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Assessing investment projects under risk and uncertainty using Discounted Cash-Flow Analysis and Monte Carlo simulation

Territorial transformation projects are subject to specific evaluation procedures that address the question of whether the planned course of actions can achieve objectives in the presence of specific constraints. The uncertainty that characterizes the development process is of particular importance in investment decision-making, Indeed, the model's input (for example, the costs of construction, the incomes, or the interest rates) can be affected by uncertainty due to the lack of knowledge and poor and imperfect information. It has been noted that this input uncertainty gives uncertain outcomes (i.e., valuation data such as the Net Present Value). To address uncertainty in feasibility studies, probability theory can be used and specific simulations based on the Monte Carlo analysis can be implemented. Starting from a real case study, the paper aims at investigating the role of uncertainty and risk in feasibility studies.
Keywords: *project appraisal, Discounted Cash-Flow Analysis, probability theory, decision-making, territorial transformation projects.*

Valutazione degli interventi di trasformazione territoriale in condizioni di rischio e incertezza utilizzando l'Analisi Costi-Ricavi e la simulazione Monte Carlo. *I progetti di trasformazione a scala territoriale sono oggetto di specifiche procedure di valutazione che mirano a verificare se le linee di azione pianificate possano raggiungere gli obiettivi prestabiliti rispetto ad alcuni vincoli di carattere finanziario. Nelle decisioni relative a tali investimenti è di particolare importanza l'incertezza che caratterizza il processo di sviluppo. Infatti, l'input del modello (ad esempio, i costi di costruzione, i redditi o i tassi di interesse) può essere influenzato dall'incertezza dovuta alla mancanza di conoscenza e alla scarsa e imperfetta informazione da parte dell'analista. Tale incertezza dell'input fornisce risultati incerti (cioè, indicatori di fattibilità finanziaria come il Valore Attuale Netto). Per affrontare l'incertezza negli studi di fattibilità, è possibile utilizzare la teoria della probabilità e implementare simulazioni specifiche basate sull'analisi Monte Carlo. Partendo da un caso di studio reale, il paper si propone di indagare il ruolo dell'incertezza e del rischio negli studi di fattibilità.*
Parole chiave: *stima del progetto, analisi costi-ricavi, teoria delle probabilità, processi decisionali, progetti di trasformazione territoriale.*

1. Introduction

Long-term investment projects in the domain of territorial transformations are complex processes characterized by a series of actions coordinated and correlated among them, which have the aim of reaching a certain objective in a given time, with required quality and limited resources (Fontes *et al.*, 2020; Gardiner and Stewart, 2000).

Projects are made an object of specific evaluation procedures that address the question of whether the planned course of actions is likely to achieve objectives under specific constraints. Among the existing evaluation procedures, a very important role is played by feasibility analyses (Bottero *et al.*, 2019). In this context, feasibility studies are considered as preliminary investigations into the potential benefits associated with undertaking a specific activity or project. The main purpose of the feasibility study is to analyze the full range of factors associated with the project and to determine if the investment of time and other resources will yield a desirable result (European Commission, 2014). In other terms, it is possible to say that assessing the feasibility of a project means to forecast the economic effects of an investment, to quantify them through specific evaluation procedures, to express a final judgment concerning the economic convenience of the project (Florio, 2003). In this sense, it is necessary to deal with i) economic effects; ii) quantitative analysis; iii) formalized computational tool and iv) evaluation rules.

In evaluating the feasibility of territorial projects, it is of particular importance the uncertainty that characterizes the development process. The input of the model (for example, the costs of construction, the incomes, the interest rates, and so on) can be affected by uncertainty due to the lack of knowledge and poor and imperfect information. It has been noticed that this uncertainty of the input provides uncertain outcomes (i.e., valuation figures such as the Net Present

Value) (French and Gabrielli, 2004; Nikoloudis *et al.*, 2017). To deal with uncertainty in feasibility studies, different methods can be applied, such as break-even analysis, sensitivity analysis, scenario method, and game theory (Jovanović, 1999). In this domain, a very important role is played by Monte Carlo (MC) methods. Generally speaking, Monte Carlo analysis is based on probability theory and refers to computational algorithms that allow risk to be included in quantitative analysis and decision making. The method can be used in different decision problems, including finance and insurance, project management, energy, manufacturing, transportation, and environment. The essence of the method is the invention of games of chance whose behavior and the outcome can be used to study some interesting phenomena (Kalos and Whitlock, 2008). The technique is based on the use of statistics parameters, such as mode, spread, and skewness of probability distributions, to describe and model uncertainty from various sources and produce a distribution of the possible outcomes by randomly selecting input values from the predetermined distributions.

Starting from the case of the project which has been proposed for the design competition for the development of the sea-wall in La Spezia (Italy), the paper aims at investigating the role of uncertainty and risk in feasibility studies. In particular, by means of the application of the well-known cash-flow analysis, the paper addresses the economic viability of the project comparing the outcomes of two different models: a deterministic approach, based on traditional cash-flow analysis, and a stochastic model, where the risk analysis is implemented through the Monte Carlo simulation.

After the Introduction, the rest of the paper is organized as follows: Section 2 provides the methodological background about feasibility analysis, focusing on cash-flow analysis and illustrating the analytical approaches which allow uncertainty to be included in the evaluation; Section 3 presents the feasibility analysis for the project under investigation, considering the classic deterministic approach and the probabilistic approach based on Monte Carlo simulation; Section 4 discusses the main findings of the evaluation models; Section 5 summarizes the conclusions that can be drawn from the work and highlights the future developments of the research.

2. Feasibility assessment and investment appraisal

2.1. Methodological background

Feasibility analysis aims at answering the question "will it work?" for a specific project proposal. In principle, the method is based on the identification of the full range of costs and incomes of the project in order to allow the investor to understand if minimum objectives will be achievable.

According to the scientific literature (Oprea, 2010), the feasibility analysis is iterative and continuous and it involves the following eight steps:

1. assessing the physical and legal aspects of the site;
2. estimating demand for the space;
3. analyzing competitive space;
4. estimating costs of acquisition, construction or rehabilitation;
5. estimating the cost and availability of borrowed funds;
6. estimating absorption rates;
7. developing cash-flow schedules;
8. evaluating the estimated cash-flow in terms of acceptability of the expected outcome.

A very important part of the overall feasibility study is related to the financial analysis which normally can be addressed through the Discounted Cash-Flow Analysis (DCFA). Particularly, this technique used to derive economic and financial performance criteria for investment projects (Akalu, 2003; Prizzon, 2001; Bottero and Mondini, 2013) in the form of synthetic and easy to interpret indicators that allows the Decision Maker (DM) to understand if the project should be accepted or rejected. The most used project performance criteria are the Net Present Value (NPV) and the Internal Rate of Return (IRR).

Let X be a project with real benefits B_t and real costs C_t, in $t = 0, 1, \ldots, T$ years from now and r the discount rate.

The NPV of the project can be defined as in equation 1:

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \qquad (1)$$

It has been noticed that: i) If NPV = 0, it means that the discounted benefits are equal to the discounted costs and then we should be indifferent in the decision whether to accept or reject the project; ii) If NPV > 0, it means that the discounted benefits are larger than the discounted costs and then we should accept the project; iii) If NPV < 0, it means that the discounted benefits are smaller than the discounted costs and then we should reject the project.

About the Internal Rate of Return (IRR) of the investment, the value can be derived finding the rate of return such that the project breaks even. That is, to find the rate of return which makes the present value zero as represented in the equation (2):

$$\sum_{t=0}^{T}\frac{B_t - C_t}{(1+r)^t} = 0 \Rightarrow r = IRR \quad (2)$$

It is possible to affirm that project is admissible if IRR > r (i.e. rate of return exceeds opportunity cost).

2.2. Risk and uncertainty

The uncertainty is an integral part of the development process (Loizou and French, 2012). Indeed, the appraisal model will determine specific valuation indicators (i.e. NPV or IRR) which are just some of the possible valuation figures.

In the context of construction projects for territorial transformations, the input variables are uncertain because they are open to changes over time and space. Loizou and French (2012) identify different sources of uncertainty that can be summarized as follows:

a. Financial risk: it is related to the fluctuating interest rate. The increase of the interest rate can erode the developer's resources and decrease the profit margin of the project;
b. Land cost: the variation of the land cost can affect heavily the final performance of the investment;
c. Construction: the changes in the construction costs are related to the type and quality of the end product, to the degree of the aesthetic value, to sustainability issues and building regulations;
d. Timing: this is a crucial issue in the development process and delay can lead to higher financial costs and other complications;
e. Sale/rents: any variation of the final sale/rental price can produce increased profits or losses;
f. Socio-economic elements: this issue is related to the variations that act at the socio-economic level, such as changes in the political confidence to the project, modifications of the regional economy, and so on.

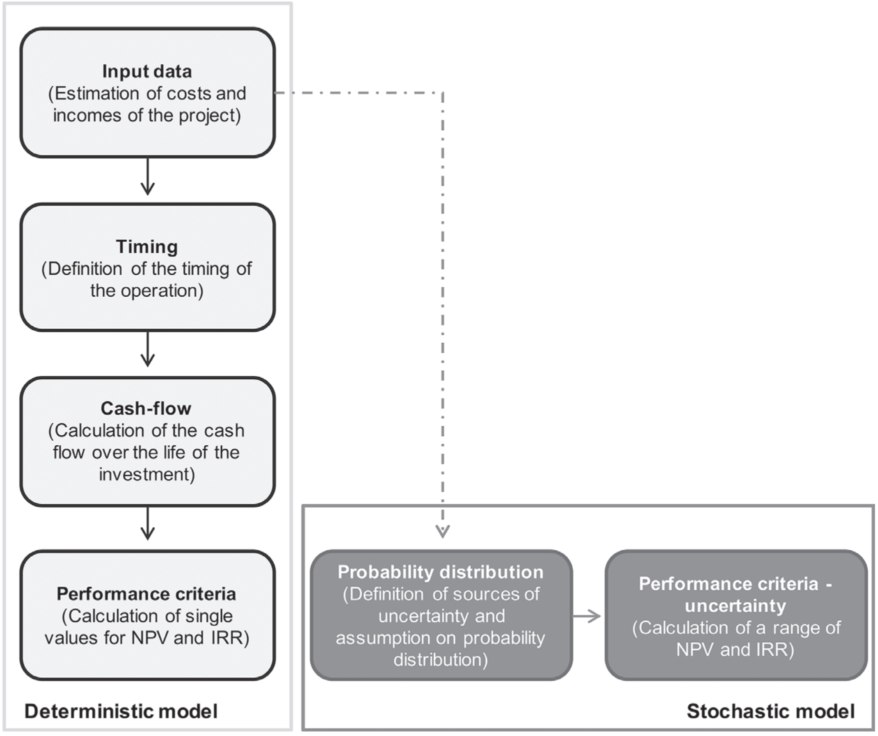


Fig. 1. Methodological framework of the Discounted Cash-Flow analysis under risk and uncertainty.
Framework metodologico dell'Analisi Costi-Ricavi in condizioni di rischio e incertezza.

The existence of the aforementioned issues makes it necessary to include the uncertainty in the model to obtain not only a single outcome but a range of possible outcomes. This can be done by recognizing that input figures are not single features but a possible range of figures that can be modeled statistically by a probability distribution (French and Gabrielli, 2004). In this sense, the risk is defined as the measure of the difference between the actual and the expected outcomes of the analysis.

Traditionally, uncertainties for investment projects are assessed by sensitivity analysis. This analysis is performed starting from each source of uncertainty to determine how much the final output vary before the project is either accepted or rejected. This approach is commonly known as the "what-if" scenario. In real-world problems, the evaluation of investment projects in the domain of territorial transformation requires a greater comprehension of the complexity of the system under investigation. In this sense, the number of "what-if" scenarios increases rapidly and new evaluation approaches become necessary (Salling *et al.*, 2007; Salling and Leleur, 2017). One of the most applied theories for dealing with uncertainty and risk in decision-making processes refers to the Monte Carlo simulation. Generally speaking, Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities – the outcomes of going for broke and for the most conservative.

As argued by Lorance and Wendling (2001), Monte Carlo simulation allows to move from a deterministic analysis to an evaluation approach which includes uncertainty and three subsequent steps

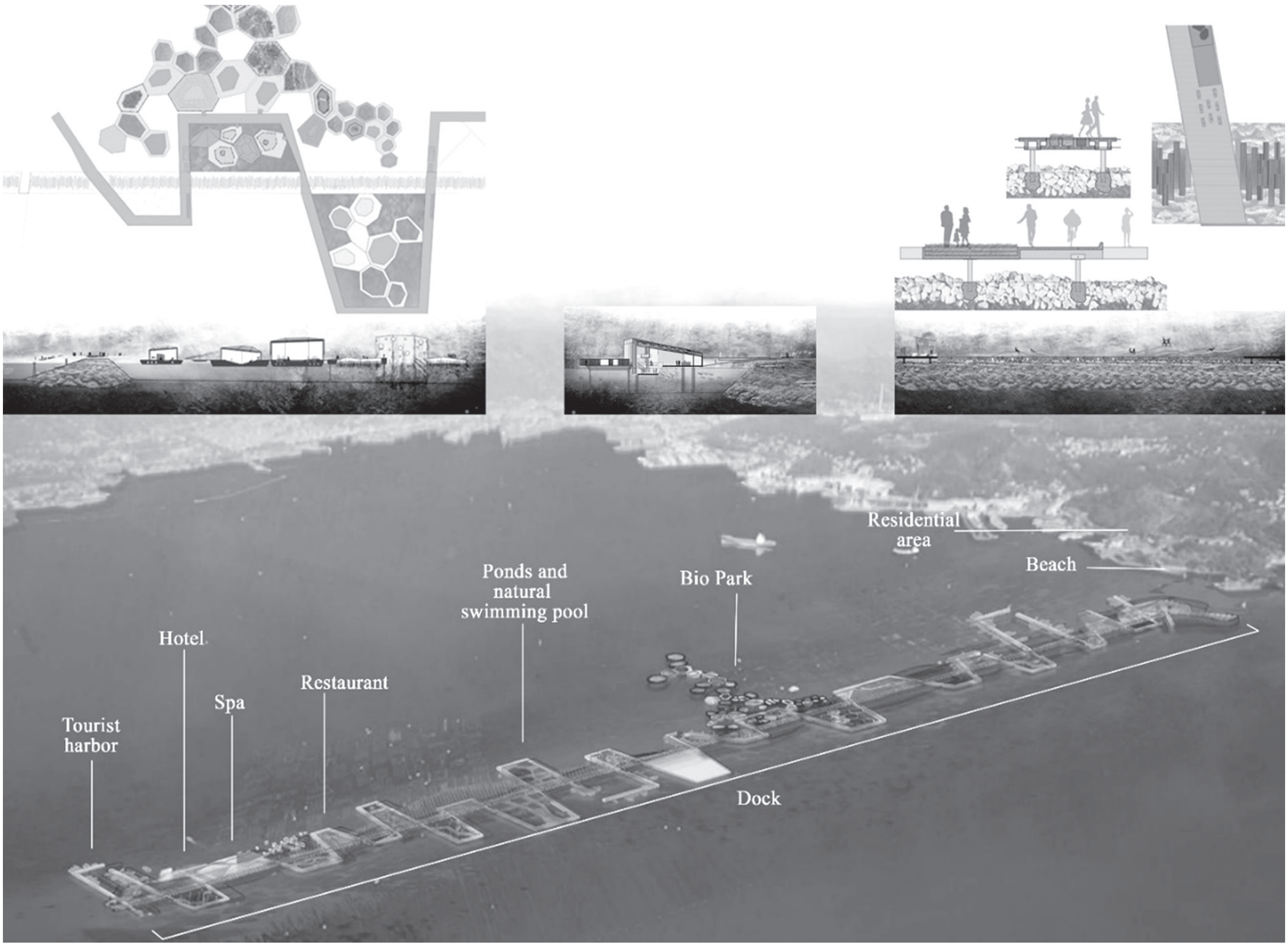


Fig. 2. Representation of the project proposal (source: Daniele Baiotto, 2012).
Rappresentazione della proposta progettuale (fonte: Daniele Baiotto, 2012).

have to be carried out in order to perform the analysis:
1. To define the deterministic model of the estimate;
2. To identify uncertainty in the estimate by specifying the possible values of the variables with probabilistic distributions;
3. To analyze the estimate with simulation.

Different applications of Monte Carlo analysis and investment projects exist in the literature, where specific simulation software are used for estimating the NPV distribution (Coates and Kuhl, 2003; Halawa *et al.*, 2013).

Figure 1 presents the main phases of the evaluation, considering both the deterministic model and the stochastic model, where the Monte Carlo simulation is included.

3. Application

3.1. Description of the project

In the present study, the data concerning a real case study have been considered for the evaluation model and the simulation. In detail, the object of the investigation of the present research is the development project for the breakwater of La Spezia (Italy)[1]. The main idea of the project is to maintain the original structure of the existing sea-wall and to add a pedestrian path that will allow the sea-wall to be walked through. Moreover, the new dock will be crossed by several specific modules that are destined to host particular functions and services, such as a public beach, different bars and restaurants, a hotel, a residential area, a park (Baiotto, 2012). Table 1 summarizes the main characteristics of the project whereas Figure 2 provides a graphic representation of the proposed layout.

[1] The project has been developed by the design team coordinated by the Italian architect Daniele Baiotto and it concerns the development of the sea-wall in La Spezia (Italy) with an overall environmental requalification of the area and the creation of new function and services. Mention has to be made that the project was proposed for the design competition which was advertised in 2012 by the Port Authority of La Spezia.

Tab. 1. Main functions of the project proposal.
Principali funzioni della proposta di progetto.

Function	Description
Dock	The longitudinal path of 2,200 meters will allow to walk through the overall sea-wall. It is made of prefabricated modules in reinforced concrete.
Ponds and natural swimming pool	The project considers the construction of an area of about 10,000 m^2 with ponds and natural swimming pools with a public function to attract people and touristic to the sea-wall.
Hotel and spa	An exclusive hotel and a resort will be constructed in the area with an overall surface of around 8,000 m^2.
Restaurant	The hotel will be integrated by a restaurant which has a surface of 900 m^2
Bio Park	The Bio Park is an organic structure that is designed to develop itself over the years according to a plug-in model. This structure will host different tourist and educational activities related to the coastal and sea environment.
Tourist harbor	The project considers the construction of three tourist harbors with place for 200 boats.
Beach	The main element of the proposal is the construction of a public beach with a total surface of 20,000 m^2 on the internal side of the sea-wall.
Residential area	The project proposes the construction of residential zones in different areas of the master plan for a total surface of 9,600 m^2.

3.2. Discounted Cash-Flow analysis

According to the methodology described in Section 2.1, a Discounted Cash-Flow Analysis has been developed for the project under investigation.

Table 2 summarizes the main input for the analysis of the foreseen costs and the incomes. As it is possible to see from Table 2, the costs are represented by the investment cost of the transformation and by the operation and maintenance costs while the incomes are related to the revenues produced by the project.

A fundamental step of the analysis is represented by the timing of the project. In the case under investigation the project will be developed over 12 years that are arranged in four periods. The first and the second periods represent the core of the transformation while the third and the fourth periods concern the finishing of the proposal. Table 3 details the timeline chart for the project.

The final step of the evaluation comprises the creation of the table for the cash-flow feasibility

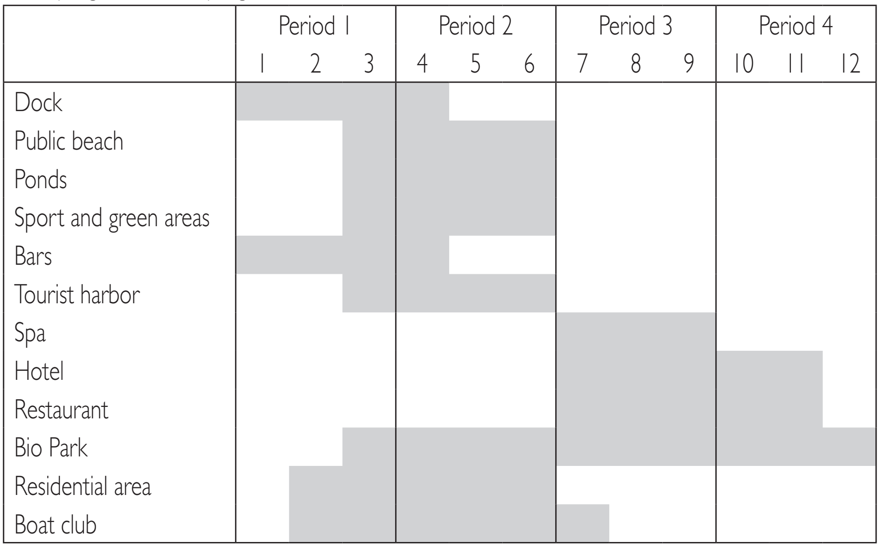
Tab. 2. Input data for the DCFA.
Dati di input per l'Analisi Costi-ricavi (ACR).

	Surface	Lenght	Number	Construction costs				O&M costs		Incomes		
	m^2	*m*	*n.*	*€/m^2*	*€/m*	*€/each*	*€*	*%* (1)	*€/year*	*€/m^2*	*€/each*	*€/year*
Dock		2,200			5,000		11,000,000		1,000,000			
Public beach	20,000			250			5,000,000					
Ponds	10,000			500			5,000,000					
Sport and green areas	5,000			500			2,500,000					
Total							**23,500,000**		**1,000,000**			
Bars	600		20	300			180,000	20%	520,000		2,500	2,600,000 (2)
Tourist harbor			200			29,000	5,800,000	40%	960,000		12,000	2,400,000
Spa	5,000			1,500			7,500,000	50%	2,920,000		80	5,840,000 (3)
Hotel			80			100,000	8,000,000	50%	2,044,000		200	4,088,000 (4)
Restaurant	900			1,000			900,000	70%	572,320		20%	817,600 (5)
Bio Park	5,000			4,000			20,000,000	60%	1,401,600		10	2,336,000 (6)
Residential area	9,600			1,800			17,280,000			7,500		72,000,000
Boat club	2,000			2,000			4,000,000			9,000		18,000,000
Total							**63,660,000**		**8,417,920**			**108,081,600**

Management costs	2.0% of the construction cost
Technical costs	8.0% of the construction cost
	yearly
Debit (passive) interest rate	5.00%
Credit (active) interest rate	2.00%
Discount rate	3.00%
Acceptability threshold	8.00%

(1) The O&M costs are calculated as a percentage of the incomes
(2) Each bar earns 2,500 € per week
(3) The number of visitors is 200 per day
(4) The price of the room is 200 €/night and the occupancy rate over the year is 70%
(5) The income is calculated as the 20% of the revenues of the hotel
(6) The entrance ticket is 10 €, the visitors per day are 800 and the entrance rate over the year is 80%

Tab. 3. Timeline chart for the project.
Cronoprogramma del progetto.



study, which is reported in Table 4 whereas the outcomes of the evaluation are summarized in Table 5.

From Table 5 it is possible to see that the final NPV of the transformation is 45 million Euros and the IRR is 44.46%; according to these results, the project can be considered as feasible. Analyzing the indicators for the different considered periods, it is interesting to put in evidence that the NPV and the IRR are negative only for the first phase of the investment while they increase over the life of the project and they are, respectively, 2.4 million Euros and 12.8% for the second

Tab. 4. Cash-flow analysis for the project.
Analisi Costi-Ricavi della proposta di progetto.

		yea											
		1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
	Static costs-incomes												
COSTS	€												
INVESTMENT COSTS													
Dock	11,000,000	3,300,000	3,300,000	2,200,000	2,200,000	0	0	0	0	0	0	0	0
Public beach	5,000,000	0	0	1,250,000	1,250,000	1,250,000	1,250,000	0	0	0	0	0	0
Ponds	5,000,000	0	0	1,250,000	1,250,000	1,250,000	1,250,000	0	0	0	0	0	0
Sport and green areas	2,500,000			625,000	625,000	625,000	625,000	0	0	0	0	0	0
Bars	180,000	45,000	45,000	45,000	45,000	0	0	0	0	0	0	0	0
Tourist harbor	5,800,000	0	0	1,450,000	1,450,000	1,450,000	1,450,000	0	0	0	0	0	0
Spa	7,500,000	0	0	0	0	0	0	2,250,000	2,250,000	3,000,000	0	0	0
Hotel	8,000,000	0	0	0	0	0	0	800,000	2,400,000	1,600,000	1,600,000	1,600,000	0
Restaurant	900,000	0	0	0	0	0	0	90,000	270,000	180,000	180,000	180,000	0
Bio Park	20,000,000	0	0	400,000	4,000,000	3,000,000	2,000,000	3,000,000	3,000,000	3,000,000	800,000	600,000	200,000
Residential area	17,280,000	0	2,592,000	1,728,000	2,592,000	4,320,000	6,048,000	0	0	0	0	0	0
Boat club	4,000,000	0	200,000	400,000	2,000,000	1,000,000	400,000	0	0	0	0	0	0
TOTAL	**87,160,000**	**3,345,000**	**6,137,000**	**9,348,000**	**15,412,000**	**12,895,000**	**13,023,000**	**6,140,000**	**7,920,000**	**7,780,000**	**2,580,000**	**2,380,000**	**200,000**
MANAGEMENT COSTS	1,743,200	145,267	145,267	145,267	145,267	145,267	145,267	145,267	145,267	145,267	145,267	145,267	145,267
TECHNICAL COSTS	6,972,800	581,067	581,067	581,067	581,067	581,067	581,067	581,067	581,067	581,067	581,067	581,067	581,067
TOTAL INVESTMENTS COSTS	**95,876,000**	**4,071,333**	**6,863,333**	**10,074,333**	**16,138,333**	**13,621,333**	**13,749,333**	**6,866,333**	**8,646,333**	**8,506,333**	**3,306,333**	**3,106,333**	**926,333**
OPERATION AND MANAGEMENT COSTS (yearly)													
Bars	520,000	130,000	260,000	390,000	520,000	520,000	520,000	520,000	520,000	520,000	520,000	520,000	520,000
Tourist harbor	960,000	0	0	240,000	480,000	720,000	960,000	960,000	960,000	960,000	960,000	960,000	960,000
Spa	2,920,000	0	0	0	0	0	0	876,000	1,752,000	2,920,000	2,920,000	2,920,000	2,920,000
Hotel	2,044,000	0	0	0	0	0	0	204,410	817,640	1,226,460	1,635,280	2,044,100	2,044,100
Restaurant	572,320	0	0	0	0	0	0	57,232	228,928	343,392	457,856	572,320	572,320
Bio Park	1,401,600	0	0	28,032	308,352	518,592	658,752	868,992	1,289,472	1,499,712	1,555,776	1,597,824	1,611,840
Beach, ponds and public spaces	1,000,000	0	0	250,000	500,000	750,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
TOTAL OPERATION AND MAINTENANCE COSTS	**9,417,920**	**130,000**	**260,000**	**908,032**	**1,808,352**	**2,508,592**	**3,138,752**	**4,486,634**	**6,568,040**	**8,469,564**	**9,048,912**	**9,614,244**	**9,628,260**
TOTAL COSTS	105,293,920	4,201,333	7,123,333	10,982,365	17,946,685	16,129,925	16,888,085	11,352,967	15,214,373	16,975,897	12,355,245	12,720,577	10,554,593
INCOMES													
INCOME (sales)													
Residential area	72,000,000	0	3,600,000	7,200,000	10,800,000	10,800,000	14,400,000	14,400,000	10,800,000	0	0	0	0
Boat club	18,000,000	0	900,000	1,800,000	2,700,000	2,700,000	2,700,000	7,200,000	0	0	0	0	0
TOTAL INCOMES FROM SALES	**90,000,000**	**0**	**4,500,000**	**9,000,000**	**13,500,000**	**13,500,000**	**17,100,000**	**21,600,000**	**10,800,000**	**0**	**0**	**0**	**0**
INCOME (yearly)													
Bars	2,600,000	650,000	1,300,000	1,950,000	2,600,000	2,600,000	2,600,000	2,600,000	2,600,000	2,600,000	2,600,000	2,600,000	2,600,000
Tourist harbor	2,400,000	0	0	600,000	1,200,000	1,800,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
Spa	5,840,000	0	0	0	0	0	0	1,752,000	3,504,000	5,840,000	5,840,000	5,840,000	5,840,000
Hotel	4,088,200	0	0	0	0	0	0	408,820	1,635,280	2,452,920	3,270,560	4,088,200	4,088,200
Restaurant	817,600	0	0	0	0	0	0	81,760	327,040	490,560	654,080	817,600	817,600
Bio Park	2,336,000	0	0	46,720	513,920	864,320	1,097,920	1,448,320	2,149,120	2,499,520	2,592,960	2,663,040	2,686,400
TOTAL YEARLY INCOMES	**18,081,800**	**650,000**	**1,300,000**	**2,596,720**	**4,313,920**	**5,264,320**	**6,097,920**	**8,690,900**	**12,615,440**	**16,283,000**	**17,357,600**	**18,408,840**	**18,432,200**
TOTAL INCOMES	108,081,800	650,000	5,800,000	11,596,720	17,813,920	18,764,320	23,197,920	30,290,900	23,415,440	16,283,000	17,357,600	18,408,840	18,432,200
CASH-FLOW		-3,551,333	-1,323,333	614,355	-132,765	2,634,395	6,309,835	18,937,933	8,201,067	-692,897	5,002,355	5,688,263	7,877,607
INTERESTS													
exposure *yearly*		-3,551,333	-5,052,233	-4,690,490	-5,057,780	-2,676,275	3,499,746	22,367,684	30,121,397	28,826,072	33,251,905	38,275,130	45,387,234
passive interests 5.0%	-1,051,406		-177,567	-252,612	-234,525	-252,889	-133,814	0	0	0	0	0	0
active interest 2.0%	-3,126,839	0	0	0	0	0	0	-69,995	-447,354	-602,428	-576,521	-665,038	-765,503
ANTE TAXES CASH-FLOW		-3,551,333	-1,500,900	361,743	-367,290	2,381,506	6,176,021	18,867,938	7,753,713	-1,295,325	4,425,833	5,023,225	7,112,104

Tab. 5. Final outcomes of the evaluation.
Risultati finali della valutazione.

Performance indicators	Period 1	Period 2	Period 3	Period 4
NPV	–4,531,593 €	2,368,703 €	22,838,072 €	45,386,857 €
IRR	/	12.80%	41.93%	44.46%

period and 22.8 million Euros and 41.93 % for the third period. Mention has to be made to the fact the reported indicators have been computed excluding taxes.

3.3. Risk simulation

To include the uncertainty in the model, the cash-flow analysis has been implemented employing the Monte Carlo simulation. The computer program @RISK has been used for the evaluation (www.palisade.com).

The first step of the simulation consists of defining the probability distribution of the variables. Different forms of distribution are available, such as normal, triangular, lognormal, and so on and the choice depends on the market analysis and the experience of the valuer (French and Gabrielli, 2004).

For the case under examination, it has been decided to select the variables which have the highest incidence on the total investment cost and incomes (i.e., construction costs of the dock, Bio Park, and residential areas and incomes of residential areas and hotel). For all the selected variables a triangular distribution has been defined and this choice is due to the small dimension of the sample used for the comparison. In the triangular distribution, we define the minimum and maximum values, which are most likely to occur. Figure 3 and Table 6 report the variables used for the simulation and the assumptions made.

The model has been run with 10,000 iterations to determine the range of probabilities of all the possible outcomes of the evaluation. The results of the Monte Carlo simulation are represented in Table 7. Moreover, Figure 4 provides a graphical representation of the results of the simulation considering the overall life of the investment project (Period 4).

As it is possible to see, the Monte

Tab. 6. Probability distribution of the selected variables.
Distribuzione della probabilità delle variabili selezionate.

Input	Distribution	Minimum	Likeliest	Maximum
Costs				
Dock (€/m)	Triangular	4,500	5,000	5,500
Bio Park (€/m^2)	Triangular	3,000	4,000	5,000
Residential (€/m^2)	Triangular	1,000	1,800	2,600
Market values				
Residential (€/m^2)	Triangular	5,000	7,500	10,000
Hotel (€/room)	Triangular	150	200	250

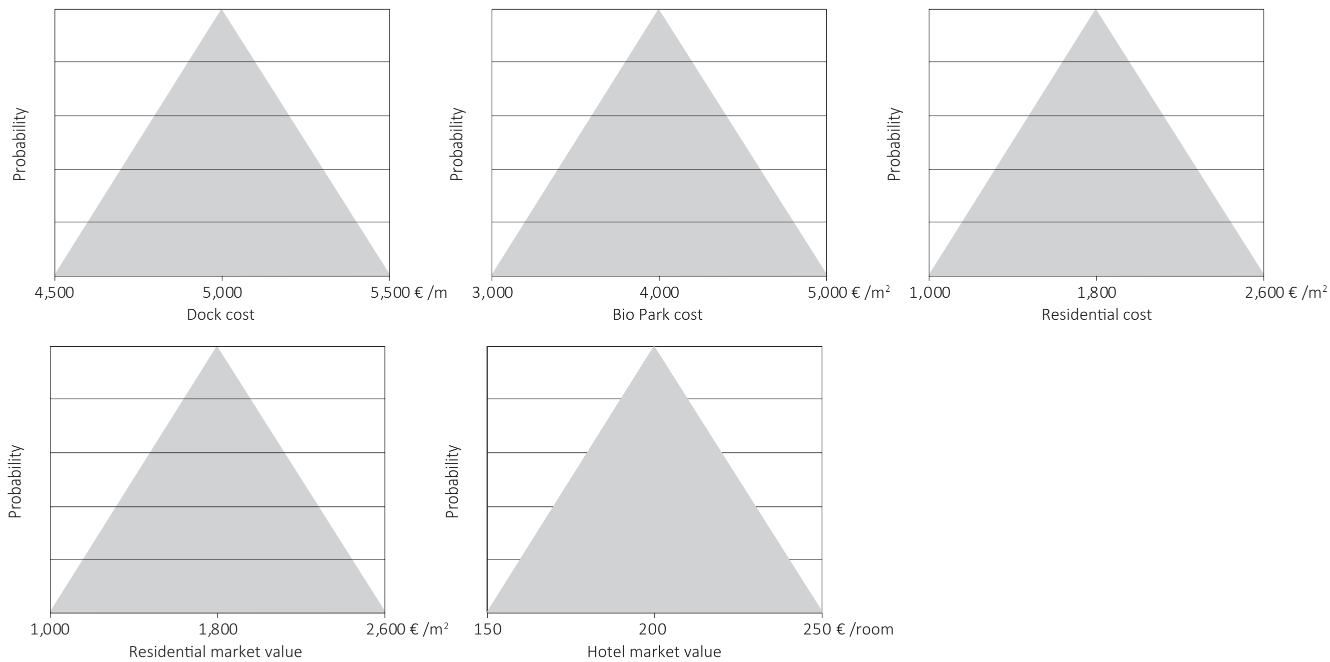


Fig. 3. Triangular distribution of input variables.
Rappresentazione della distribuzione triangolare delle variabili di input.

Carlo simulation provides an output range for NPV and IRR. Considering the full life of the project (Period 4), the analysis puts in evidence that the majority of outcomes (90%) lies, within the interval [28.8 M€, 62 M€] for the NPV and [23.2 %, 68.0%] for the IRR.

Considering the first period, as was expected, this is the most critical phase of the transformation where the feasibility of the investment is not reached yet and the 90% of outcomes are negative both for the NPV and for the IRR.

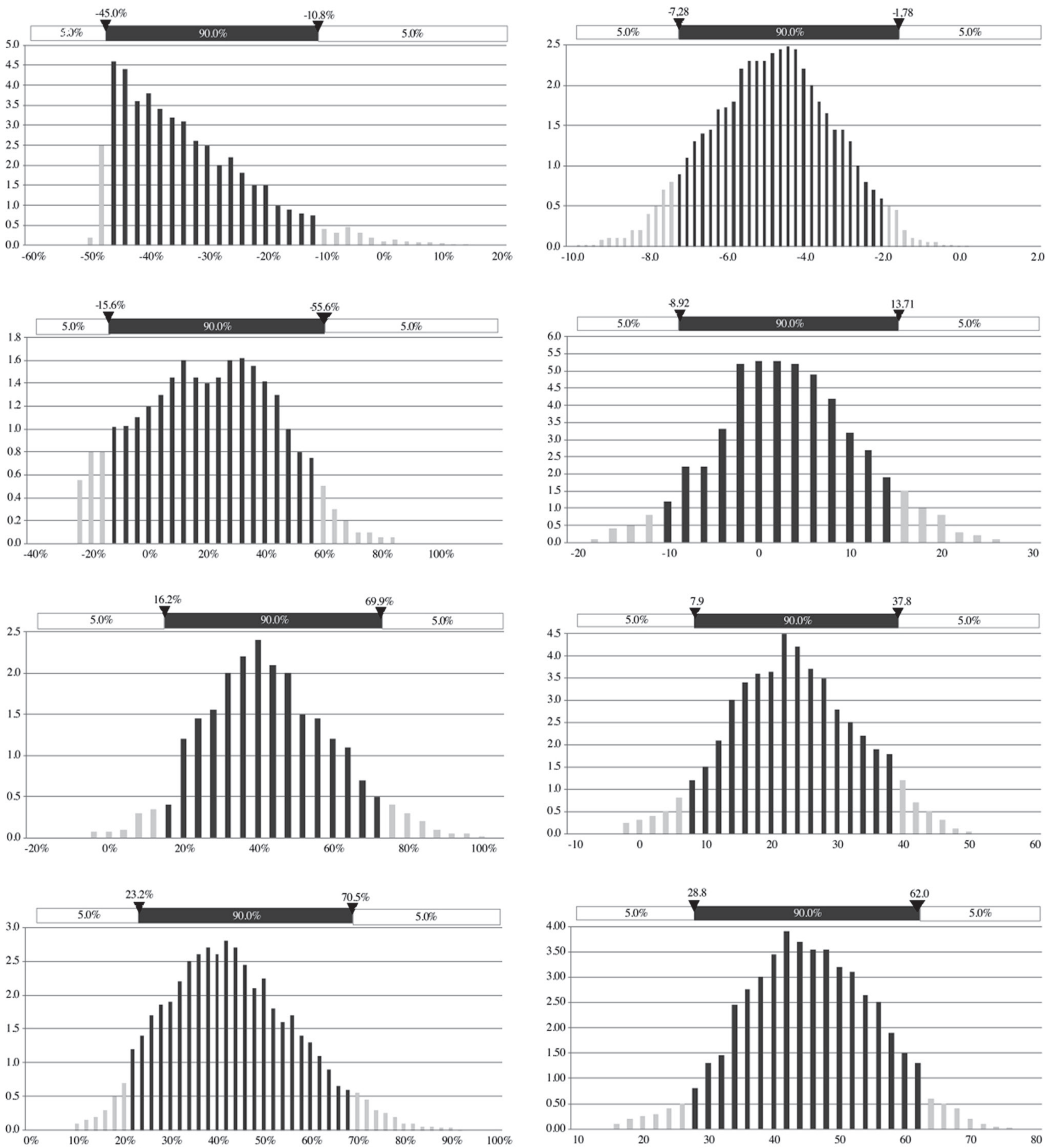


Fig. 4. Monte Carlo simulation for the outcomes of the DCFA for the four periods considered in the analysis (top: first period; bottom: last period). The left column represents the MC simulation for IRR and the right column represents the MC simulation for NPV.

Simulazione Monte Carlo (MC) dei risultati dell'ACR (Analisi Costi-Ricavi) per i quattro periodi considerati (in alto: primo periodo; in basso: ultimo periodo). La colonna di sinistra rappresenta la simulazione MC per il TIR (Tasso di Rendimento Interno) e la colonna di destra rappresenta la simulazione MC per il VAN (Valore Attuale Netto).

Tab. 7. Statistics of the Monte Carlo simulation.
Statistiche della simulazione Monte Carlo.

	NPV 1	IRR 1	NPV 2	IRR 2	NPV 3	IRR 3	NPV 4	IRR 4
Minimum	-9,797,192.12	-50.854%	-18,105,805.58	-21.95%	-2,413,432.74	-0.609%	17,670,258.82	11.596%
Maximum	586,940.01	12.870%	23,605,251.25	87.52%	50,499,924.38	97.965%	77,204,350.25	98.279%
Mean	-4,531,584.88	-31.623%	2,368,738.28	18.71%	22,838,119.25	42.287%	45,386,906.05	45.346%
Mode	-5,082,270.88	-44.615%	-1,267,636.87	27.07%	21,249,600.97	36.114%	43,147,493.73	39.357%
Median	-4,527,980.70	-34.075%	2,353,391.81	18.16%	22,852,703.73	41.906%	45,420,942.23	44.448%
Std Dev	1,648,095.47	11.269%	6,830,235.15	21.40%	9,036,138.78	16.233%	10,033,109.28	14.392%
Skewness	0.0019	0.9061	0.0024	0.1895	0.0012	0.1237	0.0057	0.3060
Minimum	2.6734	3.5075	2.6253		2.5635	2.6485	2.5771	2.6926

As far as the second period is considered, in 90% of the cases the NPV varies within the interval [-8.92 M€, 13.71 M€] and the IRR within the interval [–15.6%, 55.6%].

About the third phase, the project performs much better and the results show that in the majority of outcomes the NPV is positioned within the interval [7.9 M€, 37.8 M€] and the IRR within the interval [16.2%, 69.9%].

4. *Discussion of the results*

Comparing the outcomes provided by the two evaluation modes, it is possible to highlight some interesting findings.

As far as the deterministic approach is considered (Table 5), the outcomes are single figures and they show that the investment is not suitable in its initial phase while it performs positively from the second period on.

The outcomes of the probabilistic approach (Table 7) are not very different from those provided by the deterministic model but the use of the Monte Carlo simulation has the advantage of providing additional information about the certainty of the results.

Let us consider for example the performance indicators related to the second period. From the deterministic model NPV and IRR are 2.4 M€ and 12.8%, respectively (Table 5). In the simulation model the results are uncertain and the majority of the outcomes lies within the interval between –8.92 M€ and 13.71 M€ for the NPV and –15.6% and 55.6% for the IRR. This means that modelling the uncertainty in the inputs allows the uncertainly of the outcomes to be defined. In this case, the Decision Maker would be aware of the fact that the profitability of the investment is less certain than it was in the first model. According to the Monte Carlo simulation, the pro-

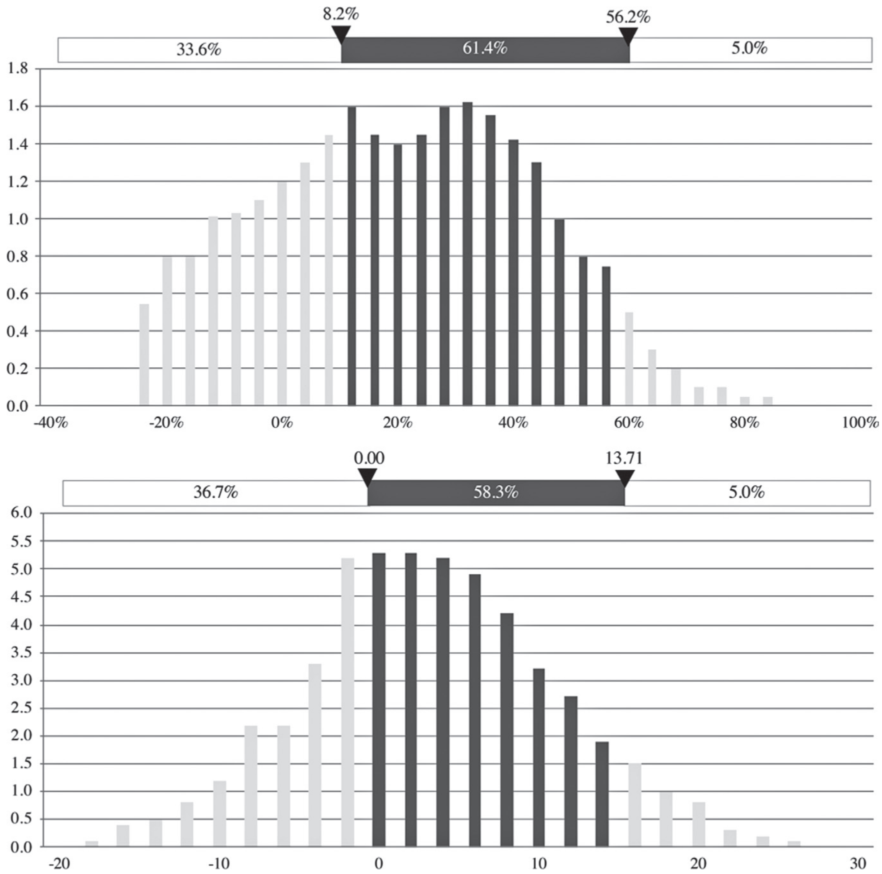


Fig. 5. Monte Carlo simulation showing the probability of having an acceptable IRR (top) and a positive NPV (bottom) with reference to the second period of the investment.
Simulazione Monte Carlo che mostra la probabilità di avere un IRR accettabile (in alto) e un NPV positivo (in basso) con riferimento al secondo periodo dell'investimento.

bability of having an acceptable IRR is 61.4% and the probability of having a positive NPV value is 58.3% (Figure 5). The decision as to whether to proceed or not with this project will therefore depend on the risk perspective or tolerance of the decision-maker.

Considering the results of the Monte Carlo simulation, mention has also to be made to the skewness parameter. Generally speaking, the skewness indicates the degree of asymmetry of the distribution around its mean. From the results of the performed application it is possible to notice that the values of the skewness are positive for all the considered periods, indicating distributions with asymmetric tails extending towards more positive values.

5. Conclusions

The paper considers the role of uncertainty and risk in the feasibility assessment of investments. Starting from the case study related to the project for the requalification of the sea-wall in La Spezia (Italy), two evaluation models based on the DCFA have been developed. The first model was based on a deterministic approach whereas the second model was implemented by means of the Monte Carlo simulation in order to include the uncertainty in the analysis.

The results of the work show the overall feasibility of the project under investigation and the outcomes of the Monte Carlo simulation provide additional information about the certainly of the findings. This is a crucial point in real-world decision-making processes where the input variables, such as construction costs and timing, are not fixed (Berto *et al.*, 2020; Mangialardo and Micelli, 2017).

Through the proposed approach the research showed that the DM can be made aware of the risk of the transformation and the decision about the construction of the project will depend on their attitude to risk.

From the point of view of the limits of the present study and future work that should be carried on, it would be of scientific interest to better investigate the probability of the selected variables in order to verify if other distributions are more appropriate.

Secondly, further research will be developed in order to consider the robustness of the model by means of the study of the inter-relationships among the variables in order to verify of correlations exist.

Moreover, different approaches that allow uncertainty and risk to be considered in the evaluation will be investigated. In this context, mention should be made to the Real Option theory as proposed by Dixit and Pindyck (2012). According to this approach, decision making about the economical projects consists of a flexible process (D'Alpaos, 2012; Dell'Ovo and Oppio, 2019) and each project is divided into several decision-making phases. After finishing each phase, entering certain information obtained from the market conditions (the discount rate and the amount of expenses and revenues), a new decision is made. When a decision is to be made, options that might occur for the life cycle of a project are taken into account and their effect on estimating the discount rate of the project and computing the NPV are considered (Halawa *et al.*, 2013).

The study will also consider expanding the results of the present application including in the evaluation model also non-monetary and qualitative factors, such as social consequences and environmental impacts, which have a fundamental role in the case under examination. This could be done by integrating the possibility theory and probability distribution in the Cost-Benefit Analysis approach (Mohamed and McCowan, 2001; Salling and Leleur, 2011).

Finally, due to the private/public nature of the project under exam and to the presence of criteria supporting the decision that cannot be measured in economic units, it would of scientific interesting to investigate the application of multicriteria analysis (Abastante, 2016; Bottero and Ferretti, 2010; Bottero *et al.*, 2016; D'Alpaos and Bragolusi, 2018) which allows the different dimensions of the problem to be taken into account and the uncertainty of the measures to be included in the evaluation model.

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