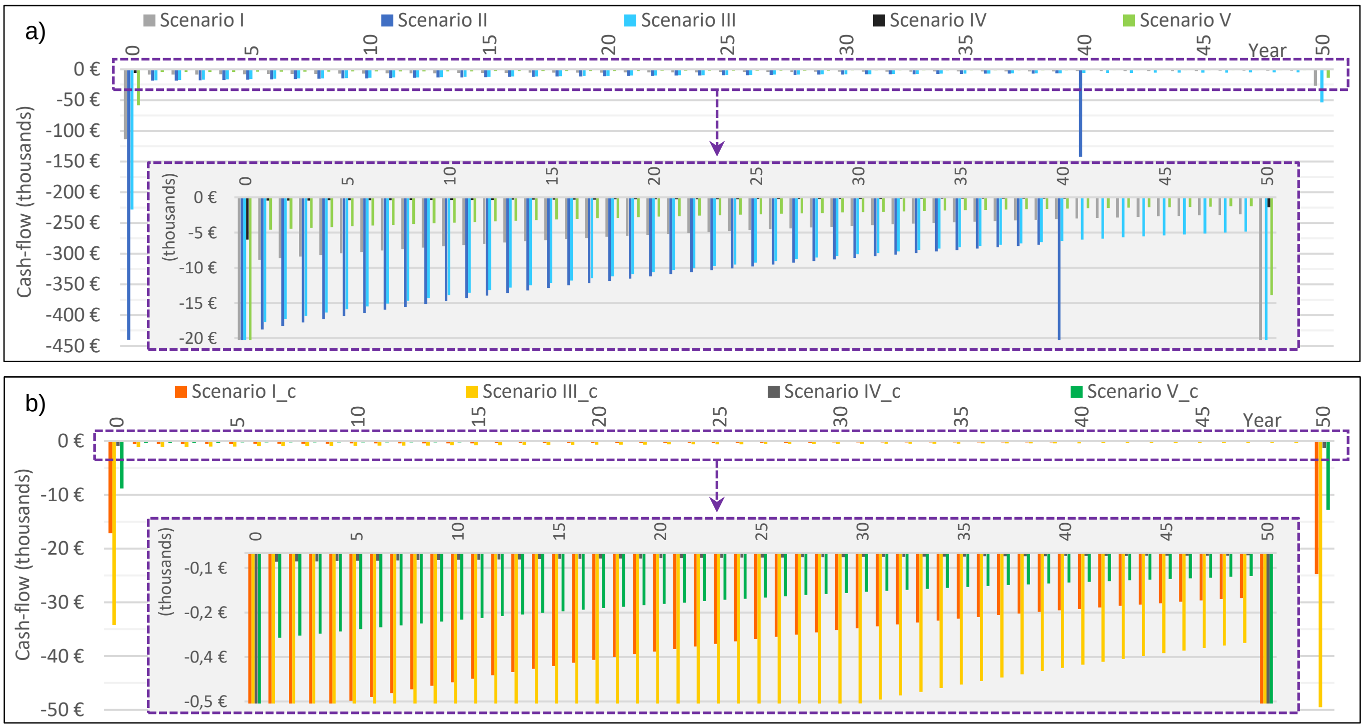


Fig. 4. Cash-flow for financial analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

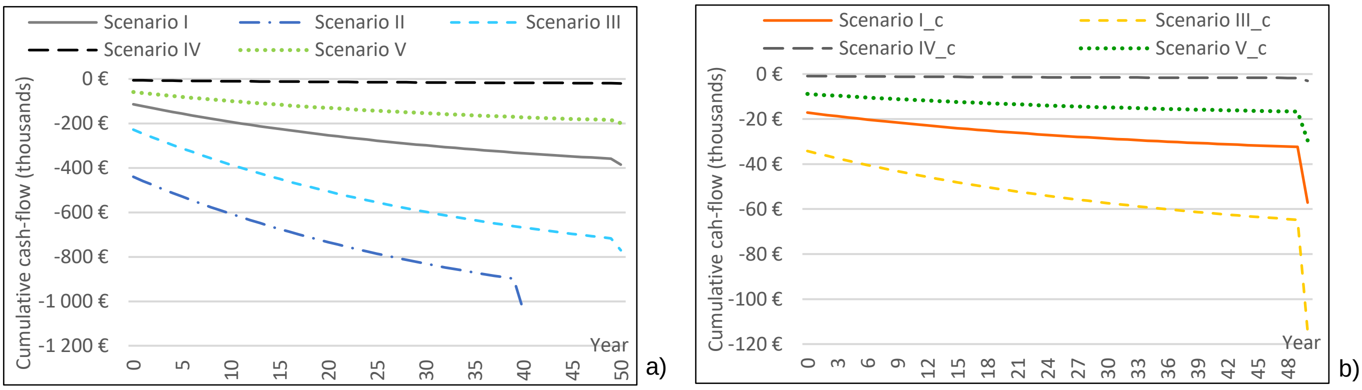


Fig. 5. Cumulative cash-flow for financial analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

4.2. Economic analysis

Despite the scenarios being unattractive financial investments, greening the station is profitable at the economic level (as shown in **Fig. 6** and **Fig. 7**, updated non-cumulative and cumulative cash flows, respectively).

Parameters for which quantifications are related with the users' perceptions have the highest influence on economic analysis. Both aesthetics and satisfaction improvement are essential for users' well-being. Due to their impact on thousands of passengers, they reflect high economic benefits.

Space rental generates significant gains for scenario V that is barely visible in the least frequented zone of the station and, consequently, affects few users.

Scenarios I (outdoor) and III (platform), for both living and green walls, tend to increase gains until the end of the systems life cycle. Even though these scenarios are more expensive than other facade solutions (scenarios IV and V), greater green areas and installation's site add higher aesthetic value. In addition, scenario III has the highest potential to improve users' comfort, thus, it is the most profitable long-term scenario.

Scenarios IV (train-metro interface) and V (east side new space) are less beneficial in terms of comfort and aesthetics. Installations' site is barely visible, with lower number of exposed passengers, and green areas are smaller.

As previously stated, scenario V (living wall) is economically sustainable due to space rental that counteracts cumulative cash flows trend losses every year.

Despite the significant gains resulting from the large area of green extensive roof (scenario II), this scenario has the disadvantage of having poor visibility (except for surrounding buildings). Consequently, aesthetic passengers' perception is marginal, leading to lower economic benefits. Even though scenario II only generates gains in the first ten years of its lifespan, at the end it reflects cumulated gains.

4.3. Socioenvironmental analysis

The socioenvironmental analysis involves both society and environment value (**Fig. 8** and **Fig. 9**, updated non-cumulative and cumulative cash flows, respectively). Figures' trend and cash flows are similar to previous ones (economic analysis), which denote the higher weight of economic parameters.

Nevertheless, socioenvironmental input can reverse the depreciation found in scenario II. Scenario IV (train-metro interface) benefits the most from socioenvironmental analysis. Noise attenuation generates significantly positive cash flows which are increased with the greater number of passengers.

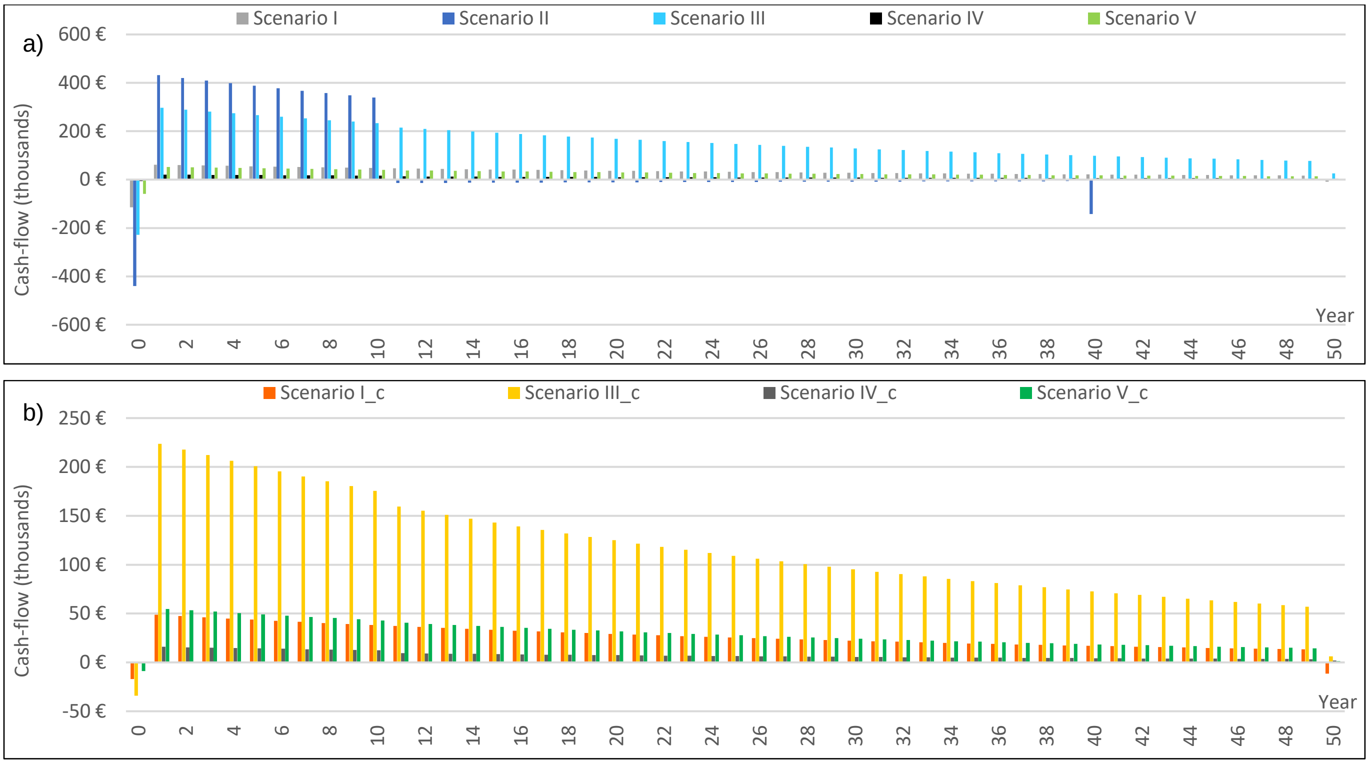


Fig. 6. Cash-flow for economic analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

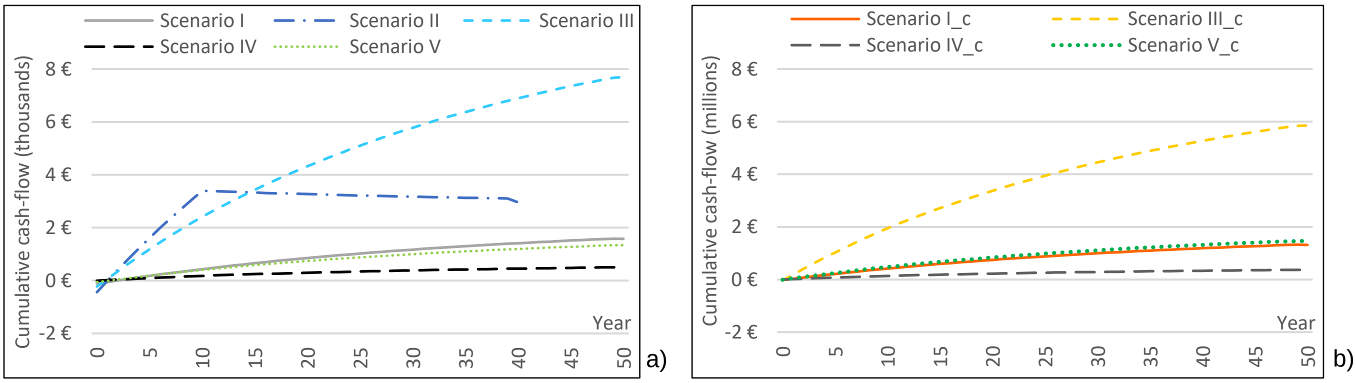


Fig. 7. Cumulative cash-flow for economic analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

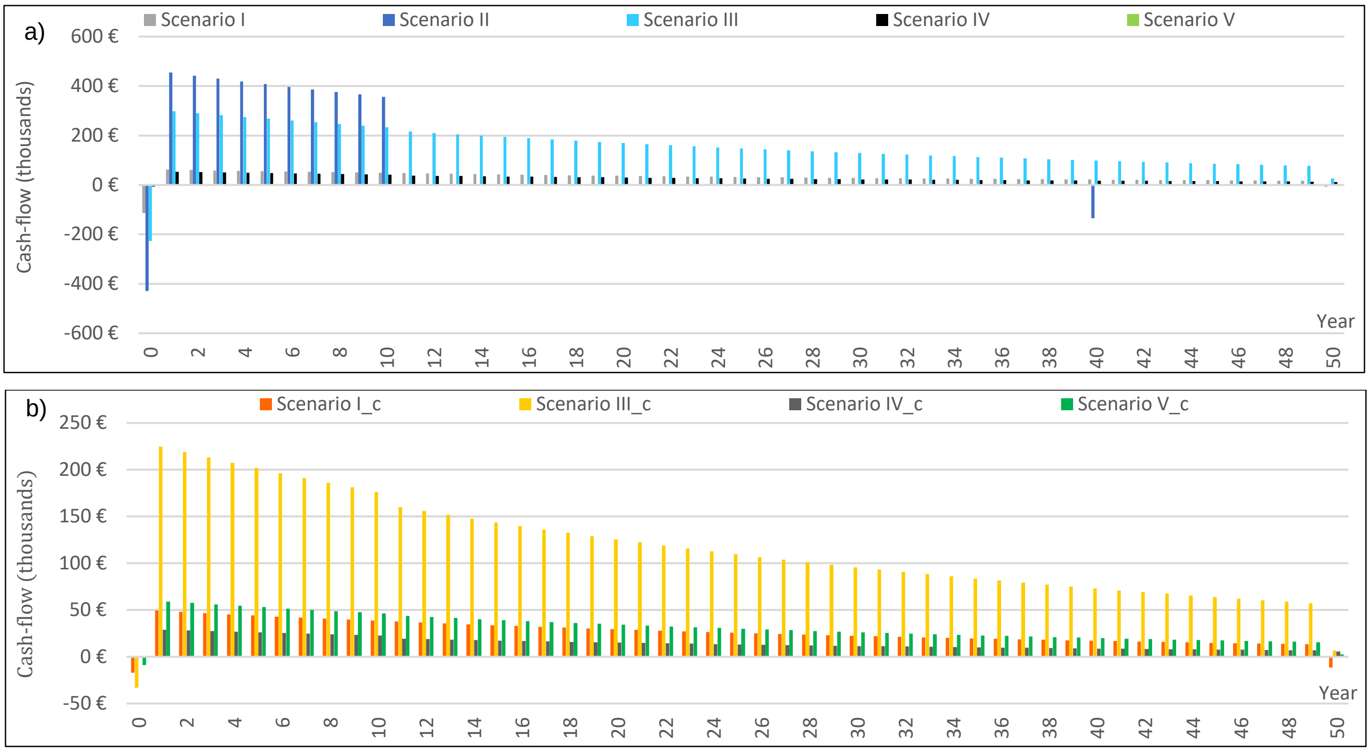


Fig. 8. Cash-flow for socioenvironmental analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

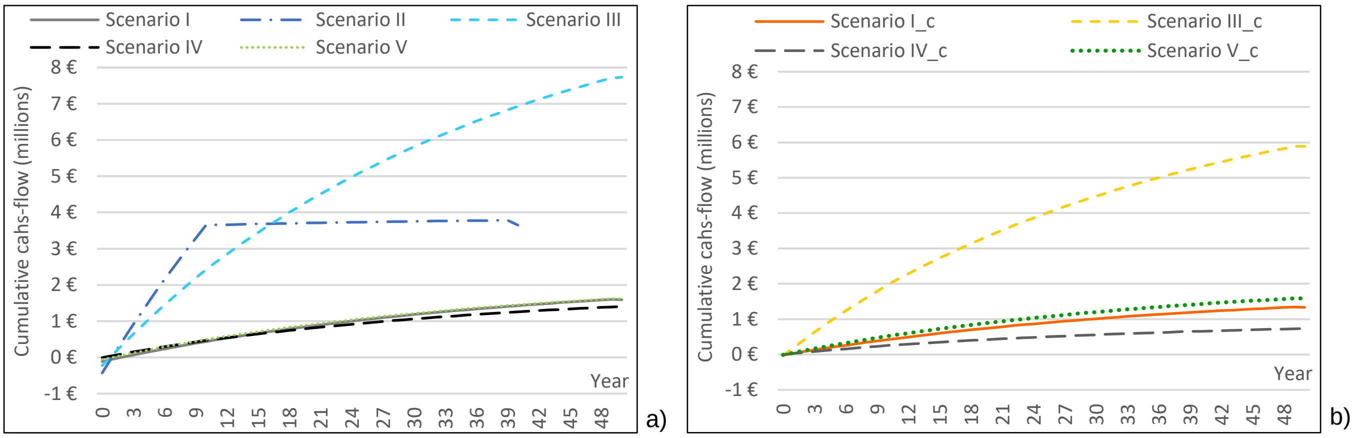


Fig. 9. Cumulative cash-flow for socioenvironmental analysis: (a) living walls and green roof scenarios and (b) green facades scenarios.

4.4. Summary discussion

Table 3 summarises the NPV (Net Present Value) of all analysed scenarios for each parameter of economic analysis. Presented values include benefits and costs for all studied dimensions: infrastructure, user and environment. The colour scale allows the identification of the order of magnitude of the results.

Scenarios III and III_c are the ones with the greatest social and environmental value, with a significant benefit at the end of the 50 years' time horizon. Cost differential is nearly 650 000 € and cumulative gain is about 2 000 000 € higher for the living wall system (scenario III). However, in relative terms, green façade (III_c) generates gains which are 50 times higher than its costs and living wall has 10 times higher benefits than its costs. Both systems generate significant benefits, so the decision for the best scenario (greatest absolute gain or most profitable one) depends on the investor's intention and the available budget.

In other façade scenarios (I, I_c, IV, IV_c, V, V_c), the trend is similar to scenario III. As expected, living walls generate the highest absolute gains and green facades generate the greatest relative gains (5 times higher than living walls, on average). This evidence suggests that NPV only reflects benefits and costs of each scenario and, consequently, another profitability methods will return different conclusions. For instance, scenario IV (the less profitable) has the greatest benefits relatively to costs; climber's system (IV_c) has 200 times more gains than costs. So, NPV does not show the most feasible scenario.

Scenario V, which is less visible and with slight passenger flow, shows a significant output from space rental. Despite this, an increase of occupation rate is predicted in the scenario's installation site (east side of station), which leads to higher economic benefits (user's value).

Table 3
NPV values of feasibility study for the analysed scenarios.

Scenario	NPV Financial analysis	NPV Economic analysis	NPV Socioenvironmental analysis
I	-385 292.82 €	1 573 957.41 €	1 588 201.86 €
I_c*	-57 109.92 €	1 314 365.24 €	1 328 609.70 €
II**	**-1 040 946.23 €**	2 961 149.15 €	3 534 271.84 €
III	-770 585.65 €	**7 697 009.07 €**	**7 726 612.99 €**
III_c*	-114 219.84 €	5 853 117.42 €	5 882 721.33 €
IV	-20 278.57 €	502 223.02 €	1 404 921.95 €
IV_c*	**-3 005.79 €**	**372 351.19 €**	**734 524.39 €**
V	-198 729.98 €	1 334 263.00 €	1 619 149.62 €
V_c*	-29 456.70 €	1 468 081.02 €	1 586 660.36 €

*Green facade scenario (climbers)
**40 years' analysed period (another are 50 years)

For the extensive green roof scenario (II), the difference between the analysis period affects the NPV reliability. However, the results are comparable with others given its constant chart's progress (see **Fig. 7** and **Fig. 9**). Thus, green roof proposal is the most expensive but not the one with the highest return.
Results are coherent and significantly favourable. All five scenarios turn up feasible. It is concluded that a 50 years' study enhances the NPV value, with benefits between 734 524.39 € (IV_c) and 7 726 612.99 € (III). Aesthetics improvement, noise attenuation and new spaces are the most valued benefits, which are the parameters that increase infrastructure and user value. Environmental benefits (vicinity) generate moderated monetary gains.
Internal rate of return (IRR) and payback period (PP) are not appropriate to this case study results. Financial analysis shows only negative cash flows, while economic and socioenvironmental parameters generate substantial gains from the first analysed year.
Given these results, although the systems are designed for long-term, the investment´s payback is substantial and almost immediate. This is in line with Vijayaraghavan's study (2016), previously mentioned in section **1.3**.

5. Sensibility analysis

The sensibility analysis predicts the variability of the obtained results for feasibility study (see section **3.**). Parameters with higher variance are selected due to their effect on the financial parameter (NPV).
Fig. 10 shows the influence of a 10% quantified value's variation, for each parameter, on the final NPV. NPV range is obtained throw the average of all scenarios ranges for each parameter (because of their similarity). Results identify the most elastic variables, which variance causes a higher impact on NPV.
Parameters with higher influence on NPV value are related to individual perceptions (see **Fig. 10**) like aesthetics improvement and users' satisfaction (infrastructure and user dimensions, respectively). Discount rate also shows a significant elasticity, as expected. Wide variations are not expected for any of the parameters, which could modify the obtained trends.

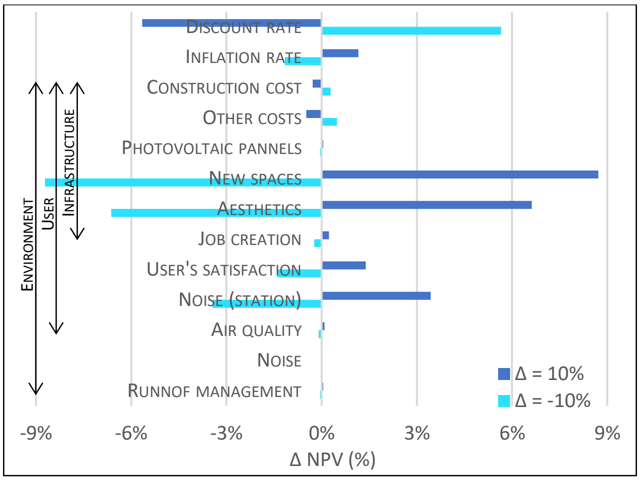


Fig. 10. Socioenvironmental parameters' influence on NPV.

According to the results, the following sensibility analysis is limited to significant parameters (higher elasticity). Variance is estimated for three scenarios: most probable, optimistic and pessimistic (presented in **Table 4**). For this case study, the most probable and optimist scenarios are similar. The most probable fluctuations are obtained in line with actual trends and existing estimations:

- *Discount rate.* It is admitted a decrease of 7.5% due to the expected reduction of risk rate. This reduction, fixed at 10%, results from growth on green infrastructures business.
- *Inflation rate.* In Portugal, inflation has been increasing since 2014. According to the prevision of *Banco de Portugal* (Portugal Bank's) prevision, the inflation rate should increase about 5% until 2018.
- *New spaces.* Rental prices tend to increase in Portugal's main cities (like Lisbon), due to the country's economic recent recovery. It is admitted, according to national sites for property values, an increase of 7,5%.
- *Aesthetics.* Aesthetics relates with station's property and users' satisfaction values. Thus, it is assumed that aesthetic value improves also 7,5%.
- *User's satisfaction.* Population's well-being results in public health and productivity improvements. Even satisfaction has been a growing concern, it is admitted a slight increase of 7,5% (since urban green spaces are not proposed for this case study, but punctual solutions).
- *Noise station.* It is admitted a marginal progress, because of the difficulty of assuming evolution assumptions.

NPV values, for each scenario, are presented in **Fig. 11**. Pessimist and optimistic/most probable scenarios show a decrease of 4% and an increase of 12% in comparison to the base scenario, respectively.

Table 4
Range of socioenvironmental parameters' variation.

Parameter	Δ (%)		
	Most probable	Optimistic	Pessimistic
Discount rate	− 7,5	− 7,5	+ 7,5
Inflation rate	+ 5	+ 5	− 5
New spaces	+ 7,5	+ 7,5	0
Aesthetics	+ 7,5	+ 7,5	0
User's satisfaction	+ 7,5	+ 7,5	0
Noise (station)	0	0	0

As the optimistic scenario matches the most probable scenario, it is predicted that greening Entrecampos Rail Station will be more profitable in the future. All analysed scenarios are feasible at the end of the economic study.

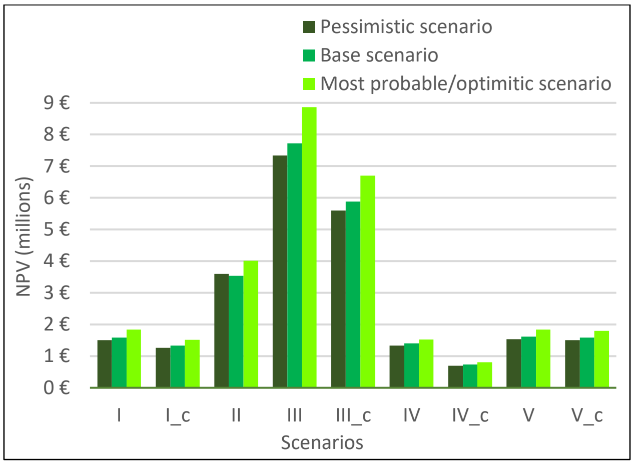


Fig. 11. Proposed scenarios' sensibility analysis.

6. Conclusions

The proposed methodology for the feasibility study of greening Entrecampos Rail Station seems to be appropriate. Incremental cost-benefit analysis for three dimensions (infrastructure, user and environment) provides a planned quantification of benefits with coherent and interrelated results. In addition, selected benefits correspond to specific advantages for the case study, generating more reliable results.

All greening analysed scenarios are financially unfeasible. However, in economic and socioenvironmental terms investments are profitable, with significant gains for society.

Financially, costs range from 3 005.79€ (scenario IV_c) to 1 040 946.23€ (scenario II). Economic gains range between 372 351.19€ (scenario V_c) and 7 697 009.07€ (scenario III). Socioenvironmental analysis shows gains from 734 524.39€ (scenario IV_c) to 7 726 612.99€ (scenario III).

As mentioned before, scenarios that provide higher cumulative benefits (III, III_c and II, in descending order) do not correspond to the ones with the highest relative return (IV_c, III_c and V_c, in descending order). Scenario III_c corresponds to the most competitive solution as it generates considerable gains (5 882 721.33 €) which are about 50 times higher than financial losses (-114 219.84 €). In case of the adoption of the several scenarios, feasible conclusions for each scenario are not complementary and should not be extrapolated. Although the same methodology approach was used, each scenario was studied according to its specific characteristics. As a result, the potential increase of installing simultaneous green solutions is not known.

Appreciation of infrastructure and user enhances final gains related to benefits with high returns. In ascending order, aesthetics improvement (infrastructure), user's satisfaction (user), new spaces rent (infrastructure) and noise attenuation (user) are the most valued parameters.

The sensitivity analysis performed to the CBA shows the high influence of discount and inflation rates, recreation, aesthetics improvement, well-being and station's noise reduction on the NPV value, ranging from 1,5% to 9%.

Regarding station problems (see section **2.1.**), green infrastructures contribute essentially to sense of comfort (aesthetic and functional) and promotion of infrastructure (which increases safety perception). Additionally, noise attenuation, air quality improvement and runoff management (green roof scenario), are advantages for infrastructure, user´s well-being and vicinity environment.

Concluding, greening Entrecampos Rail Station, in Lisbon, is an innovative proposal with clear benefits for its vicinity. Nevertheless, the benefits quantification was a complex process with a significant uncertainty of the results.

The estimated gain for each scenario may not reflect equivalent monetary gains. However, the CBA implies the conversion of all parameters for the same unit so those can be compared. For easier understanding, although there are huge scale differences, investment in green infrastructures is compared to a forest one: there is a significant initial effort (investment) and maintenance costs which culminate in long term benefits for the society.

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