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Abandoned Industrial Areas with Critical Environmental Pollution: Evaluation Model and Stigma Effect

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Abstract: The paper illustrates the phases and results of an evaluation model applied to abandoned industrial areas affected by critical environmental pollution. The main aim is to provide the economic evaluation of the impacts of critical environmental pollution on the market value of the areas, in anticipation of their future requalification and refunctionalization. Firstly, two mass appraisal models are applied: a regressive model in order to isolate the effects of real estate valorization generated by the requalification interventions of the abandoned steel mill areas of Bagnoli in Naples (Italy); an autoregressive model in relation to the chronology of the interventions and the real estate market dynamics, in order to predict values and costs of the building products to be realized on the areas. Subsequently, using the Ellwood model, the irreversible damage suffered by the areas in question due to the effect of critical environmental pollution is estimated. This irreversible damage corresponds to a "stigma" effect, or a loss to property value due to the presence of a risk perception-driven market resistance: for the abandoned steel mill areas of Bagnoli the reduction in the market value is equal to 28.63% approximately. The state of contamination of the areas is also described, estimating the related environmental remediation costs as a "deduction" to be applied to the "capital value" of the areas.

Keywords: abandoned industrial areas; environmental pollution; mass appraisal models; ARMA; ARIMA; stigma effect; Ellwood model; environmental remediation costs

1. Introduction

The development, rationalization, reuse and conversion of the industrial fabric play a fundamental role in urban transformation processes.

The history of the industrialization of the city of Naples is characterized by the "drama" that the relationship between industry and territory has assumed in the western area, in regard to the abandoned steel plant called ex-"Italsider" or "Ilva". This wound in the city has greatly marked the evolution of the reflection on the relationship between city and industry. Yet, these industrial areas can play a strategic role in territorial development, not only in relation to the economic growth of the urban area, but also in relation to its territorial rebalancing, and therefore to the creation of new territorial connections based on polycentrism, to the requalification of the peripheral areas, to the safeguard of the natural environment [1].

In this reflection, the theme of the reconversion of abandoned industrial areas is currently part of a hypothesis that aims to replace the traditional logics of building expansion with redevelopment actions, rehabilitation interventions and reuse strategies for existing structures on the territory. The question of the reuse of abandoned industrial areas has its own characteristics, and can be divided into a series of quite diversified possibilities, often deeply linked to the specific characteristics of the territories in which they are located [2].

Ultimately, in certain contexts, under specific conditions and through defined procedures, the need for remediation of polluted sites can be transformed into an important opportunity for local sustainable development and increase in collective well-being. However, also due to the continuous regulatory evolution and the variety of possible specific situations, the verification of these conditions often presents great complexity [3,4]. It is within this framework that this work is located, in order to pursue a dual objective of stimulating and supporting the decision-making process: on the one hand, conveying knowledge that belongs to a single specific case study to different application fields; on the other hand, to encourage the diffusion of a culture of the recovery of polluted sites capable of fully grasping the existing opportunities, quantifying the impacts in monetary terms of critical environmental pollution on the areas market value, in prevision of their future requalification and refunctionalization.

The issue of the recovery of polluted sites has been at the center of environmental protection objectives in Italy for several years now. Given the widespread diffusion of the problem (the potentially contaminated sites on the Italian territory are more than 12,000), experts and policy makers agree in stressing the urgency of speeding up the implementation of adequate intervention policies: whether we refer to punctual areas or individual sites with a high concentration of sources of pollution, or it refers to plants at risk of accidents, these realities constitute a serious threat - both potential and effective—for people and the environmental resources concerned [5].

The recent complex experience of the decommissioning of the former Italsider area in Bagnoli clearly reveals the difficulties associated with large-scale operations. However, more recent policies encourage reuse perspectives for these areas, specifically assigning them roles consisting in:

- real estate assets, in which the transformation constitutes a mediation element with the city;
- cultural development, in which the industrial archeology assumes a value of memory and testimony;
- environmental resources, in which the regeneration is strictly tied to the creation of urban parks and green areas;
- urban resources, in which the redevelopment is enacted through the relocation of services and functions of great relevance, or through the development of innovative economic activities.

In the framework of the above-detailed general objectives, the present study will apply a multiple regression model, in order to procced to an appraisal of the effects of real estate valorization that could be generated by a redevelopment intervention in an urban area of the city of Naples.

In particular, the appraisal will be performed taking into account the variables of real estate price for the properties involved in the transformation processes of the abandoned industrial areas in Coroglio-Bagnoli.

The values of the building products to be realized on the sites that were subjected to interventions, will be obtained through the application of an autoregressive moving average model (ARIMA), considering the long duration of the redevelopment period of the areas, and the related uncertainty on the evolutions of real estate prices.

In the case study, a further complexity—from an estimative point of view—is represented by the critical contamination state of the soils. In fact, environmental pollution produces a damage on the areas, which negatively affects their market value beyond the mere remediation cost. In fact, it is logical—and not only—that a "damaged", and subsequently "regenerated" economic good certainly has a lower market value than an equivalent good in a condition of "new" good. This depreciation of regenerated goods derives from a reduction of its service life, which cannot be canceled through recovery interventions of any kind, also because of the probabilistic nature of the concepts of duration and reliability for a regenerated good. Then, the current state of environmental pollution of the examined areas constitutes an element of strong uncertainty for economic operators, leading to a value reduction that has to be determined and accounted in the evaluation model to be implemented.

These considerations lead to the necessity of quantifying what in literature is called "stigma" effect, also defined as "a market- imposed penalty that can affect a property that is known or suspected to be contaminated, property that was once contaminated but is now considered clean, or a never contaminated property located in proximity to a contaminated property" [6,7]. So, in order to identify the "stigma" effect for the abandoned industrial areas of Bagnoli, due to the presence of a risk perception-driven market resistance, Ellwood's model, integrated with Real Options Analysis, will be applied in the case study. The property value reduction will be estimated starting from the future building values, and then reflected on the current market value of the abandoned industrial soils

2. Literature Review

Property value models represent relevant tools through which economists analyze environmental externalities [8]. The existing literature is relatively complete on the issue of whether or not a stigmatized place has an effect on nearby property values.

A paper by Ridker [9] in the 60s was the starting point for this strand in literature, focused on the analysis of the influence of contaminated and noxious sites. In particular, Ridker distinguishes three measurement strategies: the immediate effects of pollution on health, housing and materials, which would tend to overestimate the costs; the costs of fixing these immediate effects; and finally, market effects, especially those on land and property values. In the same direction are the studies of Havlicek et al. [10], Mendelsohn et al. [11], and Nelson et al. [12].

The reference literature reveals a wide variability in the estimation of the economic impacts produced by contaminated and noxious sites, or also concerning the economic effect of location vis-à-vis with high voltage power lines, hazardous and non-hazardous disposal sites, and other NINMBYs ("Not In My BackYard") and LULUs ("Locally Unwanted Land Use") [13–26].

Gamble et al. [13], and about ten years later Folland et. al. [14], studied the impacts of nuclear power plants on the values of surrounding real estate properties, but the former showed no significant effect on residential properties while the latter concludes that the value of neighboring farmland decreased by about 9%. Thayer et al. [15] suggest that non-hazardous and hazardous waste disposal sites cause about a 1% or 2% reduction in house price per mile, respectively, up to four miles. Smolen et al. [16] found a significant impact for an existing hazardous waste site and strong negative reaction to a proposed site; they also showed that the effect on property values dissipated after the site was dismantled. Michaels and Smith [17] and Kohlhase [18] found that distance from Superfund sites was a positive and significant determinant of property values in Boston and Houston, respectively. Reichert et al. [19] found that landfills caused a 5–7% decrease in property values but the effect was only for urban houses near the site, while in rural areas the impact was practically nil.

Many researchers have used real estate data to study the impact of contaminated and noxious sites, typically with a cross-sectional data set referred to a single point in time. However, as they do not include post-cleanup property values in the analysis, these studies cannot analyze correctly the effects of cleanup. Often overlooked in the abovementioned studies is the weight and/or duration of the negative impact for hazardous sites that are cleaned up as, over time, the hazard has been eliminated. In this regard, post-cleanup property values have been examined over a substantial period by Kiel in several studies [20–24]. A further exception are Kohlhase [18] and Dale et al. [25]: the former considers an almost cleaned up toxic site, finding statistically insignificant coefficients on price and distance; the latter do not distinguish between long-term and temporary stigma, moreover, they quantify the discontinuity of the distance-price gradient surrounding the smelter by including indicator variables for two specific neighborhoods.

Concerning more recent studies, McCluskey et al. [26] use a model of neighborhood turnover with external economies; they show that both temporary stigma and long-term stigma are possible equilibrium outcomes after the discovery and cleanup of a hazardous waste site. Simons and Winson-Geideman [27] report the results of Contingent Valuation studies conducted in eight states of U.S., with the aim of evaluating the effects on residential properties impacted by Leaking Underground Storage Tanks. Negative discounts for marginal bidders with affected ground water are quite consistent, varying from −25% to −33%. Kiel and Williams [28] examine several Superfund sites across the U.S. and find that some have the expected impact, while others have either no impact or a positive impact on local property values. Using a meta-analysis approach to examine what factors contribute to a decrease in property values, they find that larger sites in areas with fewer blue-collar workers are more likely to have a negative impact.

A common element emerges in all the examined studies: as it is logical to expect, the effect on real estate values depends critically on the distance from the contaminated and noxious site.

3. Materials and Methods

3.1. Steps of the Evaluation Model

The proposed model considers the combined employment of several different evaluation methods.

The Residual Method (also called "Trasformation Value Method") constitutes the backbone of the proposed estimation model, as it allows to determine the value of the areas as the discounted difference between the incomes related to the sale of the building products, the realization of which is provided for by the "Coroglio-Bagnoli" Executive Urban Plan (PUE), and the costs related to urbanization and construction, in addition to the expenses of soil remediation, the cost of which will be taken into account following the determination of the ordinary market value or "capital value" of the soils. The Transformation Value method can be applied both to the buildable soils and to the existing artifacts of industrial archeology as long as their destination is individuated in the "Coroglio-Bagnoli" PUE; it is possible to perform the estimation of the existing building products which do not have a specific transformation destination according to the subrogation value, through the Depreciation Cost Approach.

The value of the future building products has been estimated through the multiple regression model, which allows to take properly into account the economic contribution generated by the future interventions of urban regeneration on the building products. In particular, the implemented regression model allows to determine an average unit value of the residential market, then differentiated according to the various thematic areas and intended uses detailed in the Executive Urban Plan. The costs of the building transformation are then elaborated, based on parametric unit costs obtained from official informative sources.

The time horizon of future incomes and costs is consistently wide—higher than a decade—so the Transformation Value must be adapted according to the future variations of the dynamics of the building market. An ARIMA autoregressive model is therefore applied to evaluate the future indexes of revaluation/devaluation of the building products and of the construction costs, in order to adequate the costs and the incomes of the building products that will be realized on the estimated areas over time.

The employment of the Ellwood model is, in the considered case, "inverted" from its original purpose: in fact, the general aim of this model is to obtain an estimation of the capitalization rate of a building investment through a detailed financial analysis of all the costs related to it. The model will instead be employed to determine, for the abandoned industrial areas of Bagnoli, the variations of the fruitfulness rate of the building stock due to the uncertainty of the future environmental conditions of the sites, considering the risk related to a present consciousness of the conditions and the effective outcomes of the expected regeneration interventions. Correspondingly, different unit values of the building components—which constitute the incomes of the transformation value "method"—will be obtained in the two foreshadowed scenarios: "with" and "without" effects of the risk related to the perception of the environmental pollution in the areas after the regeneration. The difference between the two values allows to determine the decreased appreciation of the building products—and, then, of the soils, according to the logic of the transformation value—in comparison with buildings with the same characteristics, but non similarly affected by a history of past critical environmental pollution.

Synthetically, the estimation model of the areas is articulated in the following, logically consequent, phases:

- individuation of the property surfaces;
- definition of the architecture of the Transformation Value Method;
- time distribution of urbanization and construction interventions, and prediction of the chronology of the sales of future building products;
- unit market value appraisal of the future building products through the multiple regression model;
- appraisal of urbanization and construction costs;
- calculation of revaluation/devaluation indexes of property values and construction costs through the use of autoregressive ARIMA models;
- market value appraisal of the industrial archeology artifacts and of the existing constructions through the Transformation Value Method or the Depreciation Cost Approach;
- application of the transformation value method for the market value appraisal of the areas;
- implementation of the Ellwood model for the determination of the capitalization rate with and without considering the risk related to the perception of the environmental pollution of the areas;
- re-application of the Transformation Value Method for the estimation of the market value reduction of the areas taking into account the results of the Ellwood model.

The methodological structure of the single methods which constitute the appraisal model described above, is detailed in the following before proceeding to the related application in order to realize the examined evaluation.

3.2. Residual Method

In accordance with IVS guidelines, the Residual Method (also called "Trasformation Value Method") indicates the residual amount after deducting all known or anticipated costs required to complete the real estate development project for a specific intervention area from the back-discounted value of the future completed project, also taking into account all the risks associated with the several phases of the real estate investment project [29]. This method can be integrated with other models that may vary in complexity and tools used, depending by input granularity, multiplicity of the development phases of real estate investment, algebraic and analytical tools. So as area dimension, temporal duration of development intervention, complexity of the proposed development project, are further elements of complexity in the application of the method [29].

The following basic elements and inputs require consideration in the application of the Residual Method for the appraisal of building area: market value of the completed building(s) achievable on the examined area, construction costs (including safety costs and tax charges), taxes and fees of various kinds for building permits, charges for professional and technical skills necessary to carry out the building intervention, finance costs, consultants and marketing costs, development project profit, discount rate, development project timetable.

In general terms, the Residual Method applied for the appraisal of a building area can be expressed as follows:

$$Vba = [(Vta - Ct)/q^n]$$

Here Vba is the market value of the built area considered, Vta is the market value of the transformed area (or market value of the building achievable on the same area), Ct is the total transformation cost of the area, q^n is the financial discount factor, as the above terms are not temporally aligned.

In any case, the application of the Residual Method must be performed according to Ordinariness Theory, which provides the use of average or ordinary input parameters in the implementation phases of the method [30].

3.3. Multiple Regression Analysis

The price function, defined for each property category located on the area under study, can be expressed symbolically as follows [8]:

$$PK_{ji} = (x_v, x_{jt})$$

Here, PK_{ji} is the market price of generic property, x_v ($v = 1, 2, \ldots r$) represent the environmental variables and x_{jt}, ($t = 1, 2, \ldots s$) indicate the remaining variables that contribute to the formation of real estate prices, and that in general relate to:

- the extrinsic property characteristics related to location (accessibility to tertiary activity area, distance from the main traffic lines, etc.);
- the intrinsic characteristics of the property related to the position (front, orientation, panoramic views, etc.).
- the technological characteristics (plants, apartment finishes, etc.);
- the production characteristics (such as locative, exemption from payment of taxes and duties, level of productivity of agricultural land or building capacity, etc.).

Among x_{jt} variables, the time of sale of real estate can also be understood. This variable is normally used as a "temporal" reference to take into account price changes due to the inflationary process or other market contingencies. Using the Fj function, the price change of the property is calculated in discrete terms. That is, it must be determined as the difference of function values obtained by assigning the measure to the environmental variables, in the situation "with" (x_{vp}) and in the situation "without" (x_{va}) intervention. The quantification of the variables must be operated on the basis of the measurement system (techniques, dichotomous measures, scores, etc.). If this function is linear and environmental variables are represented by rating scales, the price change can be calculated as the sum of the implicit marginal prices of the same variables, namely the algebraic sum of the price changes due to differences of variables taken individually. In the remaining cases, the price change must be determined by simultaneously introducing—in the function—the environmental variables in accordance with the respective amounts (x_{vp} and x_{va}). It is clear that the mathematical formulation of the price variation, and consequently the symbolic expression of the G_j function, depends on the algebraic structure of the function price F_j. Assuming, as an example, that F_j has one of the three forms of a function - linear, multiplicative or exponential—which represent the most commonly used functional dependencies in the econometric analysis of the housing market, it follows that the price change is given by one of the following equations:

$$F_j \text{ linear } (PK_{ji} = \sum\nolimits_t a_{jt}\, x_{jt} + \sum\nolimits_v a_v\, x_v)\text{: } \Delta PK_{ji} = \sum\nolimits_v a_v\, (x_{vp} - x_{va});$$

$$F_j \text{ multiplicative } (PK_{ji} = \prod\nolimits_t x^{ajt}{}_{jt} + \prod\nolimits_v x^{av}{}_v)\text{: } \Delta PK_{ji} = \prod\nolimits_t x^{ajt}{}_{jt} \prod\nolimits_v (x^{av}{}_{vp} - x^{av}{}_{va});$$

$$F_j \text{ exponential } (PK_{ji} = e^{\sum_t ajtxjt + \sum tavxv})\text{: } \Delta PK_{ji} = e^{\sum_t ajtxjt}\, (e^{\sum_v vavxvp} - e^{\sum_v vavxva}).$$

In these equations, a_v and a_{jt} are respectively the regression coefficients of the environmental variables (x_v) and the remaining endogenous variables (x_{jt}) of the price function. Price variation evaluation also requires the determination of the amounts of the x_v environmental variables in the previously existing situation and in the one subsequent to the implementation of interventions. This problem must be solved in different ways, depending on whether the evaluation of externalities is carried out in ex ante or ex post conditions.

3.4. Autoregressive Models (ARMA, ARIMA)

Statistical autoregressive models are commonly used for time series analysis, as they are capable of relating the current value of a variable with its previous values, thus establishing a statistical dependency between observations corresponding to different times.

There are several autoregressive models, among which the most used are:

- Autoregressive models (AR);
- Moving Average models (MA);
- Autoregressive Mixed Moving Average models (ARMA);
- Autoregressive Integrated Moving Average models (ARIMA).

In general, an autoregressive model (AR) is characterized by an order p, which determines the number of previous observations the variable is connected to. Therefore, an *AR(p)* autoregressive model of order p can be expressed as follows [31]:

$$y_i = \varphi_0 + \varphi_1 \cdot y_{i-1} + \varphi_2 \cdot y_{i-2} + \cdots + \varphi_p \cdot y_{i-p} + \varepsilon_i$$

An autoregressive model can therefore be assimilated, both in form and in resolution, to a regression model: in particular, for $p = 1$, it corresponds to a simple regression model; for $p > 1$, it becomes a multiple regression model. In the equation, y_i are generic terms of the series, while φ_j are the model coefficients and ε_i is the error, the deviation from the model of the single i-th term.

As in a multiple regression model, the model coefficients can be determined using the Ordinary Least Squares principle.

$$\sum_{i=k+1}^{n} \varepsilon_i^2 = \sum_{i=k+1}^{n} (y_i - \varphi_0 - \sum_{j=1}^{k} \varphi_j \cdot y_{i-j})^2$$

It can be noted that, though the model applies to all the terms in the series, the terms $y_0, \ldots, y_{1-k}$ of the series are of course not available. Therefore, they can be equaled to 0, or they can be identically defined through the Equation:

$$y_0 = \cdots = y_{1-p} = \frac{\varphi_0}{1 - \sum_{j=1}^{p} \varphi_j}$$

The series is called stationary if $\varphi < 1$, while it is not stationary if $\varphi = 1$, and it is necessary to differentiate it in order to apply the methodology: this test is named Dickey-Fuller test [31].

A moving average (MA) is a time series consisting of the averages of sequential value intervals of another time series. Given a series $(y_1, \ldots, y_n)$, the relative moving average is expressed by the relation:

$$z_t = \frac{1}{2k+1} \cdot \sum_{j=-k}^{k} y_{t+j}$$

In the Equation, t can only assume the values between k+1 and n-k. By introducing in the equation unit sum symmetric coefficients, capable of diversifying the weight of the previous terms into the averages, weighted moving averages presenting reductions in the variations compared to the simple moving averages are obtained. This concept leads to the definition of the *MA(q)* moving average models, expressed by an equation of order q having the formula:

$$z_t = a_t - \omega_1 \cdot a_{t-1} - \omega_2 \cdot a_{t-2} - \omega_q \cdot a_{t-q}$$

The process is stationary, and requires that the coefficients have a zero average. a_t constitutes the error related to the single term, $a_{t-1}, a_{t-2}, \ldots, a_{t-q}$ represent the terms of the original series; $\omega_1, \omega_2, \ldots, \omega_q$ are the coefficients to be estimated by the method, and z_t is the term of the moving average series, the forecast of which can therefore be obtained.

The auto-regressive moving average model (ARMA) is a type of linear mathematical model that provides an instant-by-instant output value based on the previous input and output; it is also referred to as the Box-Jenkins model, named after its inventors George Box and Gwilym Jenkins [32].

Given a system as an entity that, instant by instant, receives an input and an output value calculated according to internal parameters that vary themselves according to linear laws, each internal parameter is then equaled at every instant to a linear combination of all the internal parameters of the previous instant and input value, while the output value will in turn be a linear combination of the internal parameters and, in some cases, also of the input value.

Algebraically, the input and output values at a given instant are two scalars while the internal parameters form a vector. The output scalar is the product between the vector of parameters and a fixed vector, which is part of the model, with the same dimension as the number of parameters, summed to the input, multiplied by a coefficient that, in the so-called "improper" systems, differs from 0. The vector of parameters is at every instant calculated as the sum of the products between the input scalar and a vector, and the previous vector of parameters and a matrix. It can be considered as a combination of *AR* and *MA* models and is characterized by two orders: p, as in the *AR* model, and q, as in the *MA* model. An *ARMA(p,q)* model is described by an equation with the formula [31]:

$$y_i = \varphi_0 + \varphi_1 \cdot y_{i-1} + \cdots + \varphi_j \cdot y_{i-p} + \varepsilon_i + \vartheta_1 \cdot \varepsilon_{i-1} + \cdots + \vartheta_q \cdot \varepsilon_{i-q}$$

In other terms, the deviation does not appear in the model as a pure scalar, but is re-elaborated and defined through the functions of moving averages.

ARIMA(p,d,q) models constitute the general case of an autoregressive model, that the other autoregressive models detailed above are a specification of. In addition to the combination of auto-regression and moving averages proposed by the ARMA models, they present the possibility to differentiate the initial time series if it is not stationary, while the other models cannot operate directly on non-stationary series, and would require preliminary differentiation. Among the parameters of the model, the order d refers to the differentiation order: the first order, for example, refers to linear variations, the second order to quadratic variations and the third order to cubic variations. The differentiation process, exemplified for the first order—from which the differentiations of subsequent orders derive by iteration—consists in the transformation of each y_i term of the initial series into a z_i term of a new series through [31]:

$$z_i = y_i - y_{i-1}$$

The iteration of the differentiation—that is to say the incremental definition of the differentiation order—continues as long as the Dickey-Fuller test shows that the series is non-stationary. Except from the differentiation, the model coincides with an *ARMA* model.

3.5. Depreciation Cost Approach

The Depreciation Cost Approach follows the principles of International Valuation Standards (Cost Approach) and it is based on the postulate of substitution of evaluated assets [30,33,34]: considering the nature of production factors for the evaluated building components, if the market shows no direct appreciation for them, their total value does not exceed the amount corresponding to the sum of the values attributable to the area and reproduction cost of components (that are comparable with the evaluated assets for the complex of the related relevant characteristics, including the in-use condition). Using the "depreciated reconstruction cost", the market value of a building must be determined as a sum of the following components:

- substitute value or reconstruction cost (surrogate value), with current market prices, of existing building products, technological systems and special works, excluding the deduction for physical wear and tear and/or obsolescence, if present;
- market value of the area where the building products are located (including the adjacent appurtenant areas).

The basis to use this procedure is the acknowledgement that buildings tend to decrease their market value over time. According to the estimative logic, this value reduction is to be reconnected to three factors: physical wear and tear, income decay and functional and economic obsolescence. The first two factors are different but both are an expression of physical depreciation. The physical wear and tear derives by the limited economic life or service life of the building, with a decrease of its efficiency. The income decay reflects the utility reduction of a building in use, compared to its corresponding condition if it were new, as over the time it requires more expensive maintenance interventions in order to keep the same conditions of efficiency. Analytically, physical wear and tear is considered equal to the physical depreciation, while income decay only includes the value decrease related to the absence of programmed maintenance. The third factor can be divided into functional obsolescence and economic obsolescence: the former is a loss of value that can be attributed to the innovations of more modern technological systems, which have lower service costs and/or higher efficiency with the same construction cost; the latter is a loss of value related to the environment conditions and the surrounding properties, in addition to particular events that can reduce the asset value.

The depreciation for economic obsolescence, then, can occur for a variation of the "external conditions" of the evaluated asset, or for possible use changes, pollution and urban congestions, general economic situation, etc. Often, these factors can determine a significant reduction of human and productive income activities carried out in the building. However, the valuation of the depreciation for economic and functional obsolescence is quite complex, and it would cause significant operational problems, concerning the determination of some essentials parameters such as the expenses to dismantle existing systems and/or the installation of new systems, and the lower expense or the higher utility generated as a consequence of the substitution of the system. For these reasons, often the existing literature suggests to avoid the analytical calculation of the depreciation caused by functional obsolescence, considering its influence in the depreciation caused by physical wear and tear adopting, empirically, an economic life that is lower than service life and/or by varying the discount rate [35].

That said, the literature suggests to quantify the contribution of physical wear and tear as follows [35]:

$$\Delta C_{dlog} = (C_0 - Vr) \cdot \frac{(1+i)^n - 1}{(1+i)^v - 1}$$

where: ΔC_{dlog} is the depreciation by physical wear and tear; C_0 is the initial value for the functional element considered; V_r is the residual value at the end of the service life of the functional element considered; i is the discount rate; v is the number of service life years of the functional element considered; n is the number of life years spent by the functional element considered at the moment of its evaluation.

The partial contribute of the income decay to depreciation is related to the cost of the necessary building interventions to eliminate it, decreased by the residual value of the part/component/element that was substituted. Assuming the substituted part has no residual value, the additions cost can be determined as the financial sum of the annual quotas of reintegration accumulated in order to reach the expense for the intervention of extraordinary maintenance at the expected moment of execution. Then, the deduction by income decay can be analytically determined with the following formula [35]:

$$\Delta C_{dred} = C_0 \cdot m \cdot \frac{(1+i)^n - 1}{(1+i)^s - 1}$$

where: ΔC_{dred} is the depreciation by income decay; C_0 is the initial value of the functional element considered; m is the cost of extraordinary maintenance intervention, expressed as a quota of the initial value of the element C_0; i is the discount rate; s is the standard period between two interventions of maintenance; n is the number of life years spent by the functional element considered at the moment of its evaluation.

The building constitutive elements are notoriously heterogeneous between them, in function, realization time, technological characters and typology. For these reasons, the depreciated reconstruction cost has to be determined considering the constitutive functional elements, according to the following operational phases: individuation of the building typology and classification, when possible, of products, assets or components in homogeneous groups; evaluation of the reconstruction cost of the building products, assets or components as above; breakdown of the building in functional elements and calculation of the percentage cost of the single elements on the total cost; definition of an analytical depreciation function for each functional element; evaluation of the depreciated reconstruction cost for each functional element, in order to obtain the total value of the depreciated reconstruction cost of the building.

3.6. Ellwood's Model

In real estate field, Ellwood's model is applied to estimate the risk-return for property investments. The assumptions of the model are the following:

- the purchase of the property is made entirely with equity capital; this assumption allows to eliminate three variables from Ellwood's financial analysis due to their low incidence on the final result: the rate of hetero-financial capital, the interest rate for the loan recovery and the duration of the amortization period;
- the availability period of the property constitutes an endogenous variable of the model;
- income invariability.

The capitalization rate is obtained from the resolution of the following equations [34–40]:

$$R \cdot \left[\frac{(1+r_i)^m - 1}{r_i \cdot (1+r_i)^m} \right] + \left[\frac{P \cdot (1+r_v)^m}{(1+r_i)^m} \right] = K \tag{1}$$

$$VA = R \cdot \left[\frac{(1+r_i)^m - 1}{r_i \cdot (1+r_i)^m} \right] + \left[\frac{P \cdot (1+r_v)^m}{(1+r_i)^m} \right] \tag{2}$$

$$VA' = R \cdot \left[\frac{(1+r_i)^m - 1}{r_i \cdot (1+r_i)^m} \right] + \frac{P \cdot \left[(1+r_v)^m - 1 \right]}{(1+r_i)^m} \tag{3}$$

$$\begin{aligned} &\left[P \cdot r_c \cdot \left(1 - C_{sfin} - 0.85 \cdot C_{redditi} \right) - P \cdot 2/3 \cdot \left(S_{qr} + S_{mas} \right) - V_{cat} \cdot C_{imu} \right] \cdot \left[\tfrac{(1+r_i)^m - 1}{r_i \cdot (1+r_i)^m} \right] + \left[\tfrac{P \cdot (1+r_v)^m}{(1+r_i)^m} \right] = \\ &= \left[P \cdot (1 + S_{comm}) \right] + \left[V_{cat} \cdot \left(S_{trasf} + S_{not} \right) \right] \end{aligned} \tag{4}$$

$$r_c = \frac{\left[(1 + S_{comm}) + \left(\tfrac{V_{cat}}{P} \right) \cdot \left(S_{trasf} + S_{not} \right) - \tfrac{(1+r_v)^m}{(1+r_i)^m} \right] \cdot \left[\tfrac{r_i \cdot (1+r_i)^m}{(1+r_i)^m - 1} \right] + \left[2/3 \cdot \left(S_{qr} + S_{mas} \right) + \left(\tfrac{V_{cat}}{P} \right) \cdot C_{imu} \right]}{\left(1 - C_{sfin} - 0.85 \cdot C_{redditi} \right)} \tag{5}$$

The capitalization rate is obtained from the Equation (1) where financial assets and liabilities of a property investment are summarized: revenues are the perceived net income during the availability period of the property and the investment residual value, while liabilities consist in the property purchase price, to which the revaluation or devaluation at the end of availability period of property should be added or subtracted. The costs correspond to the expenditure items required to start the investment (property purchase price, brokerage fees and expenses related to the ownership transfer, such as taxes and legal fees). Given that in Ellwood's model revenues and costs are attributable to different times, they have become financially consistent considering their discount at the initial year taking into account a specific internal return rate of property investment (r_i).

Equation (2) outlines the stochastic evolution of the investment present value. It coincides with the first member of Equation (1). While in Equation (3), the present value for every year is equaled to the sum of financial real cash flow (gross revenues generated by property lease) and virtual cash flows (revaluation or devaluation annual of real estate capital). Specifying with r_c the gross capitalization rate, expressed by the ratio between real estate rent (C_a) and property purchase price (P), Equation (1) can be rewritten considering Equation (4), where:

- C_{sfin}: percentage of losses due to property vacancy or to leaseholder's debt, it depends by conditions related to supply and demand of real estate and can be estimated as a reduction on real estate rent;
- $C_{redditi}$: taxes percentage on real estate income;
- S_{qr}: percentage corresponding to the reintegration share for the annual renewal of the real estate capital at the end of its useful life, it also can be estimated as a reduction on real estate rent;
- S_{mas}: percentage corresponding to of maintenance, administration and insurance costs, depending by property type; it can be assumed as a reduction on construction costs;
- V_{cat}: cadastral value of property; in the Italian context it is determined by multiplying the cadastral real estate income (raised by 5%) for 110 (first home) or for 120 (ordinary situation);
- C_{IMU}: municipal property tax, depending by property type and destination;
- S_{comm}: property marketing fee, calculated as percentage on the property market value;
- S_{trasf}: property transfer taxes (registration, mortgage and cadastral), calculated as percentage of the cadastral value (3% for the first home and 10% in other cases in Italian context);
- S_{not}: notary fees, calculated as percentage on declared value in the notarial deed (eventually increased if there is a property mortgage).

Equation (4) can be rewritten also in the form of Equation (5), where capitalization rate is the unknown quantity. To estimate capitalization rate, special care is needed both determining the revaluation rate and the internal rate of return. The latter in particular is calculated as a function of r_v: $r_i = r_v \cdot (1 + 3\sigma)$.

In determining capitalization rate, a further issue is related to the presence, in the Equation (5), of the cadastral value, being it another unknown quantity. For simplicity, the cadastral value is assumed to be equal to the property purchase price.

Ellwood's model can be implemented with Real Options Analysis, allowing a risk analysis for different project solutions (or options). In particular, considering a binomial paradigm, it is possible to develop the variations of the initial investment value through further probabilistic scenarios of multiplicative type, defined by u and d coefficients (respectively, greater and lower than one). The u and d coefficients represent the future evolution of the initial state to a favorable or unfavorable scenario. The value of u and d coefficients derives from the result of the investment risk analysis, statistically calculated by the standard deviation (σ) on the time series of the revaluation/devaluation rate. Moreover, using a scenarios tree, the Real Options Analysis allows to identify the availability period (m) of the property in the most pessimistic scenario (lower branch of the scenarios tree), in which we should dispose of the property for to recover the initial capital (see Figure 1).

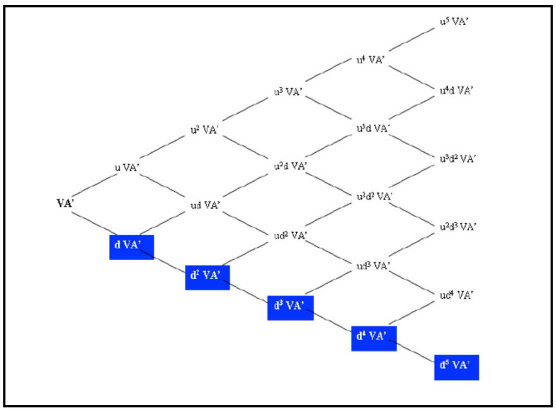


Figure 1. Example of scenario analysis tree for a real estate investment with a period of 5 years.

The definition of the probabilistic evolution states occurs through the following mathematical expressions [36–40]:

$$u = e^{\sigma\sqrt{dt}} \quad d = e^{-\sigma\sqrt{dt}}$$

where: e is Euler's number assumed equal to 2.718; σ is the standard deviation (volatility); dt is the time interval between subsequent evolutions of the considered scenario.

In the scenario analysis tree, the terms $u^t \cdot VA'(t)$ and $d^t \cdot VA'(t)$ constitute the "best case" and "worst case". To identify the availability period (m) it is necessary to define *t-year* where:

$$d^t \cdot VA'(t) < d^{t-1} \cdot VA'(t-1)$$

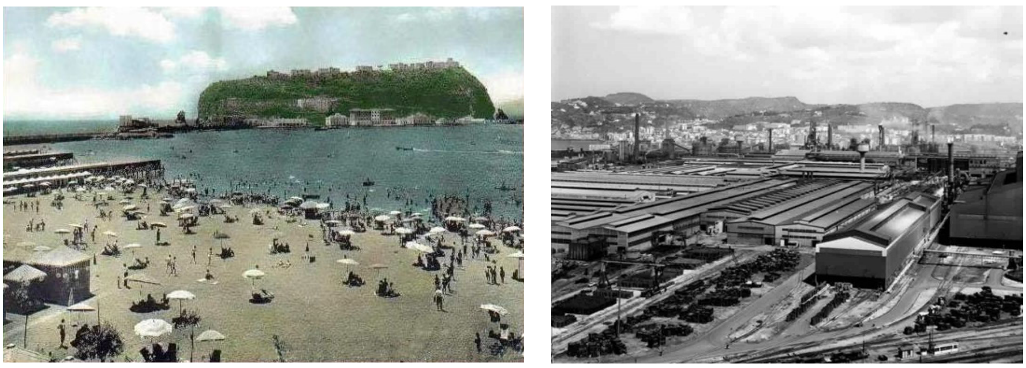
In other words, this relation defines the moment in which the disposal of the real estate investment becomes necessary (most negative scenario), since in this case its economic convenience declines and the ordinary investor is obliged to sell the property. Once the availability period (m) has been calculated in this way, it can be used to determine the effective value of K, VA and VA' at the end of the availability period.

4. Case Study: The Abandoned Steel Mill Areas of Bagnoli in Naples (Italy)

4.1. Recent History of Coroglio-Bagnoli Area [41,42]

The district of Bagnoli, together with Fuorigrotta and the island of Nisida, constitutes the Xth Municipality of the City of Naples and falls within the large volcanic area of the so-called "Campi Flegrei". It is delimited to the north by the Pianura district and the Municipality of Pozzuoli, to the west by the Pozzuoli Bay, to the east by the Fuorigrotta district.

The environmental amenities of Bagnoli inspired, already at the end of the 19th century, the possibility to carry out ambitious projects of urban transformation and valorization: the architect Lamont Young, in 1889, presented a design proposal to convert the Bagnoli district into a "small Venice "through the construction of an artificial canal connecting Bagnoli and Mergellina and of a metropolitan line departing from Coroglio and crossing the whole city of Naples. In 1892, Lamont Young obtained the concession but was unable to set up a company to finance and complete the project. A decade later, the typology of projects that involve Bagnoli radically changes (see Figure 2).



(**a**) (**b**)

Figure 2. *Cont.*

(c)

Figure 2. The abandoned steel mill area of Bagnoli in the mid-nineteenth centuries (**a**), mid-twentieth centuries (**b**), and today (**c**) (Source: [38,39] for pictures (**a**,**b**), authors for picture (**c**)).

In 1904 Law n. 351 concerning "Measures for the economic resurgence of the city of Naples" is issued with the aim of imposing a mainly industrial vocation on the city of Naples. Considered suitable for these purposes and destination, construction works for a steel production and transformation steel plant by the Genoese company Ilva S.p.A. began in 1905 in the Bagnoli area. The industrial development of the area is in the meantime evidenced by the establishment of other business activities, in particular on the beach of Bagnoli, where in 1908 a production line for copper sulphate, phosphoric acid and phosphate fertilizers was installed. The industrial steel plant of Ilva S.p.A., with an extension of around 120 hectares, was inaugurated in 1910. However, steel production stopped after the First World War, until 1924. Post-war economic difficulties led Ilva to become a company under public control.

Due to the high level of iron and steel production reached, two piers were built in 1930 in the Bagnoli area, the "north pier" and the "south pier". In 1938, the factory of the Swiss company Schweizerische Eternitwerke AG (formed in 1901), which later became "Eternit AG" in 1923, was built in the Bagnoli area, for the production of asbestos cement products. The repair of the damages of the Second World War and the subsequent productive reactivation of the rolling mills and the steel mill took place in 1946, until recovering the total pre-war production capacity only in 1951. The establishment of the company Cementir was built in the area next to the Ilva plant in 1954, with the aim of using blast furnace slag as a raw material for the production of cement. The expansion of steel production made it necessary to create an additional area of soil, the so-called "Colmata a mare" (sea fill): an expanse of about 20 hectares has enclosed between the two piers built in 1930, consisting of inert materials and waste materials from the construction sites, which was realized between 1962 and 1964.

The six decades of history that led Bagnoli to move towards a decisive expansion of industrial production, and an intensification of the exploitation of the soil and resources in this direction, clashed with the deindustrialization and outsourcing process that involved Italy and, in general, western economy.

The guideline n. 83/478/CEE of 19 September 1983 forbid to place on the market several products related to asbestos and to asbestos cement, among which those containing crocidolite. Therefore, in 1985, unable to continue highly noxious works, the Eternit establishment closed and the area was subjected to the first land remediation.

In the mid-nineties, industrial production in the Bagnoli area is totally zeroed. About 200 hectares of industrial wrecks populate a totally different scenario from what was visible a century earlier, and expanses of metal sheets close the perspective towards the sea.

4.2. Summary of the Provisions of the "Coroglio-Bagnoli" Executive Urban Plan (PUE) [41,42]

The value of the examined soils is directly related to the property surfaces to be realized, synthetically reported in Table 1, which also reports the detail of the territorial area and the net land area for each of the thematic areas listed of the PUE (as of the Prime Ministerial Decree 15 October 2015).

Table 1. Summary of land surfaces (both gross and net of infrastructure or urbanization works).

Thematic Area	*Territorial Area (ha)*	*Net Land Area (ha)*
Thematic area 1	*112.00*	*54.80*
Thematic area 2	*17.54*	*14.87*
Thematic area 3	*24.08*	*12.63*
Thematic area 4	*7.11*	*3.54*
Thematic area 9	*24.00*	-

The building volumes and the surfaces of areas of public interest that are expected to be realized in each thematic area were obtained in the Technical Implementation Rules of the Executive Urban Plan. The Plan only reports the volumes, for the buildings; the surfaces were obtained considering an ordinary average floor height according to the intended use:for the residential sector and for social housing (ERS) an ordinary floor height h_{int} of 3 mt was considered, while for the hospitality and tertiary sector an ordinary floor height of 4 mt was assumed.

The overview of the property surfaces and volumes is reported in Table 2.

Table 2. Overview of the property volumes and surfaces to be realized, for each thematic area.

Thematic Area	*Residential*		*Social Housing ERS*		*Hospitality*		*Tertiary*	
	m^3	m^2	m^3	m^2	m^3	m^2	m^3	m^2
Thematic area 1	-	-	-	-	-	-	-	-
Thematic area 2	*154,626*	*51,542*	-	-	*153,772*	*38,443*	*91,138*	*22,784*
Thematic area 3	*256,500*	*85,500*	*23,500*	*7833*	-	-	*64,000*	*16,000*
- Sub-area 3A	*110,000*	*36,667*	-	-	-	-	*19,000*	*4750*
- Sub-area 3G	*146,500*	*48,833*	*23,500*	*7833*	-	-	*45,000*	*11,250*
Thematic area 4	-	-	-	-	-	-	*165,000*	*41,250*
Thematic area 9	-	-	-	-	-	-	-	-
Total	***411,126***	***137,042***	***23,500***	***7833***	***153,772***	***38,443***	***320,138***	***80,034***

For the thematic areas where new building volumes are planned, the following are the total property surfaces and volumes:

- Thematic area 2: total 399,536 m^3 and 112,769 m^2;
- Thematic area 3: total 344,000 m^3 and 109,333 m^2;
- Thematic area 4: total 165,000 m^3 and 41,250 m^2.

For the 3G sub-area, the Technical Implementation Rules provide for the construction of tower-type buildings which are graphically divided into no. 15 floor levels for the residential sector (with the exception of the buildings destined to Social Housing).

The surfaces related to urbanizations, green areas, parking lots, areas of common interest are summarized in Table 3.

Table 3. Urbanizations, green areas, parking lots, areas of common interest of future realization for each thematic areas.

Thematic Area	*Urbanizations*	*Green Areas*	*Parking Lots*	*Areas of Common Interest*	*Total*
	m^2	m^2	m^2	m^2	m^2
Thematic area 1	*32,600*	*841,547*	-	-	***874,147***
Thematic area 2	*13,400*	-	*13,300*	-	***26,700***
Thematic area 3	*72,600*	*65,518*	*22,200*	*15,600*	***175,918***
Thematic area 4	*2600*	*26,106*	*11,500*	*4800*	***45,006***
Thematic area 9	-	-	-	-	**-**
Total	***121,200***	***933,171***	***47,000***	***20,400***	***1,121,771***

The existing buildings in the areas can be basically reconnected to the so-called "industrial archeologies", together with the artifacts realized within the Sport Park that constitutes the entirety of the Thematic area 9.

5. Results

5.1. Unit Market Value Appraisal of the Future Buildings to be Realized According to P.U.E.

The expression of the Transformation Value "method" employed for the estimation of the market value of the areas is the following:

$$V_{BF} = \sum_{t=1}^{n} V_{mt} \cdot r_{vt} \cdot q^{-t} - \sum_{t=1}^{n} (K_{ut} + K_{ct}) \cdot r_{ct} \cdot q^{-t} + V_{PRE} - K_{BON}$$

In the formula, V_{BF} is the market value of the industrial areas; t corresponds to the number of the years from the beginning of the transformation to the t-th year; n is the number of years from the beginning of the transformation to the sale of the completed building products; V_{mt} is the income related to the sale of the building products in the t-th year; K_{ut} is the income related to the sale of the building products in the t-th year; K_{ct} is the construction cost of the building products in the t-th year; r_{vt} is the building revaluation/devaluation rate for the t-th year; r_{ct} is the revaluation/devaluation rate of the construction cost for the t-th year; V_{PRE} is the total market value of the existing buildings in the areas; K_{BON} is the amount of the total environmental remediation cost of the of the areas.

In order to correctly apply the method, it is necessary to take as a reference a time line chart of transformation interventions and sales, which also indicates the percentage of realization of the interventions, allowing to distribute costs and incomes over time.

In accordance with the indications from the time line charts of Bagnoli Futura S.p.A. and Invitalia S.p.A. about the transformation of the areas, and with the latest indications about the timetable of the remediation interventions, the time schedule reported in Table 4 was realized.

Table 4. Timetable of the transformation interventions of the areas and sales of the building products.

Activities	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
				t = 1	*t = 2*	*t = 3*	*t = 4*	*t = 5*	*t = 6*	*t = 7*	*t = 8*	*t = 9*	*t = 10*	*t = 11*	*t = 12*
Operations of environmental remediation															
Realization of infrastructures and facilities in the common areas				*12.5%*	*12.5%*	*12.5%*	*12.5%*	*12.5%*	*12.5%*	*12.5%*	*12.5%*				
Realization of the building products					*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.12%*		
Sale of the building products							*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.11%*	*11.12%*

For obvious reasons of consequentiality, the construction of the building structures was assumed to begin one year after the start of construction works of urbanizations and common areas; correspondingly, it was assumed that the sale operations took place at the time of the conclusion of the construction works of the building products (at least two years after the start of the corresponding building construction works); for this reason, a time horizon of 12 years was assumed for the implementation of the entire building intervention program (see Table 4). From a logical point of view, it should be noted that this estimate, referred to the moment of the transfer of the areas to the company Invitalia (15 October 2015) is carried out ex post, therefore considering only the operational conditions known at the present time.

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The application of the multiple regression model for the estimate of the unit market value of the finished building products provides for the acquisition of a sample of real estates and their relative characteristics, or explanatory variables, considered to be significant to determine real estate sale prices.

In examining the districts of Naples with properties that bear more similarities to those of Bagnoli, the choice falls on the nearest district of Fuorigrotta, and more specifically on the main street "Via Diocleziano", including both the estates close to its eastern end, namely Piazzale Tecchio, and its last eastern part, already falling in the Bagnoli district. All the sample properties belong to the segment of the residential sector.

The individuated explanatory variables are the following:

- environmental quality (P_1), related to the value of the context in which the property is located, concerning both natural and the built environment, in terms of aesthetic value, public green areas and common areas, variety of the building products and house density: within the sample it is measured with scores from 0 to 2, increasing with the proximity to the public green areas such as the Mostra d'Oltremare and the Robinson Park, and the distance from the less aesthetically pleasing areas near Cavalleggeri bridge;
- infrastructural quality (P_2), which indicates the connection of the property with its closest context—integration with the main streets, well-structured access ways, presence of urbanization works—and with the wider urban context, signaled by the possibility to use means of public transport, the vicinity to metro stations: it is measured in the sample properties with scores from 0 to 3, increasing with the proximity to railway stations—valuing Napoli Campi Flegrei more than the less connected Napoli Cavalleggeri Aosta—and with the collocation on a main street;
- floor level (P_3), which increases the panoramic quality of the estate and, then, the aesthetic quality of the view: it is measured by equaling the score to the number of the floor where the property is located, varying between 0 and 10;
- in-use condition (P_4), related to the age and to the technological condition of the estate: it is evaluated through the attribution of a score equal to 2 for new or just renovated properties, 1 for properties in good conditions and 0 for properties that require a renovation intervention;
- presence of an elevator (P_5), characteristic which determines, if negative, a value reduction for the apartments located at higher floor levels: a score equal to 1 is assigned to properties served by an elevator or located at the second floor or below, while a score equal to 0 is attributed to properties without the elevator, or located at third floor or above.

The sample was gathered by consulting real estate property sale advertisements published on the main national specialized portals, referred to the year 2019–2020, in this way, a sample of n. 53 real estate properties (opportunely corrected according to the indications provided by the Bank of Italy regarding the average difference between bid prices and sale prices) was obtained.

Table 5 reports the descriptive statistics of the real estate sample.

Table 5. Statistical description of the real estate sample.

Description	*Surface (m^2)*	*Vu (€/m^2)*	*P1*	*P2*	*P3*	*P4*	*P5*
Average	93.25	2449.52	1.28	1.72	3.36	1.15	0.91
Std. Error	4.29	79.40	0.10	0.11	0.36	0.06	0.04
Median	90.00	2434.78	1.00	2.00	3.00	1.00	1.00
Std.Deviation	31.23	578.03	0.72	0.77	2.62	0.46	0.30
Kurtosis	−0.60	0.15	−0.91	−1.09	−0.08	1.19	6.40
Asimmetry	0.28	0.35	−0.48	0.54	0.61	0.62	−2.86
Interval	113.00	2755.14	2.00	2.00	10.00	2.00	1.00
Minimum	37.00	1369.86	0.00	1.00	0.00	0.00	0.00
Maximum	150.00	4125.00	2.00	3.00	10.00	2.00	1.00

Through the application of the multiple regression model with no known term, the function that describes the unit price is the following:

$$V_u = 442.63 \cdot P_1 + 44.45 \cdot P_2 + 69.54 \cdot P_3 + 630.41 \cdot P_4 + 891.37 \cdot P_5$$

The statistical-estimative tests performed on the model have provided values that validate the deriving results (see Table 6); in particular, the coefficient of determination R^2, equal to 0.961, and the adjusted coefficient of determination $R^2{}_{adj}$, equal to 0.937, are both higher than the limit value of 0.90 suggested in the estimative doctrine.

Table 6. Test of the multiple regression model.

Index or Test	*Value*	*Result*
R^2	0.961	***Verified***
$R^2{}_{adj}$	0.937	***Verified***
s^2	524.18	***Admitted***
t_1	3.519	***Verified***
t_2	0.339	***Admitted***
t_3	2.409	***Verified***
t_4	4.528	***Verified***
t_5	4.117	***Verified***

The estimation function so obtained and validated was then used to estimate the unit market value of the real estates of future realization, distinguished for each thematic area and intended use.

Considering the typologies of transformation of the areas, and the intention of providing a significant increase in their value, a higher score of environmental quality P_1, in comparison with those in the sample, was assigned to all the target estates: in particular, a variable score between 3 and 4 (instead of 0-1-2) is assigned to the sub-area 3A, located in proximity of the sea, and to the area 1, characterized by a wide presence of green areas, placed in the Urban Park.

For what concerns infrastructural quality, considering the railway lines indicated in the plan, a P_2 score equal to the maximum present in the estimative sample is assigned for all thematic areas, that is to say 3. Assuming, then, as a reference, an average number of six floor levels for each building, an average P_3 score of 3 is attributed—i.e., the average floor level for an apartment located in a 6-storey building—to the floor level characteristic for all the thematic areas, with the exception of the tower buildings of the sub-area 3G, to which an average value of 8 is attributed (as there is a height of 15 floors for them). The state of conservation has, for all the thematic areas, a P_4 score of 2, as it concerns newly built properties or, in the case of pre-existing buildings, properties subjected to total renovation. Even if they are new buildings, an elevator is assumed for all buildings, hence with a P_5 score of 1.

After attributing the scores associated to each of the explanatory variables as detailed, the unit market values for the residential sector have been calculated for each of the thematic areas of the plan.

Table 7 reports the scores attributed to the property characteristics for each thematic area, and the unit market values provided by the multiple regression model (MRA).

Table 7. Scores attributed to each characteristic for the different thematic areas and results of the MRA.

Thematic Area	P_1	P_2	P_3	P_4	P_5	V_u (€/m^2)
1	4	3	3	2	1	€ 4672.81
2	3	3	3	2	1	€ 4187.82
3A	4	3	3	2	1	€ 4672.81
3G	3	3	3	2	1	€ 4187.82
3G-Towers	3	3	8	2	1	€ 4568.80
4	3	3	3	2	1	€ 4187.82

For the extra-residential sectors, that is to say for the estates destined to social housing, to the tertiary and hospitality sector, the unit market values were determined through the application of opportune destination's value ratios π_i elaborated according to the data sourced by the National Observatory on Real Estate Values (OMI) of the Italian Revenue Agency [43].

Through the applications of the destination ratios reported in Table 8 to the unit market values of the residential sector outlined in Table 7, the unit market values for properties belonging to other market shares were obtained (see Table 9).

Table 8. Elaboration of the destination's value ratios sourced by the O.M.I. Italian Revenue Agency [43].

Market Segment	V_{umin} (€/m^2)	V_{umax} (€/m^2)	V_{umean} (€/m^2)	Destination's Value Ratio (π_i)
Residential	2050	3100	2575	-
Social housing	1450	2200	1825	0.71
Tertiary/Hospitality	2000	3000	2500	0.97
Car box	1500	2300	1900	0.74
Commercial	1750	3500	2625	1.02

Table 9. Unit market values for social housing, tertiary and hospitality sector.

Thematic Area	$V_{u,res}$ (€/m^2)	$V_{u,sh}$ (€/m^2)	$V_{u,ter}$ (€/m^2)	$V_{u,hos}$ (€/m^2)	$V_{u,box}$ (€/m^2)
	Residential	Social Housing	Tertiary/Hospitality	Commercial	Car Box
1	€ 4672.81	€ 3317.70	€ 4532.63	€ 4766.27	€ 3457.88
2	€ 4187.82	€ 2973.35	€ 4062.19	€ 4271.58	€ 3098.99
3A	€ 4672.81	€ 3317.70	€ 4532.63	€ 4766.27	€ 3457.88
3G	€ 4187.82	€ 2973.35	€ 4062.19	€ 4271.58	€ 3098.99
3G-Towers	€ 4568.80	€ 3243.85	€ 4431.74	€ 4660.18	€ 3380.91
4	€ 4187.82	€ 2973.35	€ 4062.19	€ 4271.58	€ 3098.99

Table 10 summarizes the gross surfaces of the building products of new construction, calculated as the ratio between the building volumes indicated in the PUE and the corresponding ordinary floor height (namely 3 mt and 4 mt, respectively for the residential sectors and for all the other intended uses), to be realized in the various thematic areas and distinguished according to the intended use.

Table 10. New buildings achievable in each thematic area.

Thematic Area	*Residential*	*Social Housing*	*Tertiary*	*Hospitality*	*Car Box*
	m²	*m²*	*m²*	*m²*	*m²*
1	-	-	-	-	-
2	*51,542.00*	-	*22,784.50*	*38,443.00*	*39,953.60*
3A	*36,666.67*	-	*4750.00*	-	*12,900.00*
3G	-	*7833.33*	*11,250.00*	-	*6850.00*
3G-Towers	*48,833.33*	-	-	-	*14,650.00*
4	-	-	*41,250.00*	-	*16,500.00*

5.2. Appraisal of the Transformation Costs of the Areas

The unit parametric costs of urbanization and building production are developed on the basis of the Price List of Building Types published by DEI—Tipografia del Genio Civile [44].

The determination of the total technical construction cost of urbanizations and urban surfaces of common interest, referring to the specific territorial context of Naples and at the time of estimation, is detailed in Table 11.

Table 11. Technical construction cost of urbanizations and common areas.

Thematic Area	*Primary Urbanizations*	*Green Areas*	*Parking Lots*	*Beach*	*Total*
	K_u (€)	***K_u (€)***	***K_u (€)***	***K_u (€)***	***K_u (€)***
1	*€ 1,814,788.80*	*€ 27,317,877.94*	*€ 2,377,881.11*	*€ 1,720,731.20*	*€ 33,231,279.05*
2	*€ 614,095.20*	*€ 2,606,593.53*	*€ 622,273.75*	-	*€ 3,842,962.48*
3	*€ 1,917,036.11*	*€ 2,606,593.53*	*€ 598,474.35*	*€ 1,215,261*	*€ 5,122,103.99*
4	*€ 119,152.80*	*€ 1,449,730.59*	*€ 538,056.25*	*€ 373,926*	*€ 2,106,939.64*
		TOTALE			***€ 44,303,285.16***

In addition to the total technical cost, determined as above in € 44,303,285.16 (Q_1), safety expenses (as the 2% of the technical construction cost), and the VAT tax (equal to 10%) on the summation of technical cost and safety expenses have to be considered. Concession costs and tributes have been assumed as the 3% (Q_3) of the technical construction cost. The costs related to the professional activities (Q_2) needed to perform the interventions of urban transformation have been estimated according to the available framework. Concerning the passive interests (Q_4) for capital credits, considering the time horizon of the transformation (12 years), their entity is obtained applying the following formula, after adapting the costs according to the revaluation indexes described in the following:

$$Q_4 = \sum_{t=1}^{n} t \cdot \frac{Q_1 + Q_2 + Q_3}{n} \cdot i$$

where:

- n is the duration, expressed in years, of the transformation action;
- t indicates a generic year located between the beginning and the end of the transformation;
- Q_1 is the technical construction cost, including safety expenses and VAT tax;
- Q_2 is the total expense for professional activities;
- Q_3 is the amount of the expense for concession costs and tributes;
- i is the interest rate.

The interest rate has been evaluated as 4.95%, as indicated in the document related to the Global Effective Average Rates provided by the Bank of Italy for the fourth trimester of 2015 [45].

The quota (Q_5) of legal expenses, marketing and commercialization and miscellaneous expenses can be totally evaluated as the 4% of the summation of Q_1, Q_2, Q_3 e Q_4, while the quota (Q_6) related to the entrepreneur-transformer's gross income has been calculated as an average 20% of the sale value of the future building products [46]. Since urbanizations and common areas do not have a sale value, their Q_6 component has been considered as zero. The summation of all the above detailed Q_i components leads to the total transformation value Q_7.

The determination of the total transformation cost of urbanizations and common areas through the integration of the described shares and additions is reported in Table 12.

Table 12. Overview of the total transformation cost of urbanizations and common areas.

Cost Item	*Amount*
Total technical cost	*€ 44,303,285.16*
Safety expenses	*€ 886,065.70*
VAT tax	*€ 4,518,935.09*
Q_1—Total	*€ 49,708,285.95*
Design and works management	*€ 1,571,290.88*
Testing	*€ 83,844.85*
Gelogical surveys	*€ 210,449.47*
Safety Supervisors and Coordinator	*€ 738,506.71*
Expenses for land registry and survey	*€ 189,000.00*
Q_2—Total (VAT and SI included)	*€ 2,793,091.91*
Q_3—Expenses for concession and urbanization, tributes, etc.	*€ 1,739,790.01*
Q_4—Passive interests for capital credits	*€ 13,493,490.58*
Q_5—Legal expenses, marketing and commercialization, miscellaneous expenses, etc.	-
Q_6—Enerpreneur-transformer's Gross Income	-
Q_7—Total Transformation Cost	*€ 67,734,658.45*

Likewise, Table 13 reports the overview of the technical construction cost for each typology of real estate, distinguished for each thematic area.

Table 13. Technical construction cost of the building products.

Thematic Area	*Residential*	*Social Housing*	*Hospitality*	*Tertiary*	*Car Box*	*Total*
	K_c (€)	*K_c (€)*	*K_c (€)*	*K_c (€)*	*K_c (€)*	*K_c (€)*
2	*€ 70,788,066.28*	-	*€ 52,797,827.64*	*€ 28,083,878.50*	*€ 23,259,008.22*	***€ 174,928,780.64***
3A	*€ 50,358,206.24*	-	-	*€ 5,854,788.25*	*€ 7,509,741.45*	***€ 63,722,735.94***
3G	*€ 47,929,083.23*	*€ 6,964,355.20*	-	*€ 13,866,603.75*	*€ 12,516,235.75*	***€ 81,276,277.93***
4	-	-	-	*€ 50,844,213.75*	*€ 9,605,483.25*	***€ 60,449,697.00***
			TOTAL			***€ 380,377,491.51***

Concerning the building products, differently from urbanizations and common areas, the cost evaluation of surveys and land registry operations required to elaborate a likely number of real estate units (n. 6,926, dividing the total property area by the average surface of a single unit type, assumed to be 25.00 m^2 for car boxes and 80.00 m^2 for houses and other intended uses).

The evaluation of the total construction cost of the finished building products in detailed in Table 14. It has to be underlined that, in this case as well, the construction costs that appear in the elaborations are subjected to financial operations of revaluation and/or devaluation, while the passive interests are only subjected to the operation of financial discounting.

Table 14. Summary of the total transformation cost of the building products.

Cost Item	*Importo*
Total technical cost	*€ 380,377,491.51*
Safety expenses	*€ 7,607,549.83*
VAT tax	*€ 85,356,709.09*
Q_1—Total	*€ 473,341,750.43*
Design and works management	*€ 16,383,079.18*
Testing	*€ 936,025.32*
Structural design	*€ 2,923,130.42*
Gelogical surveys	*€ 1,806,869.16*
Safety Supervisors and Coordinator	*€ 7,700,047.21*
Expenses for land registry and survey	*€ 1,411,905.60*
Q_2—Total (VAT and SI included)	*€ 31,161,056.89*
Q_3—Expenses for concession and urbanization, tributes, etc.	*€ 16,566,961.27*
Q_4—Passive interests for capital credits	*€ 179,116,385.89*
Q_5—Legal expenses, marketing and commercialization, miscellaneous expenses, etc.	*€ 20,842,790.74*
Q_6—Enerpreneur-transformer's Gross Income	*€ 254,697,313.21*
Q_7—Total Transformation Cost	*€ 975,726,258.43*

5.3. Revaluation Indexes of Real Estate Values and of Building Production Costs (ARIMA Model)

The forecast of future revaluation indexes of property values and construction costs requires the obtainment of a wide population of initial data, which are necessary for the application of the autoregressive model *ARIMA*.

So, referring to the time period 1970–2015 the following data have been found:

- for property values, the average property values for the semi-central area of Naples, provided by the National Observatory on Real Estate Values to the specialized periodical "Il Consulente Immobiliare" published by Il Sole 24 Ore and by the National Observatory on Real Estate Values of the Italian Revenue Agency, have been elaborated [43,47];
- for construction costs, the ISTAT indexes of the construction cost of a residential building have been adopted [48].

In Table 15, revaluation/devaluation indexes of property values and construction costs over the period 1970–2015 are reported.

Table 15. Variation indexes of property values and construction costs for the residential sector (1970–2015).

Year	*Variation of Property Values*	*Variation of Building Production Costs*
1970	*+2%*	*+5%*
1971	*+2%*	*+5%*
1972	*+14%*	*+22%*
1973	*+39%*	*+28%*
1975	*+28%*	*+18%*
1976	*+13%*	*+20%*
1977	*+11%*	*+20%*
1978	*+25%*	*+14%*
1979	*+20%*	*+19%*
1980	*+42%*	*+25%*
1981	*+29%*	*+23%*
1982	*+18%*	*+17%*
1983	*+15%*	*+14%*
1984	*+7%*	*+9%*
1985	*+6%*	*+9%*
1986	*+3%*	*+4%*
1987	*+3%*	*+4%*
1988	*+6%*	*+6%*
1989	*+5%*	*+6%*
1990	*+33%*	*+11%*
1991	*+25%*	*+8%*
1992	*+3%*	*+5%*

Table 15. *Cont.*

Year	*Variation of Property Values*	*Variation of Building Production Costs*
1993	*+2.9%*	*+3%*
1994	*+1.4%*	*+4%*
1995	*+1.4%*	*+2%*
1996	*+12.5%*	*+2%*
1997	*+11.1%*	*+2%*
1998	*+3.3%*	*−1%*
1999	*+3.2%*	*+2%*
2000	*−2.1%*	*+3%*
2001	*−2.1%*	*+2%*
2002	*+13.7%*	*+3.9%*
2003	*+29.6%*	*+3.0%*
2004	*+8.6%*	*+4.2%*
2005	*+31.6%*	*+3.9%*
2006	*−8%*	*+2.8%*
2007	*+19.6%*	*+3.6%*
2008	*+0%*	*+3.8%*
2009	*−1.8%*	*+0.9%*
2010	*+3.7%*	*+1.5%*
2011	*+3.6%*	*+3.0%*
2012	*−3.4%*	*+2.3%*
2013	*−5.4%*	*+0.7%*
2014	*+0%*	*−0.2%*
2015	*−3.8%*	*+0.5%*

The autoregressive model *ARIMA* implemented for the determination of the revaluation indexes of property values has a (1,1,1) order: the differencing order is 1 as the series does not result to be stationary. For the revaluation of building production cost, a (1,0,1) model has been selected, as the series is stationary and does not require differentiation. The implementation of the methodology has been realized with the software Microsoft Excel, combined with the plug-in Real Statistics Resource Pack software (Release 6.8) by Charles Zaiontz copyright (2013–2020) [49], which provided the results detailed in Table 16 for the years between the start of the transformation, namely in 2016, until the end of the sale of the building products, expected to be in 2030.

Table 16. Forecast of revaluation indexes of property values and building production (2016–2030).

Year	*Variation of Property Values*	*Variation of Building Production Cost*	*Income Revaluation Indexes*	*Cost Revaluation Indexes*
2016	*1.21%*	*1.52%*	*1.0121*	*1.0152*
2017	*1.42%*	*1.89%*	*1.0265*	*1.0344*
2018	*1.58%*	*1.85%*	*1.0427*	*1.0535*
2019	*1.69%*	*1.81%*	*1.0603*	*1.0726*
2020	*1.76%*	*1.77%*	*1.0790*	*1.0916*
2021	*1.80%*	*1.74%*	*1.0984*	*1.1106*
2022	*1.83%*	*1.70%*	*1.1185*	*1.1295*
2023	*1.84%*	*1.67%*	*1.1391*	*1.1484*
2024	*1.84%*	*1.64%*	*1.1601*	*1.1672*
2025	*1.83%*	*1.61%*	*1.1813*	*1.1860*
2026	*1.81%*	*1.58%*	*1.2027*	*1.2047*
2027	*1.79%*	*1.55%*	*1.2242*	*1.2234*
2028	*1.77%*	*1.52%*	*1.2459*	*1.2420*
2029	*1.75%*	*1.49%*	*1.2677*	*1.2605*
2030	*1.73%*	*1.47%*	*1.2896*	*1.2790*

The indexes reported in Table 16 allow to adjust costs and incomes to the different times of transformation of the areas and sale of the building products, respectively, according to the timetable set as a reference.

5.4. Appraisal of Industrial Archeology and Pre-Existing Buildings

The Transformation Value method has been applied to the pre-existing artifacts of industrial archeology if an intended use was individuated for theme in in the "Coroglio-Bagnoli" Executive Urban Plan; on the other hand, the pre-existing buildings without a specific future use have been estimated according to the subrogation value, through the depreciation cost approach. The synopsis reported in Table 17 summarizes the results of the estimations performed for each of the pre-existing buildings in the abandoned industrial areas, with the indication of the valuation method employed.

Table 17. Summary of market values of the artifacts of industrial archaeology and other pre-existing buildings.

Existing Building	*Evaluation Method*	*Estimated Value (15 October 2015)*
Steel mill	*Transformation Value*	*€ 17,963,684.30*
Blast furnace 4	*Transformation Value*	*−€ 6,829,316.61*
Applevage	*Transformation Value*	*−€ 350,123.84*
Blast furnace candle	*Transformation Value*	*−€ 66,380.12*
Coke candle	*Transformation Value*	*−€ 66,380.12*
Thermal power plant	*Transformation Value*	*€ 9,543,613.75*
AGL chimney	*Transformation Value*	*−€ 833,875.34*
Refloating tank	*Transformation Value*	*€ 123,517.86*
Slaking tower	*Transformation Value*	*€ 1,366,033.55*
Morgan warehouse	*Transformation Value*	*−€ 144,531.93*
Telex transformer	*Transformation Value*	*€ 4,414,222.60*
Mechanical workshop	*Transformation Value*	*€ 2,081,399.94*
Office building	*Transformation Value*	*€ 1,554,799.87*
Turtle Point	*Depreciation cost approach*	*€ 358,461.77*
North Pier	*Depreciation cost approach*	*€ 18,020,504.34*
Park Gate	*Depreciation cost approach*	*€ 33,528,388.42*
Sport Park	*Depreciation cost approach*	*€ 71,791,065.47*
TOTAL		***€ 152,455,083.91***

5.5. Contamination State of Abandoned Industrial Soils and Appraisal of Remediation Costs

Since the closure of productive activities, only partial remediation and environmental remediation activities have been carried out on the studied site. Italian legislation on contaminated sites has changed over time, passing from a tabular remediation approach regulated by the Ministerial Decree 471/99 [50] to an approach based on a site-specific environmental health risk analysis (Legislative Decree 152/06) [51].

The studied area has a total area of 2,479,000 m^2, of which 1,780,185 m^2 are subjected to characterization, and will be interested by remediation activities. Environmental matrices show a contamination caused by various polluting agents determined by transportations (spillage, dust, and emissions), urban development, manufacturing activities, metal working and by the previous steel and chemical activity. These inorganic (heavy metals and asbestos) and organic (heavy hydrocarbons and PAHs) pollutants have been found in soil, groundwater and in the sea.

In order to estimate site remediation costs, two areas have been identified: the ex-Eternit area (155,847 m^2) and the ex-Ilva area (1,624,363 m^2). For each area, a Characterization Plan and the Risk Analysis are available [41].

Treatment costs for the technologies were identified through market surveys and were divided according to the numerical difference between the maximum concentration of pollutants in the soil and the objective of remediation for each Thiessen polygon in which the area was divided.

The remediation objectives reported in Tables 18 and 19 have been defined based on characterization plans and on the risk analysis.

Table 18. Remediation objectives in the residential area—ex-Eternit area.

Residential Area				
Source		***Polygon***	***Compounds***	***Remediation Objective (mg/kg)***
Superficial soil	*ZR_ Met SS_1*	*ETE 11*	*ARSENIC*	*29*
	ZR_ Met SS_2	*ETE 58*	*LEAD*	*103*
	ZR_ Org SS_1	*ETE 47P*	*HEAVY HCs*	*50*
	ZR_ Org SS_2	*ETE 51D*	*HEAVY HCs*	*50*
Deep soil	*ZR_ Org SP_1*	*ETE 51D*	*HEAVY HCs*	*50*

Table 19. Remediation objectives in the commercial area—ex-Eternit area.

Commercial Area				
Source		***Polygon***	***Compounds***	***Remediation Objectives (mg/kg)***
Superficial Soil	*ZC_ Met SS_1*	*ETE 83*	*ARSENIC*	*50*
	ZC_ Org SS_1	*ETE 64D*	*HEAVY HCs*	*750*
	ZC_ Org SS_2	*ETE 69G*	*HEAVY HCs*	*750*
Deep Soil	*ZC_ Org SP_1*	*ETE 69G*	*HEAVY HCs*	*750*

According to the intended use defined for the areas, remediation targets change as exposure times and targets change (the legislation considers a commercial and industrial use, and a private, residential and public green use; see Title V, part IV, Legislative Decree 152/06 and its annexes [51]). So, this choice leads to higher remediation costs for residential uses, than for commercial uses. It can be noted that the ex-Ilva area is almost completely destined to residential use (residential use: 1,565,646 m^2 in the ex-Ilva area and 59,335 m^2 in the ex-Eternit area; commercial use: 58,717 m^2 in the Ex-Ilva area and 58,717 m^2 in the ex-Eternit area).

Following a completeness check of the characterization and of specific risk analysis of the soil matrix, based on the data from the Risk Analysis, the soil remediation costs were estimated for the two areas (ex-Eternit and ex-Ilva):

- the Thiessen polygons corresponding to the surveys where the concentration(s) of the pollutant(s) resulted higher than risk threshold concentrations or CSR (remediation objectives) were individuated;
- the areas of these polygons was measured;
- according to the contamination depth reported in the annexes of the Risk Analysis, the contaminated material volumes to clean up were calculated;
- those volumes were multiplied by the soil density (1,70 t/m^3): multiplying volume by density, the mass [t] of the soil to clean-up was obtained;
- the remediation techniques were individuated (biopile and soil washing);
- the previously calculated masses were multiplied by the unitary costs of the treatments (in €/t);
- eventually, the partial results were summed.

Table 20 reports the obtained results in terms of volume and mass for the ex-Eternit area.

Table 20. Contaminated volumes and masses in the ex-Eternit area.

Pollutants Residential Area	***Volume (m^3)***	***Mass (t)***
Hydrocarbons	*549*	*933*
Lead	*8245*	*14,017*
Arsenic	*6149*	*10,453*
Pollutants Commercial Area	***Volume (m^3)***	***Mass (t)***
Arsenic	*6099*	*10,368*
Hydrocarbons	*2274*	*3867*
Total	***23,316***	***39,638***
Residential	*14,943*	*25,403*
Commercial	*8373*	*14,235*

In Tables 21 and 22, the obtained results are expresses in terms of volume and mass, respectively for superficial and deep soil (ex-Ilva area).

Table 21. Contaminated volumes and masses in the ex-Ilva area (SS).

Superficial Soil (SS)		
Pollutant	***Volume (m^3)***	***Mass (t)***
Mercury	*26,594*	*45,210*
PCBs	*52,794*	*89,750*
Residential Area	*40,820*	*69,394*
Commercial Area	*11,974*	*20,356*
PAHS	*234,496*	*398,643*
Heavy HCs	*111,398*	*189,377*
Soils with More than One Pollutant		
PAHs and Heavy HCs	*206,933*	*351,786*
PAHs and PCBs	*73,493*	*124,938*
PAHs and Mercury	*3863*	*6567*
Heavy HCs and Mercury	*2353*	*4000*
PAHs, Heavy HCS and Mercury	*41,821*	*71,096*
PAHs, Heavy HCs and Chrome	*5248*	*8922*
PAHs, Heavy HCs, Light HCs and Mercury	*4051*	*6887*
Total	***763,044***	***1,297,175***

Table 22. Contaminated volumes and masses in the ex-Ilva area (DS).

Deep Soil (DS)		
Pollutant	***Volume (m^3)***	***Mass (t)***
Mercurio	*65,074*	*110,626*
Cromo	*41,773*	*71,014*
PCB	*69,742*	*118,561*
IPA	*236,791*	*402,545*
HC Heavy	*124,382*	*211,449*
Soils with More than One Pollutant		
PAHs and Heavy HCs	*202,380*	*344,046*
PAHs and Chrome	*30,154*	*51,262*
PAHs and Mercury	*66,358*	*112,809*
PAHs and PCBs	*19,996*	*33,993*
Heavy HCs and Mercury	*5954*	*10,122*
PAHs, Heavy HCs and Mercury	*45,268*	*76,956*
Total	***907,872***	***1,543,383***

The volumes are divided according to the type of pollutant because the treatment that leads to better results, among those used for the removal of contaminants from the matrix will be established based on that.

Table 23 shows the total volumes to be cleaned up for the ex-Eternit Area and for the ex-Ilva/ex-Italsider area, for which the contributions of surface soils (SS) and deep soils (DP) are summed.

Table 23. Total contaminated volumes and masses.

Areas	***Total Volumes (m^3)***	***Total Masses (t)***
ex-Eternit	*23,316*	*39,638*
ex-Ilva (Total SS and DP)	*1,670,916*	*2,840,558*
Total	***1,694,232***	***2,880,196***

The following technologies were considered to estimate remediation costs:

- Soil washing: ex situ treatment that consists in soil excavation and treatment with wet physico-chemical technologies; in this way, the pollutant is concentrated in the fine fraction, and must be properly disposes; the residual solid fraction can be replaced on the spot. Using a suitable system, wash water is recovered and then reused.
- Biopile: ex-situ biological treatment which provides for the formation of piles, to which nutrients and soil improvers are opportunely added in order to favor biological decay processess by autochtonous bacteria. These processes lead to the degradation of organic contamination. The treated fraction can be replaced on the spot.

The unit soil remediation costs corresponding to the two technologies detailed above, obtained from market surveys, are reported in Table 24.

Table 24. Unit environmental remediation costs.

Pollutant to Be Treated	*Remediation Technology*	*Unit Cost (€/t)*	*Applicability Field*
Metals, PCBs and All Their Combinations	*Soil Washing*	*25*	*Δ < 5·CSR*
		40	*5·CSR < Δ < 10·CSR*
		50	*Δ > 10·CSR*
Single PAHs	*Bio Pile*	*25*	*Δ <10·CSR*
	Soil Washing	*40*	*10·CSR < Δ < 20·CSR*
		50	*Δ >20·CSR*
HCs and HCs + PAHs Combinations	*Bio Pile*	*25*	*Δ <10·CSR*
	Soil Washing	*50*	*Δ >10·CSR*

Unit treatment costs depend on the difference between the concentration found in the soils (Contaminating Substances Concentration or CSC) and the Remediation Objective (CSR). The higher is the Δ = (CSC − CSR), the higher are remediation costs.

The expression "and all their combinations", reported in the first column in Table 24, also includes the simultaneous presence of HCs and PAHs with other pollutants. So, where soil contamination is caused by two or more pollutants, excluding the combination HCs + PAHs, the technology to apply is soil washing.

The cases where the soil matrix is contemporarily contaminated by HCs and PAHs require particular consideration, as in these cases it is necessary to perform laboratory tests on the real effectiveness of this method.

Summing up the residual remediation costs of the two areas reported in the corresponding annexes, the results are the following:

- Ex-Eternit area: 1,201,171 €;
- Ex-Ilva: 103,473,424 €.

The sum of the two values provides the estimation of residual remediation of the soil matrix, with a total of 104,674,595 €. Additional costs for the disposal of cement-asbestos materials (MCA, materials with cement and asbestos), present on a surface of 112,138 m^2, must be summed to this value. This area was divided in sub-areas "in progress" (55,793 m^2) and sub-areas "to be remediated" (56,345 m^2).

The volume to be disposed was obtained considering a 0.8 m soil thickness; finally, the mass to be disposed was calculated assuming a soil density of 1.7 t/m^3 (75,878.40 tons for the areas "in progress" and 76,629.20 tons for the areas to be remediated).

Concerning MCA disposal costs, they were attributed CER 170503 code (soils and rocks containing hazardous substances). MCA disposal operators have provided a cost of 230 €/t for the disposal, added to a cost of 54 €/t for transportation.

Hence, the total MCA disposal cost in the ex-Eternit area is equal to 43,246,821 €.

Finally, the total remediation cost of the abandoned industrial areas of Bagnoli is 147,921,416 €.

5.6. Appraisal of Abandoned Industrial Areas

The results of the aforementioned (partial) estimations performed are reported here:

- Total market value of the building products of future realization, equal to 1,273,486,566.05 €;
- Total cost of urbanization works and realization of common areas, equal to 54,241,167.87 €;
- Total construction cost of the building products of future realization, equal to 796,609,872.54 €;
- Total passive interests related to the financing for the enactment of the transformation plan, equal to 238,629,288.78 €;
- Total market value of the pre-existing buildings, equal to 152,455,083.91 €;
- Total environmental remediation costs, equal to 147,921,416.00 €.

On the basis of the revaluation indexes of property values and building production costs detailed in Tables 15 and 16, following the time line chart of interventions reported in Table 5, it is possible to perform the Transformation Value method. The term V_{PRE} coincides with the value of 152,455,083.91 € related to the pre-existing buildings, K_{BON} is equal to 147,921,416.00 € as of the estimation of the environmental remediation costs.

In Table 25 the transformation costs of the areas, the revaluated costs, the revaluation coefficients employed and the accrued passive interests, are reported for every year in the transformation period.

Table 25. Synopsis of the annual transformation costs for the period 2016–2030.

Description	*Urbanization Costs*	*Building Production Costs*	*Passive Interests*
2015 Value	*€ 54,241,167.87*	*€ 796,609,872.54*	-
2016	-	-	-
2017	-	-	-
2018	-	-	-
2019	*€ 7,272,384.58*	-	*€ 359,983.04*
2020	*€ 7,401,207.36*	*€ 96,610,264.33*	*€ 5,508,550.88*
2021	*€ 7,530,030.13*	*€ 98,291,828.11*	*€ 10,746,732.87*
2022	*€ 7,658,174.89*	*€ 99,964,541.55*	*€ 16,074,057.33*
2023	*€ 7,786,319.65*	*€ 101,637,254.99*	*€ 21,490,524.27*
2024	*€ 7,913,786.39*	*€ 103,301,118.10*	*€ 26,995,662.05*
2025	*€ 8,041,253.14*	*€ 104,964,981.21*	*€ 32,589,470.65*
2026	*€ 8,168,041.87*	*€ 106,619,993.98*	*€ 38,271,478.42*
2027	-	*€ 108,275,006.76*	*€ 40,573,416.96*
2028	-	*€ 110,020,108.14*	*€ 46,019,412.31*
2029	-	-	-
2030	-	-	-

Table 26 illustrates the results of the time collocation of incomes, distinguished for every year in the reference period of the estimate (2016–2030), and performed using the property revaluation indexes in Tables 16 and 17.

Table 26. Synopsis of yearly incomes for the period 2016–2030.

Description	*Income from Building Products*
2015 Value	*€ 1,273,486,566.05*
2016	-
2017	-
2018	-
2019	-
2020	-
2021	-
2022	*€ 158,250,253.85*

Table 26. *Cont.*

Description	*Income from Building Products*
2023	*€ 161,164,831.61*
2024	*€ 164,136,003.12*
2025	*€ 167,135,471.50*
2026	*€ 170,163,236.75*
2027	*€ 173,205,150.44*
2028	*€ 176,275,360.99*
2029	*€ 179,359,719.99*
2030	*€ 182,622,456.24*

The next methodological step has been that of converting the single amounts in Tables 25 and 26 in cash flows using a discount rate assumed as 4.95% (see above). Cash flows have then been elaborated, and are reported in Table 27.

Table 27. Determinatio of the cash flows related to the transformation intervention.

Description	*Cash Flows*	*Discount Coefficient*	*Cash Flows Referred to 2015*
2015 Value	-	*1.0000*	-
2016	-	*0.9528*	-
2017	-	*0.9079*	-
2018	-	*0.8651*	-
2019	*−€ 7,632,367.62*	*0.8243*	*−€ 6,291,360.63*
2020	*−€ 109,520,022.57*	*0.7854*	*−€ 86,017,025.73*
2021	*−€ 116,568,591.11*	*0.7484*	*−€ 87,239,933.59*
2022	*€ 34,553,480.08*	*0.7131*	*€ 24,640,086.65*
2023	*€ 30,250,732.70*	*0.6794*	*€ 20,552,347.80*
2024	*€ 25,925,436.58*	*0.6474*	*€ 16,784,127.64*
2025	*€ 21,539,766.50*	*0.6168*	*€ 13,285,727.98*
2026	*€ 17,103,722.48*	*0.5878*	*€ 10,053,568.07*
2027	*€ 24,356,726.72*	*0.5600*	*€ 13,639,766.96*
2028	*€ 20,235,840.54*	*0.5336*	*€ 10,797,844.51*
2029	*€ 179,359,719.99*	*0.5084*	*€ 91,186,481.64*
2030	*€ 182,622,456.24*	*0.4845*	*€ 88,480,580.05*

Considering the cash flows detailed above, the value of € 152,455,083.91 related to the pre-existing buildings, and the amount of € 147,921,416, namely the total amount of the environmental remediation costs, the application of the transformation value method leads to a value of € 114,405,879.26, which constitutes the market value of the abandoned industrial areas:

$$V_{\text{areas}} = [(109{,}872{,}211.35\text{ €} + 152{,}455{,}083.91\text{ €}) - 147{,}921{,}416.00\text{ €}]$$

$$V_{\text{areas}} = 114{,}405{,}879.26\text{ €}$$

The above value corresponds, in unit terms of territorial surface, to €/sqm 60.81 (114,405,879.26 €/1,881,420.00 sqm).

It must be noted that this value of 114,405,879.26 € corresponds to the value that the examined areas assume following the detraction of the total remediation costs needed to make the soils apt to be transformed according to the uses provided for by the plan.

That being said, in order to evaluate the so-called "irreversible" damage to the abandoned industrial areas (i.e., the component of the refundable damage which is independent from the remediation of the areas) it is necessary to proceed, as anticipated, to the implementation of the Ellwood model. Table 28 summarizes the estimative input needed to implement the model; some inputs are expresses as a percentage of the unit market value of the building products (V_m).

Table 28. Estimative input employed for the implementation of Ellwood's model.

***Ca* (€/m^2)**	***€ 77.69***
C_c (€/m^2)	*€ 2,533.50*
V_m (€/m^2)	*€ 4,154.78*
C_{sfin} (%)	*5.00%*
$C_{redditi}$ (%)	*21.00%*
S_{qr} (%)	*0.50%*
S_{mas} (%)	*4.00%*
C_{IMU} (%)	*1.00%*
S_{comm} (%)	*2.00%*
S_{trasf} (%)	*3.00%*
S_{not} (%)	*1.00%*
r_v (%)	*1.71%*
σ	*0.17%*
r_i (%)	*4.95%*
u	*1.00170*
d	*0.99830*

Here: c_a is the unit annual rent payment; c_c is the total unit transformation cost of the finished building product; V_m is the unit market value of the finished building products; c_{sfin} represents the losses for vacancy and write-off; $c_{redditi}$ is the Personal Income Tax (IRPEF); s_{qr} is the annual make-up quota; s_{mas} is the expense for maintenance, administration and insurance; c_{IMU} is the Single Municipal Tax (IMU); s_{comm} is the expense for the commercialization of the property; s_{trasf} is the tax on property transfer; s_{not} is the notary fee; r_p is the property revaluation rate; σ is the standard deviation of the revaluation rate; r_d is the financial discount rate; u and d represent the terms concerning the evolution of the initial state towards a, respectively, favorable or unfavorable scenario.

The term m (availability period of the property) is determined by calculating $d^n VA'$ for subsequent years, until a decreasing *trend* occurs (Real Options Method). According to the iterative calculations performed, the 44th year reports a lower value, compared to the previous year, so the term m, corresponding to the availability period of the property, is equal to 44 years.

The evaluation of *ca*, the average annual rent payment, has been performed through an elaboration of the market values and rent payments provided by the database of the National Observatory on Real Estate Values of the Italian Revenue Agency for the macro-area of Bagnoli [43].

The amount of the weighted average annual rent payment (77.69 €/m^2/year) has been preliminarily depurated of all the expenses ordinarily sustained for the property management (27%), and is referred to the gross property surface (coherently with the unit market value of the building products). Likewise, through a weighted average referred to the property surfaces of the PUE, the average unit construction cost (2,533.50 €/m^2) and the average unit market value (4,154.78 €/m^2) have been obtained.

The elaboration of the estimative inputs reported in Table 28 in the formula that constitutes Ellwood's model provides the following outputs:

- K = 2,427.69 €/m^2 = VA;
- VA′ = 1,931.87 €/m^2;
- r′c = 11.94%.

The capitalization rate as determined above (11.94%), multiplied by the average unit market value (4,154.78 €/m^2), provides an average annual rent payment R equal to 496.08 €/m^2.

Ellwood's model has then to be re-applied by leaving the initial estimative input unvaried, and adding the term "s_{BON}".

The term s_{BON} constitutes the percentage ratio of the remediation expenses, and is calculated as the arithmetical ratio between the environmental remediation costs (147,921,416 €) and the total surface of the building products (equal to the summation of the surface indicated in Table 10, equal to

292,680.38 m^2), then calculating the ratio between this term and the average unit market value of the building products (4,154.78 €/m^2); in detail:

$$s_{bon} = [(147{,}921{,}416\text{ €} / 292{,}680.38\text{ m}^2) / 4154.78\text{ €/m}^2]$$

$$s_{bon} = 12.16\%$$

Then, in order to define the probability to be associated to the risk related to the perception of the current level of environmental pollution and transform it into an adjusted cost, it has been chosen to adopt Bayes's principle or "principle of equal probability of the events", corollary of Bayes's theorem, according to which the knowledge of the probability of an event is enriched by previous observations, and if there are not enough, or not relevant, observations, it is possible to attribute, in the simplest "binary" case (absence or presence), a 50%.

Then, assuming a 50% probability for the event (absence/presence of future contamination events), the term s_{BON} must be halved (6.08%). Inputting this parameter in the equation of Ellwood's model, the result is:

$$r''_c = \frac{\left[(1 + s_{comm} + s_{BON}) + \frac{V_{cat}}{P} \cdot \left(s_{trasf} + s_{not}\right) - \frac{(1+r_v)^m}{(1+r_i)^m}\right]}{1 - c_{sfin} - 0.85 \cdot c_{redditi}} \cdot$$

$$\cdot \left[\frac{r_i \cdot (1 + r_i)^m}{(1 + r_i)^m - 1}\right] + \frac{\frac{2}{3} \cdot \left(s_{qr} + s_{mas}\right) + \frac{V_{cat}}{P} \cdot c_{IMU}}{1 - c_{sfin} - 0.85 \cdot c_{redditi}}$$

This formula provides a return rate r''_c of the investment equal to 12.39%.

Dividing the previously found value R (496.08 €/m^2) by the rate r''_c (12.39%), a unit market value of 4003.87 €/m^2 results (reduction of 150.91 €/m^2 from the initial value of 4,154.78 €/m^2, corresponding to about 3.63% of the weighted unit market value of the building products). This requires to quantify the total refundable damage in relation to the risk perceived by ordinary market operators, considering the value reduction (3.63%) as a proxy and then, applying one more time the transformation value "method" in order to obtain the "adjusted" value of the abandoned industrial areas related to the perceived risk. Compared to the previous application of the transformation value method, the cost calculation reported in Table 25 does not vary, while the evaluation of the incomes (see Table 29) has to be adjusted considering, in this case as well, a reduction of the market value of the building products by 3.63% as proxy of the irreversible damage, as shown in Table 29.

Table 29. Synopsis of the "adjusted" incomes for the period 2016–2030.

Description	*Income from Building Products*
2015 Value	*€ 1,227,259,003.70*
2016	-
2017	-
2018	-
2019	-
2020	-
2021	-
2022	*€ 152,505,769.64*
2023	*€ 155,314,548.23*
2024	*€ 158,177,866.21*
2025	*€ 161,068,453.88*
2026	*€ 163,986,311.26*
2027	*€ 166,917,803.48*
2028	*€ 169,876,565.39*
2029	*€ 172,848,962.15*
2030	*€ 175,993,261.08*

Hence, it is possible to recalculate the cash flows as in Table 30.

Table 30. Determination of the "adjusted" cash flows related to the transformation intervention.

Description	*Cash Flows*	*Discount Coefficient*	*Cash Flows Referred to 2015*
2015 Value	-	*1.0000*	-
2016	-	*0.9528*	-
2017	-	*0.9079*	-
2018	-	*0.8651*	-
2019	*−€ 7,632,367.62*	*0.8243*	*−€ 6,291,360.63*
2020	*−€ 109,520,022.57*	*0.7854*	*−€ 86,017,025.73*
2021	*−€ 116,568,591.11*	*0.7484*	*−€ 87,239,933.59*
2022	*€ 28,808,995.87*	*0.7131*	*€ 20,543,694.95*
2023	*€ 24,400,449.32*	*0.6794*	*€ 16,577,665.27*
2024	*€ 19,967,299.67*	*0.6474*	*€ 12,926,829.81*
2025	*€ 15,472,748.88*	*0.6168*	*€ 9,543,591.51*
2026	*€ 10,926,796.99*	*0.5878*	*€ 6,422,771.27*
2027	*€ 18,069,379.76*	*0.5600*	*€ 10,118,852.67*
2028	*€ 13,837,044.94*	*0.5336*	*€ 7,383,447.18*
2029	*€ 172,848,962.15*	*0.5084*	*€ 87,876,412.36*
2030	*€ 175,993,261.08*	*0.4845*	*€ 85,268,734.99*

Finally, considering the cash flows indicated in Table 30 (the total summation is 77,113,680.06 €), the value of 152,455,083.91 € related to the pre-existing buildings (see above) and the value of 147,921,416 € as the total environmental remediation cost (see above), the application of the transformation value method leads to a result of 81,647,347.97 € as the "adjusted" value of the industrial areas:

$$V_{areas} = [(77{,}113{,}680.06\text{ €} + 152{,}455{,}083.91\text{ €}) - 147{,}921{,}416\text{ €}]$$

$$V_{areas} = 81.647.347{,}97\text{ €}$$

So, as a consequence, the component of the refundable damage related to the so-called "irreversible" is equal to 32,758,531.29 €:

$$D_{irr.} = (114{,}405{,}879.26\text{ €} - 81{,}647{,}347.97\text{ €})$$

$$D_{irr.} = 32{,}758{,}531.29\text{ €}.$$

The damage as quantified above corresponds to a reduction in the market value of the abandoned steel mill area, equal to 28.63% approximately.

6. Conclusions

The role that the "brownfields" (a term the US Environmental Protection Agency—USEPA uses to indicate "an abandoned, unused or underused industrial or commercial area in which expansion or recovery is hampered by environmental pollution is evident" [52]) can take once reclaimed and properly valorized, may have strategic importance from a production and commercial point of view, as they can be transformed into income-generating activities or converted into service and/or public utility structures. Due to their particular characteristics and location, brownfields can play an important role for the local ecosystem, to be protected and preserved.

These are interventions often able to guarantee adequate levels of economic and financial sustainability, or in any case to generate economic benefits for the communities concerned: in these cases, the resources necessary for the interventions can also be obtained with the competition from external subjects, be they private, other public administrations (or instrumental bodies) or public/private combinations. Moreover, unlike the non-populated free areas ("greenfields"), the majority of polluted sites is often characterized by an adequate supply of infrastructure and services, offering significant advantages to new managers also in economic and financial terms.

The opportunity to create a double dividend (social and environmental or economic and environmental) conducts the setting of an integrated intervention strategy essentially involving a plurality of subjects and capitals both public and private. Verifying the existence of an adequate economic convenience from an investor's point of view, can in this perspective constitute a significant opportunity to deal with the work of environmental remediation, offering the possibility to assign—in whole or in part—the burden of operations to private companies, releasing the concession to use the refurbished areas (and any properties) for production purposes. An approach that, as already underlined, would have the obvious advantage of "multiplying" the public resources available while stimulating the economic and employment development of the areas subject to intervention, while also indirectly promoting the growth of the culture of "reuse" of the heritage of the discharged or unused areas present in our country. Indeed, the indirect positive effects linked to recovery strategies in terms of sustainable development should not be overlooked: for example, the effects linked to the reduction of situations of environmental risk, the requalification of decayed areas, the creation of new jobs, the activation of other sectors of the local economy and so on.

In the framework of the initial objectives, this study aimed to apply mass appraisal models (regressive and autoregressive) in order to estimate the effects of real estate valorization generated by the redevelopment interventions on the abandoned industrial area of Bagnoli in Naples.

In first place, the study mapped the intervention area according to the economic value levels that the areas affected by building products with a defined intended use are supposed to reach.

Secondly, it highlighted the potential for the use of the autoregressive models and Ellwood's model in the field of real estate evaluations as possible tools to support decisions on real estate investments.

The further development of autoregressive models may concern the stochastic relationships between property prices and their characteristics, in order to formulate dynamic price functions to interpret the aleatory mechanisms that affect the trends of real estate markets. In line with these objectives, appropriate autoregressive approaches must be sought for the deterministic and stochastic variables on which to base the estimate of the property revaluation rates. On the other hand, the complete application development of autoregressive methodologies in the estimation field can only depend on the simplification of the current calculation procedures and on the choice of tests appropriate to the specific purposes of the assessments, as well as on the availability of databases to use for the execution of estimative analyses.

Concerning Ellwood's model, it has allowed to quantify the risk and return for the future residential housing market of Bagnoli. In other terms, Ellwood's model contributed to identify the "stigma" effect, or the value loss to property value due to the presence of a risk perception-driven market resistance. These future value losses to properties value are reflected, unavoidably, also on the current market value of the abandoned industrial soils. Stigma adjustment is a key element in contaminated soil evaluation when the impaired value approach is used; in this perspective, the Ellwood's model has proven capable to estimate accurately and quantify, through an indirect method, the stigma effect.

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