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Methodology for the Evaluation of Real Options in Real Estate Development in Areas Characterized by Uncertain Scenarios

ABSTRACT

The recovery of *brownfield* sites has been in the past, and still is today, at the centre of urban policies which have established and, in some cases, completed key urban transformation projects. In this regard, it should be noted that a preliminary remediation is often required for large transformation areas before urban functions can be established. Among other things, the recovery of these areas represents a matter of public interest in connection with environmental protection and public health goals. Investment decisions in relation to the development of *brownfields* are affected, primarily, by two critical variables: the remediation costs and market value of the area after the environmental recovery has been completed. This is in fact a complex process, which cannot be estimated with certainty, and which is influenced by a large number of variables. These include, for example, the characteristics of the project, the timing, the technology and the level of uncertainty in achieving the urban revitalization goals. In the past and in many countries, the use of public resources was the preferred means of encouraging the development of urban transformation projects of contaminated lands. On the contrary, the current economic scenario requires a new insight. One possibility would be to involve private developers from the early stages of the transformation. In this regard, given the uncertainty surrounding the remediation costs, some studies have aimed to define the financial and economic feasibility of the recovery of *brownfields* through the Real Options Theory (ROT). In this light, this study attempts to argue and support the application of the ROT. It focuses on a contaminated area intended for transformation from an industrial to a residential and commercial use, but for which remediation costs are unavoidable, although their impact is low. By changing the future scenarios, the application of the Black & Scholes formula compares and makes evident the points of view of the landowner, the real estate developer, and the public sector.

Keywords: Real Option Theory (ROT), *brownfields*, real estate development, land value estimation, transformation value, remediation costs.

Introduction

A *brownfield* site is a piece of land which was previously used for industrial or commercial purposes. Such areas of land may be contaminated by concentrations of hazardous wastes or pollution, and have the potential to be reused once cleaned up. According to the US Environmental Protection Agency (USEPA), "cleaning up and reinvesting in these properties protects the environment, reduces blight, and takes development pressures off greenspaces and working lands". For this reason, in recent years,

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the redevelopment of *brownfields* has been the subject of increased attention in many countries and a number of innovative financial and remediation techniques have been used to drive forward the redevelopment of these sites (De Sousa, 2005; Dixon, 2007; Cheng *et al*., 2011). However, especially in large transformation areas, the redevelopment process may be complicated by extensive investigation efforts, negotiations among stakeholders with differing interests, and time-consuming and costly clean-up processes that may overcome any market interest. Such situations can block or postpone the urban revitalization goals. In fact, among other things, the recovery of these areas is a matter of public interest as regards environmental protection and public health goals. Nonetheless, economic redevelopment – which is made possible by the planning – should also represent an opportunity for the private sector, rendering the project economically feasible (Talarico, 2011; Copiello, 2011). However, in some cases, real estate development cannot guarantee sufficient revenues, in terms of return on investment. In this situation, the project will not be initiated. Moreover, a challenge to *brownfield* redevelopment planning is posed by the lack of technical data relating to the site conditions. In this respect, many cities have developed brownfield inventories under the guidelines provided by the national environmental protection agencies, followed by risk-based site assessments. In many cases, however, contaminations remain unknown until the property has been sold (De Sousa, 2006).

Investment decisions concerning the development of these sites, in short, are affected by two critical variables: the remediation costs and the market value of the area after the environmental recovery has been completed. It is important to note that *brownfield* landowners are generally private firms which do not integrate real estate development into their core business. In Italy, for example, the law states that the remediation costs must be supported by the party responsible for the contamination, be that the landowner or otherwise[4]. As a result, the landowner – or the company – will most likely be willing to bear the costs only if they are lower than the market value of the land after remediation. By contrast, in the USA, some environmental firms have teamed up with insurance companies to underwrite the cleanup of distressed *brownfields* and provide a guaranteed cost, to limit the exposure of land developers to environmental remediation costs and pollution lawsuits. First of all, the environmental firm begins by performing an extensive investigation of the site to ensure that the guaranteed remediation cost is reasonable and that they will not be faced with any surprises.

Nevertheless, the costs, revenues and rate of return cannot be estimated with certainty because these factors are influenced by many variables. These include, for example, the characteristics of the projects, the timing, the technology employed and the uncertainty in achieving the urban revitalization goals (Weber *et al*., 2008). In this scenario, the traditional evaluation techniques – such as the *Discounted Cash Flow Analysis* – do not allow one to account for uncertainty and flexibility. In fact, real estate development is a multi-stage process in which different stakeholders are involved and this is more evident for *brownfields*. In this regard, given the uncertainty surrounding the remediation costs and the land value, some authors (Espinoza & Luccioni, 2007) have endeavoured to define the optimal size of the investments, so as to render the land transformation feasible from a

[4] For example, in Italy, the article no. 250 of the "Environmental Regulations" (L.D. no. 152 of April, 14th 2006) states that "If the parties responsible for the contamination do not provide directly [...], the procedures and actions referring to the Article 242 will be carried out *ex officio* by the municipality with territorial jurisdiction and, if this fails, by the Region [...]. In this case, the public actor that replaces the private one for the implementation of remediation, as indicated in Article 253 of the Law, could claim directly against the reclaimed area (Inzaghi & Vanetti, 2011).

financial and economic point of view, through the *Real Options Theory* (ROT). It is the goal of this work to extend the application of this approach. The study is therefore organized as follows: in the first section, the traditional appraisal approaches to the land value and the ROT are contrasted; the second section takes into consideration a contaminated area of land in a large urban area, for which the plan allows for a transformation from an industrial to a residential and commercial use. Even though the remediation costs are unavoidable, their economic impact is quite limited. By changing the future scenarios, the application of the *Black & Scholes* formula makes it possible to provide a comparison and demonstration of the points of view of the landowner and of the developer. The hypothesis of a strong interdependence between uncertainty and value growth is supported. In the conclusion, the main results of this application are summarized and the public actor role is outlined.

1. Land development and evaluation approaches

A real estate appraisal of land is based on principles of anticipation and development. This means that the value is established through expectations of income to be derived in the future. Land value is also affected by the interplay of supply and demand, which is in fact relatively stable. However, the economic use of a site determines its value in a specific market. In reality, if land has a utility for a particular use, there will be a category of users who will be willing to pay for it. In fact, a parcel of land can become a *site* when it is improved and ready to be used for a specific purpose. A site may have on-site and off-site improvements that make it suitable for its intended use and development (The Appraisal Institute, 2012).

The so-called *transformation value*[5] is normally brought into play so as to obtain the estimated value of an urban piece of land. The most commonly employed evaluation technique is, in this case, the *Discounted Cash Flows Analysis* (DCFA). The cash flow that is derived through the development – the implementation of which is made within a fixed and clearly-defined time-frame – is the result, as widely known, of the difference between the selling price and the construction costs. Within the traditional framework, the *Net Present Value* (NPV) and the *Internal Rate of Return* (IRR) are the main criteria for deciding upon the investment. The second is the return – debt plus equity – on the invested capital. This can be compared with a performance threshold which is considered acceptable by the investor. It can be built-up on three added components:

- the rate of return of an alternative investment with a very low-risk profile;
- the expected inflation rate;
- the risk premium on the investment.

In order to estimate the transformation value, it is first necessary to define an acceptable level of profitability together with the other variables (selling price, construction costs, timings and so on). This makes it possible to establish the estimated value of the land, as a final output. However, the most critical aspect in defining this threshold is the identification of the risk premium. Land development is, in effect, associated with multiple returns for various activities and carries a degree of risk because of the uncertainty involved

[5] In Italian real estate literature, the *transformation value*, one of the specific economic value of a property, represents the evaluation approach supporting the decision making process of a real estate investment. In Anglophone literature is possible to identify, as equivalent, the land residual technique or the yield capitalization approach that leads to DCFA.

in forecasting the timing and direction of urban development. In this respect, before an appropriate discount rate and profit percentages can be estimated, it is essential to have a clear understanding of the nature of the project cash flow and the associated risks.

The evaluation of real estate development projects, and more generally, the investment valuation, take into account uncertainty with regards, for example, to the selling price. Treating these inputs as deterministic is equal to considering a project with no risk. In this case, the discount rate is an expression of risk-free investments which are eventually adjusted only by the expected amount of inflation. However, in a real world scenario it is almost impossible to define cash flows which are characterized by an absolute degree of certainty. On the contrary, if there is uncertainty, the larger question relates to whether that stream is influenced by private risks – in relation to technology or entrepreneurship, for instance – or to market risks. On the other hand, if the cash flow is affected by market risks, this can to a certain extent be accounted for, most commonly by adjusting the discount rate. There seems to be some confusion as to how determine this discount rate, due to the lack of any agreement in literature on the question on any one set of guidelines (Kodukula & Papudesu, 2006). In addition, the risk associated with real estate investments is relatively difficult to identify when compared to the financial risk. Real estate markets are in effect characterized by imperfect information, long-term cyclical trends, illiquidity and irreversibility. The "*to start or not to start*" solution – provided by the traditional DCFA – may not be the best solution for irreversible investments. In fact, a simultaneous investment corresponds to a static decision-making process. However, real estate developments are not usually characterized by one single step; they more commonly involve a series of sequential decisions, each with a different level of risk. Moreover, the main approaches that allow for a definition of the risk premium, such as, for example, the Weighted Average Cost of Capital (WACC)[6] or the Capital Asset Pricing Model (CAPM)[7], prove partially ineffective when applied to real estate investments.

The Real Option Theory (ROT) can encourage the inclusion of flexibility as a factor in this framework as well as due consideration of the risks (Brennan & Trigeorgis, 2000). While the applications were initially limited, over the past decades many different topics have been included – to defer, abandon, switch the inputs-outputs of risky assets, alter operating scales, expand options, stage the investment, *etc.* – so much so that an extensive literature now exists on the topic (Schwartz & Trigeorgis, 2001; Guthrie, 2009). The ROT extension to the real estate market was initially accomplished thanks to the contributions of Titman (1985), Geltner (1989), Capozza & Sick, (1991). This was then further developed until the present day (Bulan *et al.*, 2009; Bauer, 2009; Bravi & Rossi, 2011). Unfortunately, the ROT is not widely used by appraisers with respect to the traditional DCFA, even though the real actors' behavior provides evidence of the model.

In fact, as a result of the high degree of variability and inconsistency in the cash flow applications employed by real estate professionals, there is a real need for an improvement in knowledge and processes. Forecasting expected values represents a greater problem because of the predictive nature of the model. In this respect, the relevant historical data and

[6] As widely known, cost of capital represents the cost of financing an economic activity, which is normally developed through some combinations of debt and equity. Since the WACC characterizes the cost of capital, it can be used as a proxy to represent the private risk referring to the project investment costs.

[7] According to this model, the expected return of a security equals the risk-free rate plus a risk premium. This last is defined as the product of β – a measure of risk specific to the security – and the difference between the overall market return and the risk-free rate. In using CAPM, a publicly traded security – twin security – is employed, under the hypothesis to have the same risk profile as the project under consideration.

market simulations are essential components of the crucial inputs into the cash flow applications. This uncertainty – which is normally included in the discount rate – can in fact be decomposed through the identification of successive stages of real estate development, each characterized by a decision-making process. In this way, the thorny problem of the use of multiple discount rates[8], which has long been the subject of discussion in literature on the topic (Zerbst, 1980; Wheaton *et al*., 2001; Hendershott & Hendershott, 2002) without any definitive solutions being identified, is bypassed.

2. Real estate development in uncertain scenarios

In order to estimate the market value of a *brownfield* through the DCFA, the remediation costs need to be included in the full costs of the project. In other words, the redevelopment will become financially feasible if the investment generates an acceptable return, *which includes* the clean-up costs. In this case, the market value refers to the reclaimed area. This approach is useful if the amount of the remediation costs has a marginal weight. This will trigger a negotiation between the landowner and the developer, in the event that they are different actors, who are respectively responsible for the clean-up and real estate development costs. In this case, it is necessary to establish how much they each cover. However, the growth of the weight of the remediation costs, compared to the estimated land value, will not render the project feasible. Moreover, in the event that the remediation costs are almost equal to the market value of the reclaimed land, the DCFA becomes an inflexible tool, wherein the feasibility of the project is difficult to test. In this case, the investment decision for the remediation becomes a strategic one.

In effect, the investment decisions are not independent from the market trend in which they take place before the transformation. In this respect, the volatility of the real estate prices associated with a particular market segment can affect the value of a site. According to a strategic approach, as, in this case, the ROT, it is possible to estimate the *brownfield* redevelopment by adopting a sequential logic. In fact, the landowner will sell the land to the real estate developer for a market price that must cover the remediation costs. By contrast, through a selection of investments, the real estate developer will look for a piece of affordable land, by comparing it to others with the same allowed uses and rights.

Obviously, he will be willing to buy the contaminated land, and proceed directly to the clean-up, for a price equal to the market value – without remediation – minus the clean-up costs. If these costs exceed the value, the developer may however choose to buy the land to be reclaimed for a price equal to the value of the deferral option. This value refers to the possibility of carrying out the clean-up only when it becomes profitable, or in the presence of market conditions where the value of the reclaimed land will be higher than the remediation costs.

The developer’s behavior, reinterpreted by the ROT, outlines an investment strategy that is comparable with an American *call option*. If the developer decides instead to postpone the investment, while waiting for better market conditions, he will, de facto, adopt

[8] In the case, for example, of a vacant land, the expected cash flow will have to be allocated between a return on the land investment - which carries an opportunity cost equivalent to the return expected by the landowner - and a return on the development and construction activities. The need to consider a return of both activities has lead to two evaluation approaches. The first considers a single discount rate to operating a cash flow before pulling out a developer's profit. The single discount rate should reflect all stages of the project. With the second method an explicit developer's profit is subtracted from operating cash flow, and a different and smaller discount rate is used to estimate land value from the residual cash flow.

a *wait and see* strategy. It is therefore necessary to compute the value of the deferral option, which is associated with the decision to clean-up the land. The remediation cost is the exercise price or the *strike price*. The value of the underlying asset corresponds to the value of the land as not reclaimed[9]. The value of the deferral option could be computed through the Black & Sholes (1973) formula:

$$C = S_0 N(d_1) - N(d_2) X \exp(-rT)$$

where C is the value of the deferral option, S_0 is the present value of the underlying asset, X it is the exercise price, r is the risk-free interest rate, T is the expiration time of the option, $d_1 = [\ln(S_0 / X) + (r + 0{,}5\sigma^2)T] / \sigma\sqrt{T}$ and $d_2 = d_1 - \sigma\sqrt{T}$, σ shows the annual volatility of the underlying asset, $N(d_1)$ and $N(d_2)$ indicate the value of the normal standardized distribution of d_1 and d_2.

On the other hand, the landowner will adopt an investment strategy comparable to an American *put option*, the exercise price of which is equal to the remediation costs and the value of the underlying asset is equal to the market value of the land as not reclaimed. The option value could be estimated, also in this case, by using the *Black & Scholes* formula:

$$P = -S_0 N(-d_1) + N(-d_2) X \exp(-rT)$$

where P is the value of the deferral option, S_0 is the present value of the underlying asset, X it is the exercise price, r is the risk-free interest rate, T is the expiration time of the option, $-d_1$ and $-d_2$ are equal to the amounts that were computed for the call option but with different signs, σ shows the annual volatility of the underlying asset, and $N(d_1)$ and $N(d_2)$ indicate the value of the normal standardized distribution of d_1 and d_2.

In defining the inputs of the option values used in the calculation, the following steps should be considered:

- the exercise price is equal to the remediation costs; these can be estimated once the remediation technique has been identified, which will allow the land recovery to be coherent with the purposes intended in the transformation;
- the value of the underlying asset corresponds to the value of available land, which is ready to accommodate new uses, with the assumption that no remediation should be carried out; this value is the sales price that the developer would be willing to pay before any development is undertaken; it can be estimated by defining the transformation value through DCFA without considering the remediation costs;
- in the absence of any representative sample of sales prices, the volatility of the underlying asset is estimated. However, the option values are calculated by assuming a variation of 10%, 20%, 30%;
- the risk-free interest rate is equal to the opportunity cost of an investment of the same duration that is characterized by a very low-risk profile (such as the rate of return on government bonds);

[9] The basic assumption of this hypothesis is that the land market value at the end of the clean-up process, is equal to the market value of a land that does not require remediation. The incurred investment by the landowner has the purpose of increasing the land market value, in order to make it competitive in comparison with other properties that have the same characteristics but which are not polluted.

– the expiration time of the option represents the period within which the landowner and the developer respectively decide to implement the remediation or to buy the contaminated land.

In short, for the real estate developer, the option value represents the estimated market value at which the land to be reclaimed may be purchased, assuming that the investment will be deferred by one year. The landowner may also decide to postpone the investment, awaiting better market conditions by adopting a *wait and see* strategy. In fact, even if clean-up costs are a little higher than the value of the reclaimed land, the landowner could sell to the developer who would be willing to pay a price equal to the maximum value of the call option.

2.1. An empirical application

Below is the presentation of the case of an urban contaminated area of land[10] which is suitable for transformation from an industrial to a residential and commercial use. A third of the area is located on the ground floor of the buildings. This piece of land, which is located in Turin, with an area of approximately 14,177 m^2 of Territorial Surface (TS), represents the Sub District 3 – "Michelin North" – of the "Michelin" district, on which the "Spina 3" plan[11] established the construction of 35,680 m^2 of Gross Floor Area (GFA). In order to establish the new functions, some demolition and land remediation actions[12] will be required. The cost of these works was estimated to be € 516,000. According to the hypothesis of transformation, the land value was set at € 303.97 / sqm. of GFA or € 765 / sqm. of TS. The total value of the land was therefore € 10,845,615. As is evident, the weight of the clean-up costs on the total value is negligible, being equal to around 5% of the land price. This is due to the characteristics of the remediation process which, in this case, does not foresee any major intervention. If the effect of the remediation costs were not so marginal, other scenarios would need to be considered. If, for example, the estimated volume of contaminated ground were equal to 100,000 cubic meters, it would be necessary to set out a different remediation process. Table 1 shows some types of remediation and their costs, consistent with this scenario.

It is evident that the estimated costs in relation to the e) hypothesis are not compatible with the project. This is because the estimated costs significantly exceed the land value and the landowner would not be willing to sell the reclaimed area to the developer for a price lower than the remediation costs. This would also be the case, prospectively, for the developer. For other types of remediation, the costs are however compatible with the market value of the land. By applying the TOR, it therefore becomes

[10] This is the area in which it was built one of the Media Villages that was planned for the XXth Turin 2006 Olympic Winter Games. The demolition and remediation processes started in July 2003, while the construction process began in November of the same year and was completed in the late 2005.

[11] This area is included within the Urban Renewal Programme (*Programmi di Riqualificazione Urbana*) "Spina 3", "Michelin", North district. These programs, funded by the Law no. 179 of 1992 were designed to implement actions of urban regeneration with the participation of public and private resources.

[12] Based on the characteristics of the subsoil and of the quality of superficial water upstream and downstream of the site, were defined the following interventions: remediation and removal of underground tanks and related piping connecting the existing installations; verification of soil quality under the tanks; underground piping removal related to the plants; removal of products containing asbestos before the demolition of the buildings.

clear that, as the remediation costs increase, so too does the value of the deferral option, to the point of becoming a decisive factor for the investment decision. This condition is verified where this value is close to the market price of a similar area of land that does not require remediation. Table 2 shows the input data for the calculation of the option value of both the landowner and the developer.

Assuming that there is a deadline within a year, in which time one can decide whether or not to perform the remediation, the value of the contaminated land is equal to the difference between the value of an area of land that does not require remediation and the clean-up costs. The rate of return of an investment with a low-risk profile is equal to 2.56%, while the cost of capital for a project of this type is equal to 8.56%. Assuming a prices volatility of 10%, 20%, or 30%, it is possible to compute the value of the deferral option by using the *Black & Scholes* formula. Table 3 shows the value of the call option for the real estate developer with exercise prices increasing up to the value of the land.

The developer will purchase the area for a price of € 10,845,615 if the landowner implements the clean-up. Otherwise, if he decides to buy the land, assuming that the remediation will be performed, he will be willing to pay a price equal to the value of the reclaimed land less the remediation costs. This will be the case if the remediation is carried out immediately.

Where remediation costs exceed the value of the reclaimed land, the developer will not be willing to buy, since this would not be a profitable investment. In fact, if he decides to defer the clean-up over time, i.e. if he decides to invest in remediation only when it becomes profitable, he could still choose to buy the contaminated land. The price at which he could buy the land to be reclaimed would then be equal to the value of the deferral option as estimated in Table 3.

In summary, for clean-up costs less than the value of the reclaimed land, the real estate developer will be willing to purchase the contaminated land for a price that will be the minimum of:

- the reclaimed land value less the remediation costs;
- the *call* option value.

However, in the event that remediation costs exceed the value of the reclaimed land, the price will be equal to the value of the call option. Therefore, taking a flexible approach to the management of environmental recovery, the value of the call option represents the price at which the land to-be-reclaimed could be purchased today if the developer were to adopt the strategy of *wait and see*. As has already been noted, this value decreases with the increase of the remediation costs. In addition, where strike prices are considerably lower than the value of the land, the volatility of the underlying asset has a limited impact on the option value. On the contrary, where strike prices slightly exceed the value of the reclaimed land (or in the case of no remediation), the option of deferring the investment becomes a strategic choice and the volatility of the underlying asset has a significant impact. In fact, in cases where remediation costs exceed the value of the land, the possibility to postpone the investment creates value. In Figure 1 it is possible to note that, for an increase in remediation costs, the deferral option adds value for the real estate developer.

Table 4 shows the added value that is generated by the deferral option. It was calculated as the difference between the value of the call option and the land value minus the remediation costs.

As regards the landowner, however, he will provide clean-up costs directly if they are lower than the value of the reclaimed land, and he will sell the reclaimed area for a price of € 10,845,615. Otherwise, he could sell the contaminated area for a value less the remediation costs. This will be the case if the clean-up is carried out immediately. However, where remediation costs exceed the value of the reclaimed land, the landowner could sell the land to the real estate developer by accepting a price equal to the estimated value of the *call* option (Table 3). It is possible to estimate the sale price at which he may be interested in selling the land, however, by calculating the value of the *put* option. Table 5 shows the value of the *put* option for rising strike prices.

In summary, therefore, for clean-up costs that are lower than the value of the reclaimed land, the selling price at which the landowner will be willing to sell the area without remediation will be the maximum of these two values:

- the reclaimed land value less the remediation costs;
- the *put* option value.

On the other hand, where remediation costs exceed the value of the reclaimed land, the selling price will be equal to the value of the *put* option. The strategic decision to postpone the investment, for both the real estate developer and the landowner, gains in value in cases where the costs of the remediation are close to or exceed the value of the reclaimed land. For remediation costs that are equal, for example, to € 11 million, the value of the land to be reclaimed, without considering the option value, is negative and is equal to - € 154,385. In this case, the real estate developer could buy the contaminated land by paying a price of € 494,673 with a volatility of the underlying asset of 10%. The landowner would be willing to sell the land to-be-reclaimed for a price of € 371,033. In this case, the two parties would agree on a selling price within this range. Therefore, even for remediation costs that exceed the land value, the real estate developer should proceed with purchasing the contaminated land for a price within this range and he should proceed to the remediation only when this investment becomes convenient.

In addition, with the increase in volatility – i.e., the increased uncertainty as to the value of the reclaimed land – there would also be a rise in both the option value and in the developer's willingness to pay. If the developer did not consider the possibility of carrying out the remediation on the basis of real profitability – or when the value of the area at the end of the remediation is higher than the costs of environmental recovery – he would forego the purchase of the contaminated land. The input data for the calculation of project NPV, ignoring the option value, are provided in Table 6.

The present value of the cash flow is negative because it represents the price of the land to-be-reclaimed, while the present value in the first year corresponds to the value of the land after the clean-up less the remediation costs. Since the latter is higher than the value of the area, the cash flow will still be negative. The discount rate, which is equal to the cost of the invested capital, amounted to 8 .56%. The NPV of the project would in this case result negative. As a consequence of this, the real estate developer would be lead to renounce the investment. In addition, where remediation costs rise against the value of the underlying asset, the real estate developer and the landowner would not be able to agree on the selling price of the land to-be-reclaimed. In fact, should the remediation costs rise to € 12.5 million, the developer would be willing to buy the land to-be-reclaimed for € 69,388, assuming volatility of the underlying asset were at 10%, while the landowner could sell the land for € 1,407,835. The selling price requested by the landowner actually corresponds to the increase in value of the land to be reclaimed, assuming that the investment is deferred by one year.

In other words, the option value could, in this case, be interpreted as an estimate of the investment that would need to be guaranteed so as to align the value of the land to-be-reclaimed to the market value – or to the value of the land not requiring remediation – under the assumption that the project will be deferred by one year.

Conclusion

This application has highlighted some important aspects regarding the environmental recovery of *brownfields*. In fact, in contexts characterized by uncertain scenarios, traditional evaluation approaches may not be able to grasp the full potentiality of a project. An analysis of the behavior of private actors in the redevelopment process can also, among other things, support public actors in defining an operational strategy that encourages transformation.

Where the possibility of development, as imposed by the planning tools, is not enough to render the recovery feasible from a financial perspective, the public actor could decide to take action directly on the remediation costs. Since remediation is preliminary to the real transformation of the area, the public action supporting the environmental recovery costs could take two forms:

- by means of a discount on the infrastructure costs[13] of a portion of the remediation costs incurred by the private sector;
- by means of a direct financing of part of the remediation costs.

In this respect and consistently with the arguments developed above, which stress the importance of the general rule driving private investment decisions in *brownfield* site redevelopments – and which corresponds to a *wait and see* decision – the public incentive of direct financing of the remediation costs would appear to be more effective. In effect, if the decision as to whether or not to invest in a redevelopment of the area represents the critical variable in connection with the expectations of private actors, an incentive in the form of a discount on public infrastructure costs will not resolve the problem of environmental recovery financing.

From the standpoint of evaluation, the effect of this decision could be measured in terms of an increase, however negligible, of the transformation value. If the subject making the remediation is not, however, the party that then proceeds to the development, this approach is not applicable. In other words, the environmental recovery cannot be initiated if the party investing in remediation would not be compensated by the expected value of the land. When the expected increase in land value is not sufficient to cover the remediation costs, the private actor defers the investment by prolonging, de facto, the *status quo* of the site.

In this context, it is therefore clear that a public intervention in the form of a direct contribution represents the best method for beginning the redevelopment. The amount of the public contribution could then be measured by calculating the value of the deferral option as shown previously. In this case, a contribution equal to the value of the *put* option, which is commensurate with the level of clean-up costs, could encourage a matching between the expectations of the land owner, in term of investment deferral, and the needs of the developer, in term of the economic feasibility of remediation.

[13] "Oneri di urbanizzazione" N.d.T.

In summary, in the spirit of an integration between public and private resources for the recovery of *brownfield* sites, the ROT could, as has been evidenced, be used for two goals; firstly, to estimate the price of contaminated land (the value of the *call* option) and, secondly, for an evaluation of public resources, so as to render the redevelopment of these areas competitive (in terms of the value of the *put* option). To this end, provided that remediation costs exceed the land value, the public body will not finance the entire cost, but only the surplus; i.e., the difference between the land value without remediation and the cost of remediation itself. As such, the landlord would be able to support costs lower than the market value at which he could then sell the reclaimed area. Otherwise, he will sell the land to-be-reclaimed to the real estate developer for a selling price that still takes into account the uncertainty of the future scenario, particularly in relation to the recovery of *brownfields*.

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Table 1. Estimates of remediation costs in a contaminated land (Euro)

	€/mq TS	**Total €**	**€/sqm. GFA**
a) Real case-study	36	516.000	15
b) Surface capping over the total area	75	1.063.275	30
c) Total digging (100,000 cubic meters) and on-site placement of safety measures	168	2.374.648	67
d) Partial digging (80.000 cubic meters) and on-site placement of safety measures only over the area involving unacceptable risk	145	2.055.665	58
e) Total digging (100.000 cubic meters) and outside disposal of contaminated soil	1.550	21.974.350	616

Source: Authors' processing on TRS Services and Environment study

Table 2. Input data for the calculation of the option value (Euro)

Input data	
Underlying asset (S_0)	10.845.615
a) Standard deviation of the underlying asset (σ)	10%
b) Standard deviation of the underlying asset (σ)	20%
c) Standard deviation of the underlying asset (σ)	30%
Risk-free rate of discount (r)	2,56%
Strike prices (X)	Remediation costs
Option expiration time (T)	1

Source: Authors' processing

Table 3. Real estate developer - *Call* option value (Euro)

Underlying asset value = land price = 10.845.615 €	**Remediation costs [€]**	**Call option value (St. Dev. 10%) [€]**	**Call option value (St. Dev. 20%) [€]**	**Call option value (St. Dev. 30%) [€]**	**Price of the land to be reclaimed without option value**
Strike price	2.000.000	8.896.165	8.896.165	8.896.165	8.845.615
	2.500.000	8.408.802	8.408.802	8.408.802	8.345.615
	3.000.000	7.921.440	7.921.440	7.921.442	7.845.615
	3.500.000	7.434.077	7.434.077	7.434.102	7.345.615
	4.000.000	6.946.715	6.946.715	6.946.876	6.845.615
	4.500.000	6.459.352	6.459.353	6.460.088	6.345.615
	5.000.000	5.971.990	5.972.000	5.974.545	5.845.615
	5.500.000	5.484.628	5.484.709	5.491.816	5.345.615
	6.000.000	4.997.265	4.997.708	5.014.422	4.845.615
	6.500.000	4.509.903	4.511.724	4.545.828	4.345.615
	7.000.000	4.022.541	4.028.504	4.090.213	3.845.615
	7.500.000	3.535.186	3.551.395	3.652.088	3.345.615
	8.000.000	3.047.933	3.085.668	3.235.840	2.845.615
	8.500.000	2.561.480	2.638.310	2.845.322	2.345.615
	9.000.000	2.079.031	2.217.228	2.483.547	1.845.615
	9.500.000	1.610.079	1.830.066	2.152.512	1.345.615
	10.000.000	1.173.473	1.483.023	1.853.167	845.615
	10.500.000	794.481	1.179.994	1.585.476	345.615
	11.000.000	494.673	922.217	1.348.562	- 154.385
	11.500.000	281.576	708.419	1.140.884	- 654.385
	12.000.000	146.241	535.320	960.424	- 1.154.385
	12.500.000	69.388	398.305	804.861	- 1.654.385

Source: Authors' processing

Figure 1. Price of contaminated land *vs.* remediation costs

Source: Authors' processing

Table 4. Real estate developer – Added value that is generated by the *call* option (Euro)

Underlying asset value = land price = 10.845.615 €	**Remediation costs [€]**	**Added value (St. Dev. 10%) [€]**	**Added value (St. Dev. 20%) [€]**	**Added value (St. Dev. 30%) [€]**
Strike price	2.000.000	50.550	50.550	50.550
	2.500.000	63.188	63.188	63.188
	3.000.000	75.825	75.825	75.827
	3.500.000	88.463	88.463	88.487
	4.000.000	101.100	101.100	101.261
	4.500.000	113.738	113.739	114.474
	5.000.000	126.375	126.386	128.931
	5.500.000	139.013	139.094	146.202
	6.000.000	151.651	152.093	168.808
	6.500.000	164.288	166.109	200.213
	7.000.000	176.926	182.890	244.599
	7.500.000	189.571	205.781	306.473
	8.000.000	202.318	240.053	390.225
	8.500.000	215.866	292.696	499.708
	9.000.000	233.417	371.613	637.932
	9.500.000	264.464	484.451	806.898
	10.000.000	327.858	637.409	1.007.552
	10.500.000	448.867	834.380	1.239.861
	11.000.000	649.059	1.076.603	1.502.948
	11.500.000	935.961	1.362.805	1.795.270
	12.000.000	1.300.626	1.689.706	2.114.809
	12.500.000	1.723.773	2.052.691	2.459.247

Source: Authors' processing

Table 5. Landowner – Value of the *put* option (Euro)

Underlying asset value = land price = 10.845.615 €	**Remediation costs [€]**	***Put* option value (St. Dev. 10%) [€]**	***Put* option value (St. Dev. 20%) [€]**	***Put* option value (St. Dev. 30%) [€]**	**Price of the land to be reclaimed without option value**
Strike price	2.000.000	0	0	0	8.845.615
	2.500.000	0	0	0	8.345.615
	3.000.000	0	0	2	7.845.615
	3.500.000	0	0	24	7.345.615
	4.000.000	0	0	161	6.845.615
	4.500.000	0	1	736	6.345.615
	5.000.000	0	10	2.555	5.845.615
	5.500.000	0	81	7.189	5.345.615
	6.000.000	0	443	17.157	4.845.615
	6.500.000	0	1.821	35.925	4.345.615
	7.000.000	0	5.964	67.673	3.845.615
	7.500.000	8	16.217	116.910	3.345.615
	8.000.000	117	37.852	188.025	2.845.615
	8.500.000	1.027	77.857	284.870	2.345.615
	9.000.000	5.941	144.137	410.456	1.845.615
	9.500.000	24.351	244.338	566.784	1.345.615
	10.000.000	75.107	384.658	754.801	845.615
	10.500.000	183.478	568.991	974.473	345.615
	11.000.000	371.033	798.577	1.224.921	- 154.385
	11.500.000	645.298	1.072.141	1.504.606	- 654.385
	12.000.000	997.325	1.386.404	1.811.508	- 1.154.385
	12.500.000	1.407.835	1.736.752	2.143.308	- 1.654.385

Source: Authors' processing

Table 6. Real estate developer – NPV of the project ignoring the option value (Euro)

Input data		
Reclaimed land value	€ 10.845.615	
Remediation costs	€ 11.000.000	
Price of the land to be reclaimed	€ 494.673	
Rate of discount	8,56%	
Year	**0**	**1**
Expected cash flow	*-€ 494.673*	*-€ 154.385*
Present value of the expected cash flow	*-€ 494.673*	*-€ 142.212*
NPV ignoring the option value	*-€ 636.885*	

Source: Authors' processing