Impacts of Urban Decay on the Residential Property Market: An Application to the City of Rome (Italy)

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Abstract. Urban decay is a complex phenomenon that encompasses physical deterioration, environmental degradation, and social disintegration that negatively affects the livability, safety, and economic vitality of urban areas, leading to demographic displacements, disinvestments and significant repercussions on housing dynamics. This study aims to develop a regression methodological approach to determine the effects of urban decay factors on the residential real estate market in Rome (Italy). The methodology involves the collection of a set of variables to describe and interpret the effects of urban decay on property values, followed by the application of Weighted Least Squares (WLS) regression to assess the marginal prices of these identified variables. The use of WLS allows to take into account the problem of heteroscedasticity in the evaluation process, ensuring its robustness. The proposed methodology is adaptable to different spatial contexts and provides valuable decision support for stakeholders involved in urban regeneration initiatives aimed at revitalizing decayed areas.

Keywords: Urban decay · property market · property values · Weighted Least Squares regression · regression analysis

1 Introduction

Urban decay represents a significant challenge for many cities; it is a complex, multifactorial process which consists of the deterioration of physical, social and economic aspects of urban spaces [1]. This phenomenon is characterized by a convergence of interrelated factors of different nature [2]. For example, from a physical perspective, decay is manifested through abandoned or poorly maintained buildings, dilapidated roads and/or infrastructure, and the presence of disamenities, such as graffiti, litter, and all the elements that contribute to an inhospitable urban environment [3].

With reference to environmental issues, the presence of degraded or abandoned buildings contributes to the problem of land consumption. These buildings, in fact, no longer

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O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14822, pp. 36–48, 2024.
https://doi.org/10.1007/978-3-031-65318-6_3

accomplish the original purpose for which they were designed, are not used efficiently, and occupy parts of the natural soil in urban areas. Moreover, their presence intensifies the heat island effect through the prevalence of impermeable surfaces like asphalt and concrete. Furthermore, these buildings can exacerbate environmental pollution due to their frequent construction with outdated materials and technologies, such as asbestos, which pose significant environmental hazards [4].

In particular, this condition is often associated with negative impacts on various aspects of urban livability and quality of life [5]. The phenomenon of urban decay is closely linked to different choices that the population makes regarding the best place to live: if the neighborhood conditions become less attractive, a change in demographic composition can occur. Some inhabitants can decide to leave the decaying neighborhoods and move to areas with a higher urban quality level, and this can be associated with a replacement of individuals who cannot access to high quality housing and neighborhood infrastructures [6]. Moreover, urban decay is often considered a catalyst for crime and violence spread in the most affected areas. This, in turn, compromises the safety of the inhabitants and encourages their displacement from these areas [7].

From an economic point of view, urban decay can significantly affect real estate investment decisions and, in general, the economic dynamism of each affected area and the entire city. It, in fact, can discourage private investors from the activation of redevelopment interventions in such areas, due to the perceived higher risks associated with them [8]. This generates a boost in the deterioration level and, in particular, also an increase in different types of obsolescence (functional, structural, environmental, etc.) [9].

These aspects do not only negatively affect the level of attractiveness [10]. The decline in the quality of services and the migration flows of residents associated with the deterioration of the urban environment contribute to a variation in housing demand, with a reduction in property values [11]. Regarding the relationship between urban decay and property values, Breger [12], one of the first Authors to study the causes of urban decay, defines it as a "*critical stage in the functional or social depreciation of real property beyond which its existing condition or use is unacceptable to the community*". Property values are defined according to the specific features of the asset and those that characterize the surrounding context, in terms of available services, quality of urban and green spaces, provision of public infrastructure, etc. Therefore, if an urban area is affected by urban decay issues, a negative impact on the real estate market can be observed [4].

Determining the impact of urban decay on property values can be an important support for public and private subjects involved in the planning of urban redevelopment strategies in those areas that are affected by this phenomenon.

In the field of sustainable urban development policies - supported by initiatives such as the New European Bauhaus [13] and the 2030 Agenda [14] - the recovery of existing resources and the reduction of natural soil consumption, as well as the activation of strategies to regenerate degraded and abandoned areas in cities are extremely necessary [15]. In this context, the issues related to urban regeneration initiatives emphasize the need for a comprehensive and inclusive approach involving different stakeholders such as investors, urban planners, policymakers, and community at large [16, 17]. These

stakeholders have often conflicting multidimensional interests, and they should work together in order to address the challenges associated with such initiatives [18]. The analysis of the existing relationships between urban decay and the real estate market plays an essential role, as it provides relevant decision support for stakeholders involved in the investment and urban development initiatives.

2 Aim

The present research is part of the outlined framework. The work's aim concerns the definition of a regressive methodological approach for the determination of the effects of urban decay's factors on the housing market quotations. The aim is pursued through a structured approach that consists of the following phases: (i) identification of the explanatory variables' set; (ii) data collection and correlation analysis; (iii) regression analysis; (iv) results discussion (see Fig. 1).

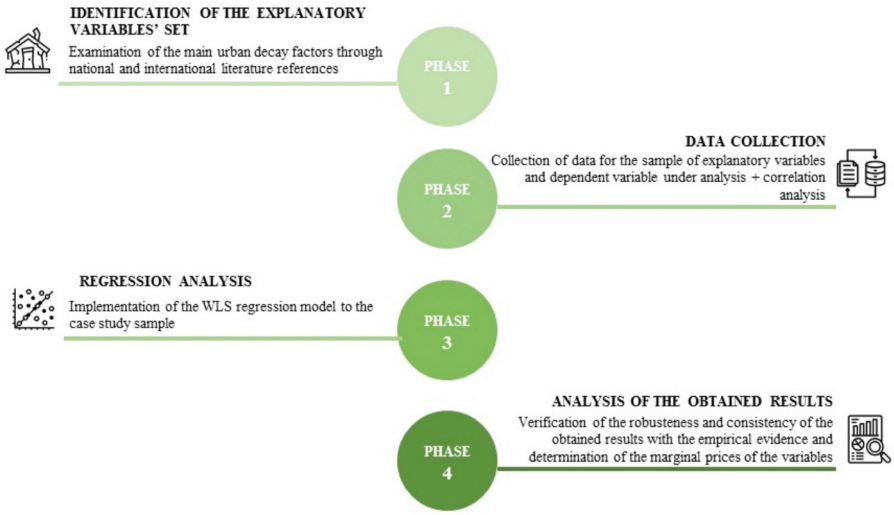


Fig. 1. The phases of the proposed evaluation methodology

The proposed methodological approach is applied to the city of Rome (Italy) with reference to the residential sector. In particular, 117 trade areas identified by the Real Estate Market Observatory (REMO) of the Italian Revenue Agency are considered.

The remainder of the research is structured as follows: Sect. 3 consists of an overview of regression models application for the real estate market analysis; Sect. 4 describes each phase of the proposed methodology; Sect. 5 discusses the obtained results for investigating the coherence with the empirical evidence; Sect. 6 provides for the conclusions of the work and the future developments.

3 Background

In the field of the real estate market study, the formation mechanisms of property prices are widely analyzed through the development and definition of several assessment models.

The Hedonic Price Method (HPM) is an approach widely used in the literature to evaluate the impact of various externalities on property values. In fact, this method makes it possible to determine the effects of the attributes of a property that are not directly measurable [19]. Typically, HPM uses regression models to identify the existing functional relationships between a dependent variable – generally the property price - and one or more independent variables. In this way, the value of the dependent variable can be assessed based on the values of the other ones [20]. In order to implement the HPM, several kinds of regression analysis can be used: parametric, nonparametric, and semi-parametric models [21].

Parametric models provide that the regression curve has a predetermined functional form described by a finite set of parameters represented by the coefficients of the independent variables. Among parametric models, Ordinary Least Square (OLS) is commonly used to identify the optimal line through a set of data points. The goal is to minimize the sum of squares of the residual errors, which are the differences between the observed and estimated values. This process allows to determine the coefficients of the line that best fit the collected data [22]. One of the main assumptions of OLS is the existence of homoscedasticity, where errors have a constant variance. Violation of this assumption, resulting in a variable variance of the errors, leads to the condition of heteroscedasticity [23]. This condition can lead to changes in both the estimated standard errors of the coefficients and the value of the coefficients. With this regard, an alternative parametric model known as Weighted Least Squares (WLS) can be implemented to solve the heteroscedasticity problem of regression analysis. WLS assigns different weights to each observation, proportional to the inverse of the variance. As a result, observations with higher estimated variances receive lower weights and vice versa. In this way, the model accounts for heteroscedasticity in the data during the parameter estimation process [24].

Unlike parametric models, the non-parametric ones do not predefine the form of the regression function that relates the dependent variable with the independent variables. Consequently, such models allow the use of flexible functions that can capture more complex and nonlinear relationships between the observed variables [25]. Non-parametric models are particularly useful when the data are not suitable for applying the parametric ones and when the relationship between the variables is not immediately identifiable. Among these ones, one of the applicable methods for the study of real estate values is Kernel estimation, which allows the value of the dependent variable at a point to be estimated based on nearby observations, giving greater weight to the variables closest to the one of interest in a fixed surround. Another non-parametric model is the Nearest Neighbor method, which differs from Kernel estimation by the presence of a variable size surround.

Semi-parametric models represent a balance by combining the ease of interpretation of results characteristic of parametric models with the flexibility offered by nonparametric models. For example, one of the simplest semi-parametric estimators to compute and

visualize is the Generalized Additive Model (GAM) which is constructed by combining generalized linear models with smooth function of independent variables. [26].

In the outlined regression analysis framework, the parametric approach emerges as the most applied model for real estate research issues. A notable example of its application is evident in the work of Chwiałkowski et al. [27], where the WLS method is used to assess the impact of the proximity of Wielkopolski National Park on real estate values in Mosina (Poland) revealing a positive influence. In another work, the same Authors [28], use both OLS and WLS to examine the effects of urban public transport on residential property prices in Poznan (Poland), reporting a higher accuracy of WLS than OLS. In another study on the city of Poznan, Trojanek et al. [29] investigate the impact of air noise on house prices. In this study, the Authors define an integrated regression model that consists not only of the application of OLS and WLS but also the inclusion of Spatial Autoregressive (SAR) and Spatial Error (SEM) models. The incorporation of SAR and SEM aims to improve the efficiency of the assessment by considering the spatial dependency of variables. In a study aimed at understanding the effects of urban green spaces on residential prices in Warsaw, Trojanek et al. [30] employ a diverse set of models, including OLS, WLS, and the Median Quantum Regression (MQR) model. This methodological comparison is chosen to ensure the robustness and reliability of the results. Some studies, by addressing issues of heteroscedasticity, such as those of Teck Hong [31] and Tse and Love [32], use, in addition to WLS, a heteroscedasticity consistent covariance matrix estimator. This further step is implemented to accurately estimate the coefficients of various attributes on house prices.

4 Methodology

4.1 WLS Regression Model

In order to study the effects of the urban decay factors on the residential real estate market of the city of Rome, a WLS regression model is developed. It is a generalization of OLS and linear regression in which knowledge of the unequal variance of the observations (heteroscedasticity) is computed into the regression. The WLS regression model reduces the heteroscedasticity problems in order to accurately assess the phenomenon to be analyzed. The main difference with OLS is the assumption of having different weights for different observations. In particular, those observations for which a greater error variance is observed correspond to lower weights.

4.2 Phase 1. Identification of the Explanatory Variables ‘Set

The phenomenon of urban decay is extremely relevant in the field of urban planning practices and real estate market analysis. In particular, it can be described as the main consequence that occurs when the balance between all the factors that characterize a specific urban area, in terms of social status, economic conditions, and environmental quality, significantly changes by providing for an in-depth transformation of the context.

The real estate market reflects all the urban transformations, both physical, demographic, and economic, easily explainable by the fact that property price is a function

of intrinsic (property-related) and extrinsic (context-related) features. The study of real estate values, therefore, can be useful for capturing the transformations taking place in the urban context, including those related to the urban decay phenomena. In order to highlight and determine the prices' effects of urban decay-related factors in the city of Rome (Italy), in the present work the dependent variable (Y) is the unit residential quotation (€/m^2) provided by the REMO for the first semester of 2023.

For the identification of the explanatory variables' set, the national and international literature of the field has been examined and, according to the obtained results, the chosen set of explanatory variables is composed of quantitative factors capable of adequately representing the social, economic, and environmental level of the 117 considered REMO areas. In particular, a set of 6 explanatory variables, adequately balanced, and capable of enucleating the main peculiarities of the urban decay phenomenon is identified. It is possible to classify them into two categories: (i) socio-economic and environmental variables and (ii) urban decay variables. The first category represents the main socio-economic and environmental features that characterize the REMO zones context, instead, the second one pertains to the enucleation of the most relevant Urban Decay factors of the zone, according to the specific case study and the literature review carried out. The 6 explanatory variables are following described:

Socio-economic and Environmental Variables

1. Residential Population (P): it consists of the number of individuals living in the i-th REMO zone according to the latest update of the population census provided by ISTAT in 2011;
2. Per-capita income (R): it is defined as the quantity of gross domestic product hypothetically produced, in a certain period of time, by a person of the i-th REMO zone. It is calculated in units of euros for one year and updated in 2021, as provided by the Urbistat Geosoftware;
3. Surface of the urban green park (V): it represents the km^2 of the territorial surface of the green parks for the city of Rome which falls within the perimeter of the i-th REMO zone (source: https://download.geofabrik.de/europe/italy.html)

Urban Decay's Variables

1. Surface of the degraded urban area (A): it represents the km^2 of territorial surface of those census sections for which the Index of Social Disease and the Index of Construction Disease, calculated by the Italian National Statistical Institute (ISTAT) for the purposes of the "Call for the submission of proposals for the preparation of the national plan for the social and cultural redevelopment of degraded urban areas (DPCM 21 October 2015)", is > 1;
2. Index of Social Disease (D): it results from the weighted average of the deviations of the values of the following indicators, referring to the semester preceding that of the survey, from the respective national average values, detected by the ISTAT census: Unemployment rate, Employment rate, Youth concentration rate, Education rate. The formula used for the calculation is the following:

$$D = 0.40 * (DIS - DISNAZ) + 0.30 * (OCCNAZ - OCC) + 0.15 * (GIOV - GIOVNAZ) + 0.15 * (SCOLNAZ - SCOL)$$

Where:

DIS = Unemployment rate; OCC = Occupancy rate; GIOV = Youth concentration rate; SCOL = Education rate; DISNAZ = National Unemployment rate; OCCNAZ = National occupancy rate; GIOVNAZ = National Youth concentration rate; SCOLNAZ = National Education rate

3. Index of Construction disease (De): compares the state of conservation of buildings in the degraded urban area with the national average value according to the following formula:

$$De = [(ERp + ERm)/TotER]/0.168$$

Where: ERp = Residential Buildings in the degraded urban area in a very bad state of conservation; ERm = Residential Buildings in the degraded urban area in a mediocre state of conservation; Tot ER = Total residential buildings in the degraded urban area; The weighting coefficient corresponds to the national percentage of residential buildings with a "very bad" or "mediocre" state of conservation.

As it is possible to see, an attempt has been made to structure a database that is balanced against factors explicitly focused on issues of urban degradation and factors involved in the definition of the phenomenon, from other points of view.

4.3 Phase 2. Data Collection and Correlation Analysis

The WLS regression model is applied to a sample that refers to the sub-municipal territorial subdivision of the city of Rome (Italy) provided by REMO. In particular, 117 are of interest in this research because no data on the presence of an offer for the residential real estate market were found in the other areas, therefore they could not be considered in this analysis.

For each of the considered REMO zones, the collection of data related to the 6 chosen explanatory variables and the dependent one is carried out. The descriptive statistics of the variables are reported in Table 1.

Table 1. Main statistical features of the sample of variables

	Average	Standard deviation	Min	Max	Variance
Y	2,610.68	1,066.48	1,125	1,125	1,137,374.10
P	17,970.78	14,352.58	536	79,837	205,996,493.7
R	20,251.70	7,526.26	8,837	57,571	56,644,578.42
V	0.26	0.52	0	3.51	0.27
A	0.54	1.11	0.001	6.23	1.22
D	7.32	6.04	1.06	40.41	36.46
De	3.23	1.55	1.12	5.95	2.42

Once the dataset has been completed, in order to identify the phenomena of the high correlation of the variables considered which may affect the robustness of the results of

the regression analysis of the subsequent steps of the proposed methodology, the Pearson coefficient is calculated. The correlation matrix obtained is shown in Table 2.

Table 2. Pearson correlation matrix

	Y	*A*	*D*	*De*	*P*	*R*	*V*
Y	1						
A	–0.2745	1					
D	–0.0690	0.0647	1				
De	0.1433	0.0906	0.2875	1			
P	0.0860	–0.1103	–0.0637	–0.0526	1		
R	0.9282	–0.1831	0.0023	0.1815	0.0268	1	
V	0.0982	–0.1436	–0.0492	–0.0127	0.1867	0.04847	1

As can be seen by the correlation results, the variables A and D are the unique ones that have negative signs with reference to the dependent variable Y. Other negative correlation relationships are observed between the variables P with D (–0.0637) and De (–0.0526), R with the variable A (–0.1831) and the variable V with A (–0.1436) and De (–0.0127). The highest level of correlation is found for the explanatory variable of the per-capita income (R) and the dependent variable (Y) of the unit residential quotation - equal to 0.9282 with a positive sign. The latter highlights the significance of the per-capita income in the explanation of the real estate values formation in the considered sample, as also attested by the literature of the field. It appears to be consistent also with the empirical evidence.

The correlation analysis shows a very low degree of interdependence of the set of chosen variables.

4.4 Phase 3. Regression Analysis

The implementation of the WLS regression model to the case study sample shows interesting statistical performance. Its application has generated a model characterized by high statistical efficiency with an R2 equal to 0.986 (corrected determination index equal to 0.986), as reported in Table 3:

Table 3. Results of the regression analysis

Variable	Coefficient	Standard error	T student	P-value
R	7294.91	72.6441	100.420	<0.00001***
V	209.655	46.2954	4.529	0.00002***

(*continued*)

Table 3. (*continued*)

Variable	Coefficient	Standard error	T student	P-value
P	255.888	73.1573	3.498	0.00068***
A	– 434.972	168.347	–2.584	0.01107**
D	–298.193	145.871	–2.044	0.04330**
De	85.3217	53.5852	1.592	0.11417

Note: *** is for $p < 0.01$, ** is for $p < 0.05$

The implemented regression is robust because the model has strong fitness measures, indicating that a suitable set of both socio-economic and environmental variables and urban decay variables has been constructed.

As it is possible to observe from Table 3, all 6 explanatory variables are statistically significant in the regression analysis. In particular, by observing the obtained p-values, it is maximum for the per-capita income variable (R) and the minimum for the index of construction disease (De). The absence of the constant term in the regression equation could be explained by observing the significance of the variable R: it means that R is the most influencing explanatory variable on the residential real estate market of the considered sample, so as to explain almost completely the phenomenon of real estate price formation. It is consistent with the empirical evidence and the reference literature in the field: income level is, in fact, considered a fundamental determinant of real estate housing prices [33, 34]. For the index of construction disease (De), the results may differ from those expected, but it should be noted that the difference, in numerical terms, with the p-value thresholds (0.10) for the eligibility of the variables in the explanation of the phenomenon under examination is minimal (0.01417). The explanatory variable De, therefore, although it is the least significant one among those considered, in absolute terms, still appears relevant in the process of formation of the real estate values of the sample in question.

The F test is always significant. The dispersion graph of the standardized residual shows that the hypothesis of homoscedasticity is not violated. The hypothesis of a normal distribution of errors is also tested. The percentage average between the detected values of the dependent variable (Y) and the estimated ones predicted by the model is about 5%. The multicollinearity coefficients (VIF) are all < 10, as following reported: $R = 5.094$; $V = 1.315$; $P = 2.368$; $A = 1.251$; $D = 2.596$; $De = 5.453$.

4.5 Phase 4. Results Discussion

Among the 6 explanatory variables, for two of them a negative coefficient is detected (Table 4). The surface of the urban degraded area (A) has an inverse functional relationship (–434.972) with the dependent variable (Y). It means that if the territorial extension of it increases, the unit residential quotation decreases. In particular, for each unit increase of the explanatory variable A, specifically equal to 6 km^2, the unit residential quotation respectively decreases by about 435 €/m^2 and vice versa, that is the marginal price of this variable. Similar comments can be made for the variable representing the

Table 4. Coefficients and significance of the variables

Variable	Coefficient	Sign
R	7294.91	***
V	209.655	***
P	255.888	***
A	– 434.972	**
D	–298.193	**
De	85.3217	n.a.

social disease (D): an inverse functional relationship with the unit residential quotation is detected, therefore, if a unit increase - equal to 40 - of the index value occurs in the i-th REMO zone, the dependent variable decreases of about 299 €/m^2 and vice versa, or the obtained marginal price of this explanatory variable (D).

For the explanatory variable that expresses the surface of the urban green parks (V) a positive functional relationship between it and the unit residential quotation (Y) is observed. In particular, if the green surface increases by 4 km^2 – unit growth – the residential quotation also increases by about 210 €/m^2 and vice versa, as the marginal price of the urban green park's surface. Also, for the number of residential population, a positive functional relationship with the housing quotations is found. Specifically, a unit increase – equal to about 80,000 residents – corresponds to a unit growth of the residential quotations equal to 256 €/m^2 and vice versa. For the most significant explanatory variable (R), the obtained positive functional relationship highlights that if the per-capita income varies through, for example, a unit equal to 57,500 €/year, the residential quotations vary too of 7,300 €/m^2.

5 Conclusions

The existence of abandoned or poorly maintained properties, often with overgrowth and disorder diseases of different kinds – from social to economic and environmental - is a complex and important real estate issue [35]. Breger [12] describes urban decay as a critical factor in the functional or social depreciation of a real estate property. For these reasons, the importance of analyzing urban decay's effects on property prices is widely recognized.

The aim of the work has regarded the definition of a regressive methodological approach for the determination of the effects of urban decay factors on the residential real estate market of the city of Rome (Italy). A structured approach has been proposed, articulated as follows: (i) identification of the explanatory variables' set; (ii) data collection and correlation analysis; (iii) application of the WLS regression to the case study; iv) analysis of the obtained results. A balanced set of explanatory variables that are able to express the wide effects on the property values of the urban decay phenomenon has been made. The implementation of the WLS regression has allowed to find interesting

results for the marginal prices of the detected variables. In particular, for the study sample, among the analyzed urban decay factors, the surface of the urban degraded area and the level of the social disease are the most influencing variables on the property values, in negative terms. In particular, a unit decrease of both variables is able to reduce the property quotations by about 367 €/m^2. Instead, with regard to the socio-economic and environmental conditions in the surrounding context of the study sample, the per-capita income has been able to increase the unit quotation of about 7,300 €/m^2, the extension of the urban green park of about 210 €/m^2 and the population residents of about 256 €/m^2. All of these variables affect, through a positive functional relationship, the residential quotations of the study sample of the city of Rome (Italy).

The proposed methodological approach has allowed to highlight in a clear and transparent way the effects of the main urban decay-related factors on the residential real estate market. Heteroscedasticity problems have been considered in order to provide for an efficient and robust regressive approach. The model's applicability to different spatial contexts and housing markets allows it to consider variables of general relevance to urban decay, going beyond the specifics of each case study. This flexibility allows for a comprehensive characterization of the effects of urban decay and their impact on marginal prices in different contexts. It can be useful for the identification of the most critical urban areas for defining adequate strategies that can improve urban livability.

Future insights can regard the examination of a different set of explanatory variables that can be able to take into account other urban decay-related issues, by also comparing the results with the ones that can be obtained through the implementation of other econometric analysis and regression techniques. Among the additional variables to be considered in future developments, elementary indicators derived from the disaggregation of the indices used in this study (D and De) could be included, allowing for more accurate capture of detailed characteristics.

Note. The current study has been developed within the current research P.R.I.N. Project 2022: "INSPIRE—Improving Nature-Smart Policies through Innovative Resilient Evaluations", Grant number: 2022J7RWNF.

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