Pricing the Tide: The Effect of the Mo.S.E. System on the Venetian Residential Market

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Abstract. During the night between November 12 and 13, 2019, Venice was struck by an exceptional high tide, that caused the flooding of 90% of the city. On October 3, 2020, the Mo.S.E. was activated. It is a system of mobile barriers, whose purpose is to reduce the impact of high tides on the city of Venice by isolating the lagoon from the Adriatic Sea whenever a tide exceeding 110 cm is forecasted. The effects of this protection system have been extensively examined with regard to the safeguarding of Venice's historical, architectural, and artistic heritage, as well as to its ecological and environmental implications. However, only a limited number of studies have investigated its impact on real estate values. The present study contributes to this line of research by analyzing the increase in market values for ground-floor and raised-floor properties located in areas of the city most exposed to high-tide flooding following the activation of Mo.S.E. Using a hedonic price model, we analyze a sample of 240 listings published between 2018 and 2024 collected leveraging a public web archiving site. Advertisements published from 2021 onward exhibit a price premium of approximately 5%, while those posted after 2022 show an effect of about 10%. Additional variables related to suitability for tourist-rental use also display strong positive effects. On the one hand, the study provides evidence of the role of Mo.S.E. in increasing housing market values; on the other, it suggests that these effects may be capitalized primarily by the tourist-rental market.

Keywords: Housing Values · Hedonic Price Model · Environmental Protection

1 Introduction and Background Literature

During the night between November 12 and 13, 2019, Venice was struck by an exceptional high tide, the second highest since 1872 (the year when observations began). The tide reached 189 cm above the Mareographic Reference of Punta della Salute (MRPS), causing the flooding of 90% of the city [1].

The extraordinary phenomenon was caused by the combination of several factors during a month — November — already characterized by frequent high tides, to which

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were added the full moon that intensified the tidal effect, the difference in the atmospheric pressure between Venice and the central Adriatic Sea, and the alternation of Bora and Scirocco winds that pushed the water mass of the lagoon first toward Chioggia and then toward Venice.

High tides, which have always existed in Venice, have progressively worsened in recent years (Fig. 1) due to climate change [2], with consequent negative effects on the built environment of the city, whose pavement level is on average one meter above mean sea level [3]. The debate on safeguarding Venice from the phenomenon of high tides began to take on political significance after the 1966 flood, when the tide reached 194 cm above the MRPS. The issue of protecting Venice was declared to be of "overriding national interest" by the first special law for Venice (Law 171/1973). This marked the beginning of a long process aimed at creating a system to protect the city from exceptional tides, including the presentation of the first feasibility study in 1981, the Mo.S.E. (Experimental Electromechanical Module) tests in 1992, and the approval of the final project in 2002. The system consists of a series of mobile barriers located at the lagoon inlets, whose purpose is to reduce the impact of high tides on the city of Venice by isolating the lagoon from the Adriatic Sea whenever a tide exceeding 110 cm MRPS is expected.

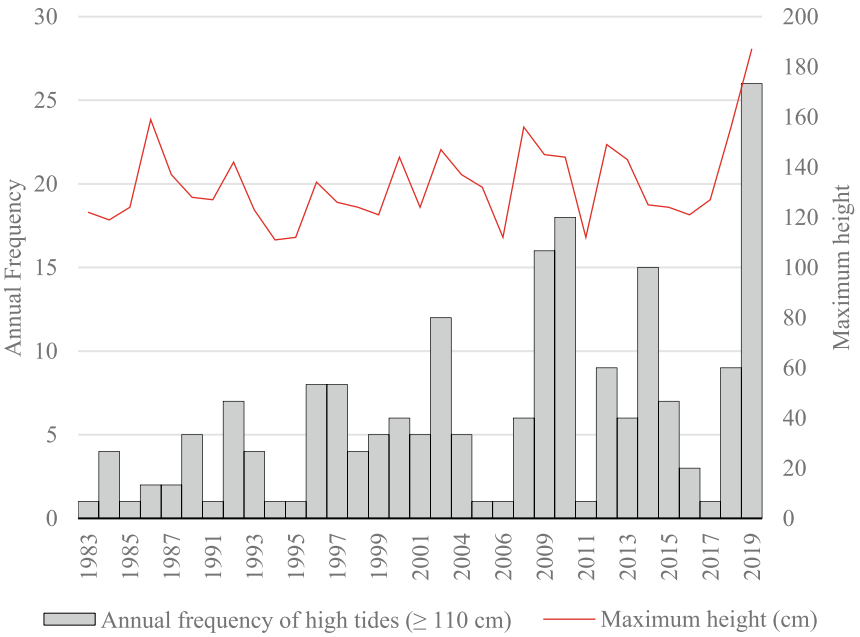

Fig. 1. High tides annual frequency and maximum height (1983–2019)

The laying of the cornerstone took place in May 2003. On October 3, 2020, the Mo.S.E. was activated for the first time. Since then, the barriers have been raised

more than 100 times, preventing damages estimated at over 2.6 billion euros.[1] Mo.S.E. has proven to be an effective system for safeguarding the historical and architectural heritage of Venice, but it has also had broader effects on the city, on residents and tourists, and on the delicate environmental system of the lagoon in which it is embedded. Mo.S.E. has attracted the attention of several scholars and has been studied from different perspectives.

Its effects have been examined with reference to the delicate environmental lagoon balance and the exchange of sediments and water between the lagoon and the Adriatic Sea [4–6], the formation of toxic substances [7], the mussels cultivation [8], the growth and adaptation strategies of algae [9], the microorganisms communities [10], and fish migration [11].

The impact of Mo.S.E. on the city has also been examined in relation to the vulnerability of architectural and cultural heritage, the assessment of restoration interventions [12], with particular focus on the rising damp in masonry buildings [13], the protection of St. Mark square [14], and the use of compensation, conservation and environmental requalification measures for the conservation of the military architectures that characterized the lagoon landscape [15].

Other studies have analyzed the economic consequences of raising the Mo.S.E. barriers on the operations of the Port of Venice, located within the lagoon [16–19], and the city itself [20].

In the scientific literature, however, only a limited number of studies examine the effect of the Mo.S.E. system on the real estate sector. The impact of high tides on hotel room fares is investigated in [21]. Using a regression discontinuity design, the authors find that hotel room prices listed on a well-known booking platform decrease when a tide exceeding 110 cm is forecasted. Although the data refer to the period preceding the activation of Mo.S.E., the study highlights the potential benefits of its operation in terms of reduced losses for the hotel industry.

A study by Rosato et al. [22], uses a GIS-integrated hybrid hedonic multi-attribute model to simulate the impact of Mo.S.E.'s activation on housing values in the historic center of Venice. The authors estimate a potential increase of 8.2% in the market value of ground-floor apartments and 3.8% for those located on upper floors. They also estimate a total increase of €1.4 billion of the city's property values (equal to approximately €320/m^2). Similarly, a research published by the Bank of Italy in November 2022 [23], based on a dataset of nearly 51,000 property listings published between 2016 and 2021, finds a 3% increase in the value of properties located above 110 cm MRPS (thus above the Mo.S.E. activation threshold), and an additional 7% increase for ground-floor apartments.

This study builds on this research strand and aims to estimate the effect of Mo.S.E. on the value of ground-floor residential properties located in the historic center of Venice five years after its first activation, through the application of a hedonic price model. The sample used for the analysis consists of listings posted on one of the main real estate advertising platforms between 2018 and 2025, collected automatically via a web-crawling program using a web-archiving platform.

[1] https://mit.gov.it/comunicazione/news/mit-con-il-centesimo-sollevamento-del-mose-altro-salvataggio-per-venezia

The remainder of the paper is structured as follows: Sect. 2 outlines the methodology, provides an overview of the data collection procedures, and describes the sample and variables employed. Section 3 discusses the empirical results, and Sect. 4 concludes by summarizing the main findings and offering suggestions for future research.

2 Analysis

2.1 The Hedonic Price Model

One of the most widely used and acknowledged methodologies for estimating property values as the sum of the implicit prices of their attributes, the hedonic price model, is based on the seminal work of Rosen [24], and can be expressed using the following equation:

$$y = \alpha + \beta_k X_k + \varepsilon \tag{1}$$

where y is the price of a property, α is the constant, β_k are the coefficients of a set of characteristics X_k (with $k = 1 \ldots l$) and ε is the error term.

In real estate valuation analyses, this model is often transformed into a semi-logarithmic specification. By using the natural logarithm of price as the dependent variable, the coefficients of the independent variables can be interpreted as percentage effects on property price [25]. The log-linear form is used in the present study and is expressed as follows:

$$\ln y = \alpha + \beta_k X_k + \varepsilon \tag{2}$$

As far as the model assumptions are concerned, homoscedasticity and normal distribution of residuals are verified by means of White Test and D'Agostino–Pearson Test respectively, while the absence of correlation among independent variables is tested using the Variance Inflation Factor (VIF).

2.2 Data Collection

To reconstruct historical data on real estate advertisements, the study leverages the public web archiving service known as Internet Archive – Wayback Machine.[2] This digital archive periodically crawls and stores complete HTML versions of publicly accessible web pages, generating time-stamped snapshots that reproduce the structure and content of the website at the moment of the capture. These snapshots are indexed chronologically and can be accessed to retrieve historical versions of a given domain. The procedure used in this study to collect the historical data is summarized in Fig. 2 and developed in the following steps:

1. **Retrieval of Archived Snapshots**. For the target real estate listing platform domain, all available snapshots for the considered year are queried and enumerated. Each snapshot represents the capture of the website at a precise date and time. For every retrieved snapshot, the procedure automatically accesses and downloads all pages reachable within the archived environment on that specific day.

[2] https://web.archive.org/

2. **HTML Parsing and Field Extraction**. The extraction of listing information is performed through structured parsing of the archived HTML documents using the Python library BeautifulSoup,[3] which facilitates the navigation and interpretation of each page's Document Object Model (DOM). Each property listing exhibits a recurring HTML structure that allows the systematic identification and retrieval of the target variables: price, surface area, location, listing description, and floor level. Asking price, surface area, and the description are retrieved by targeting specific HTML tags and class attributes in each advertisement. To determine the floor level, a different approach is followed. When explicitly provided within the structured metadata of the listing, the value is extracted directly through the same DOM-based approach described above. However, in cases where the field is not present in the listing, the extraction method performs a keyword search within the text of the description field to detect mentions of e.g. "piano terra" (ground floor). To mitigate the potential false positives (e.g., cases referencing ground-floor storage spaces rather than the property itself), a binary indicator is introduced. This "floor-source flag" distinguishes between values derived from structured metadata and those inferred from textual analysis. This flag allows manual verification and post-processing corrections where necessary.
3. **Location extraction**. The zone associated with each property is derived from the title of the listing, which follows a consistent syntactic structure. The title is organized as a comma-separated sequence in which the final element corresponds to the municipality ("Venezia"), while the immediately preceding element indicates the specific neighborhood or sub-area. For example: "Quadrilocale buono stato, primo piano, Sant'Elena, Venezia". Here, "Sant'Elena" represents the neighborhood, as it appears directly before "Venezia". The extraction procedure therefore isolates the segment preceding the municipal reference.
4. **Data Structuring and Output**. All the extracted information is consolidated into an output dataset saved in CSV format. Each record contains the following standardized fields: Title, Location, Price, Surface area, Floor level, Description, Floor source flag (structured field vs. inferred).
5. **Filtering and Cleaning**. A final post-processing step is conducted to improve dataset reliability by removing duplicate listings recurring across multiple snapshots and by selecting only those properties confirmed — either explicitly or through textual inference — to be ground or raised-ground floor units, which are required for the subsequent flood risk and housing market analyses.

The data collection process is subject to structural limitations inherent to web-archiving practices. First, the availability of archived snapshots is discontinuous. For the considered year, the Wayback Machine provides captures at an average frequency of approximately one snapshot per week. For this reason, the reconstructed dataset does not represent a continuous daily record of listings, but rather a series of periodic observations.

Second, archival completeness is partial. For each selected snapshot date, not all the pages that compose the real-estate platform were successfully preserved. On average, only 2–3 pages for a given date were retrievable. These two factors jointly constrain the final number of collected advertisements. Nevertheless, the number of listings that

[3] https://www.crummy.com/software/BeautifulSoup/bs4/

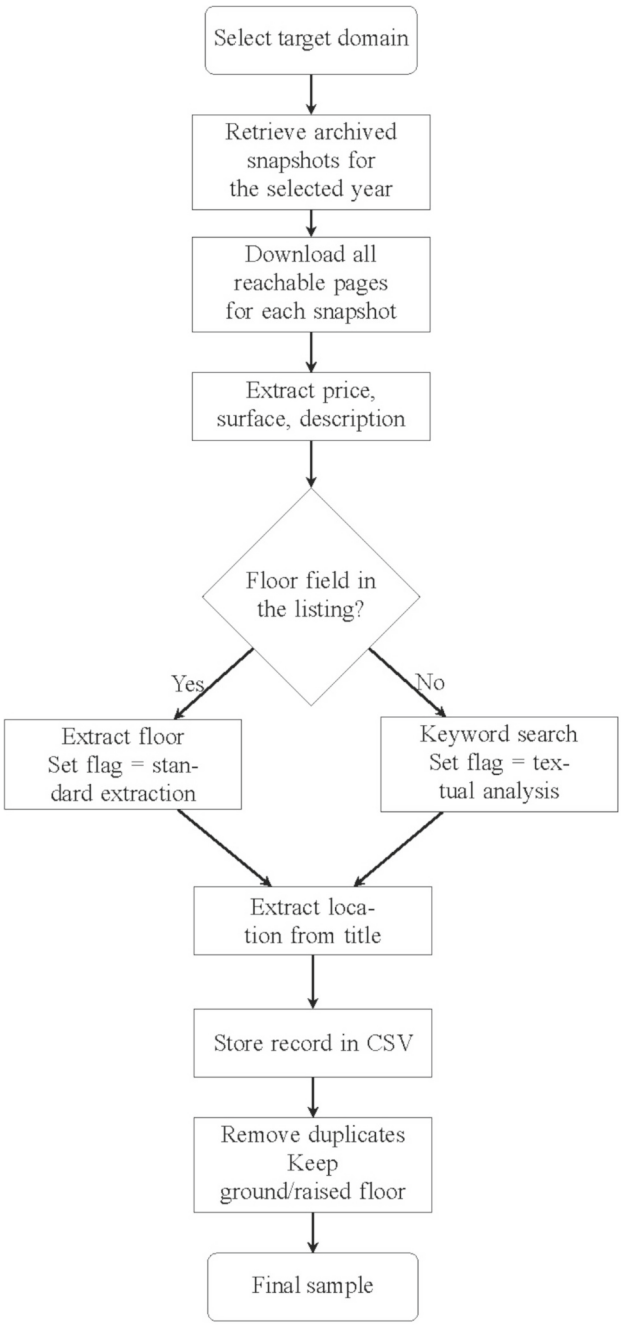

Fig. 2. Data collection workflow

could be collected for each year is comparable to the number of advertisements simultaneously published on the target real estate listing platform for the Municipality of Venice, amounting to approximately 3,000. Indeed, the procedure described above made it possible to gather a total of about 25,000 advertisements for the period 2018–2025 (no archived data were available before 2018). From this dataset, the procedure outlined in point 5 allowed the selection of a first sample of 370 non-duplicate listings referring to properties offered for sale and located on the ground or raised-ground floor levels. Listings located on the raised-ground floor level have been included due to the fact that typical residential buildings in the historic center of Venice do not feature true mezzanine or elevated floors (except for particular building typologies such as noble palaces). Rather, what is commonly referred to as a raised-ground floor level often corresponds to ground-floor units that, over the years, have undergone renovation works aimed at increasing the interior floor elevation. As a result, these units are frequently raised by only two or three steps above the external ground level.

2.3 Sample and Variables Description

Beyond the automatically collected data on property location, asking price, and floor area, a set of additional information was retrieved based on the descriptions provided in the listings. Each property's location was associated with one of the 11 OMI zones into which the historic center of Venice is divided (Fig. 3). OMI zones are defined by the Real Estate Market Monitor of the Italian Revenue Agency (Osservatorio del Mercato Immobiliare, in Italian, from which the acronym) and identify areas characterized by relatively homogeneous economic, social, and environmental conditions, within which property prices tend to be substantially uniform [26].

Asking prices were also standardized to 2018 values in order to remove the temporal component from the regression analysis, and, in particular, the effect generated by the pandemic, assuming that the impact of the Mo.S.E. on ground-floor properties can be isolated from the broader price dynamics affecting the residential sector as a whole. Using the semi-annual property value data provided by OMI, asking prices were adjusted using the average price variation relative to the first half of 2018 for each individual zone, considering properties in normal maintenance conditions. Subsequently, the 2018-homogenised unit price was calculated dividing the adjusted asking price by the floor area.

Information on the maintenance condition of each property was also extracted, distinguishing among "to be refurbished", "average", and "refurbished". For listings that provided no explicit information on maintenance condition, the average level was assumed.

The analysis of listing descriptions further revealed a set of recurrent characteristics that were explicitly coded and related to features that help position properties within the tourist rental market segment. Therefore the following dummy variables have been added to the sample: the presence of furniture; the presence of septic tanks, which — following a 2020 amendment to the municipal building code — are mandatory for Bed and Breakfasts and tourist rentals; and the compliance of the property with urban planning and cadastral regulations, whose absence, while not preventing the sale of the property, does preclude its lawful use within the tourist rental market. An additional

variable was included when the listing indicated that the property for sale was provided with a tourist rental license that is a mandatory permit for renting properties for short-term, leisure stays (in addition to the features mentioned above, starting a tourist rental business requires fulfilling several administrative procedures at both local, regional and national levels).



Fig. 3. The OMI zones of the historical center of Venice. B15 – Cannaregio Sud; B16 – San Polo; B17 – Castello Ovest; B19 – Cannaregio Nord; B20 – Dorsoduro Ovest; B21 – Castello Est; B22 – Sant'Elena; B23 – Dorsoduro Est; B24 – San Marco; B25 – Santa Croce; E5 – Giudecca;

Finally, two dummy variables identify whether a listing was published before or after the activation of the Mo.S.E. system. The first variable takes the value of 1 for all the advertisements published from 2021 onwards. The second reflects the hypothesis that the effects of Mo.S.E. on the property market may not be immediate but may become observable only after at least one year; it therefore takes the value of 1 for listings published since 2022. Table 1 summarizes the variables, their definitions, scales, and units of measurement or coding system.

Table 1. Summary of variables

Variable	Description	Scale of measures	Unit of Measure or Coding System
y	Property unit price adjusted to 2018	Ratio	€/m^2
MoSE_21	Advertisement published since 2021	Dummy	1 = yes
MoSE_22	Advertisement published since 2022	Dummy	1 = yes
Mc	Maintenance conditions	Nominal	-1 = To be refurbished 0 = Average 1 = Refurbished
Sa	Saleable area	Ratio	m^2
F	Forniture	Dummy	1 = yes
Upc	Urban planning compliance	Dummy	1 = yes
St	Septic tanks	Dummy	1 = yes
Trl	Tourist rental license	Dummy	1 = yes
MM	Area of the Real Estate Market Monitor	Nominal	B15, B16, B17 … E5

3 Results and Discussion

A preliminary analysis was carried out using the entire sample of 370 observations. The results were unsatisfactory in terms of statistical significance. The reason may lie in the fact that the listings are distributed across all Venice neighborhoods, which include areas that are more or less exposed to the phenomenon of high tides. It can therefore be assumed that the prices of ground-floor properties located in areas not affected by major tide events did not experience any change due to the activation of Mo.S.E. However, the available data do not allow for sufficiently precise geolocation of individual properties to match them with the city's altimetric profile.

For this reason, the analysis was restricted to a subset of neighborhoods that are more frequently exposed to high tides and are located between the northern side of the lagoon and the Canal Grande (Cannaregio, San Marco, Castello, and Sant'Elena). Figure 4 shows a map identifying the areas at risk of flooding at tide levels of 110 cm or higher, along with the zones included in the reduced analysis. The regression was thus conducted on a reduced sample of 240 observations.

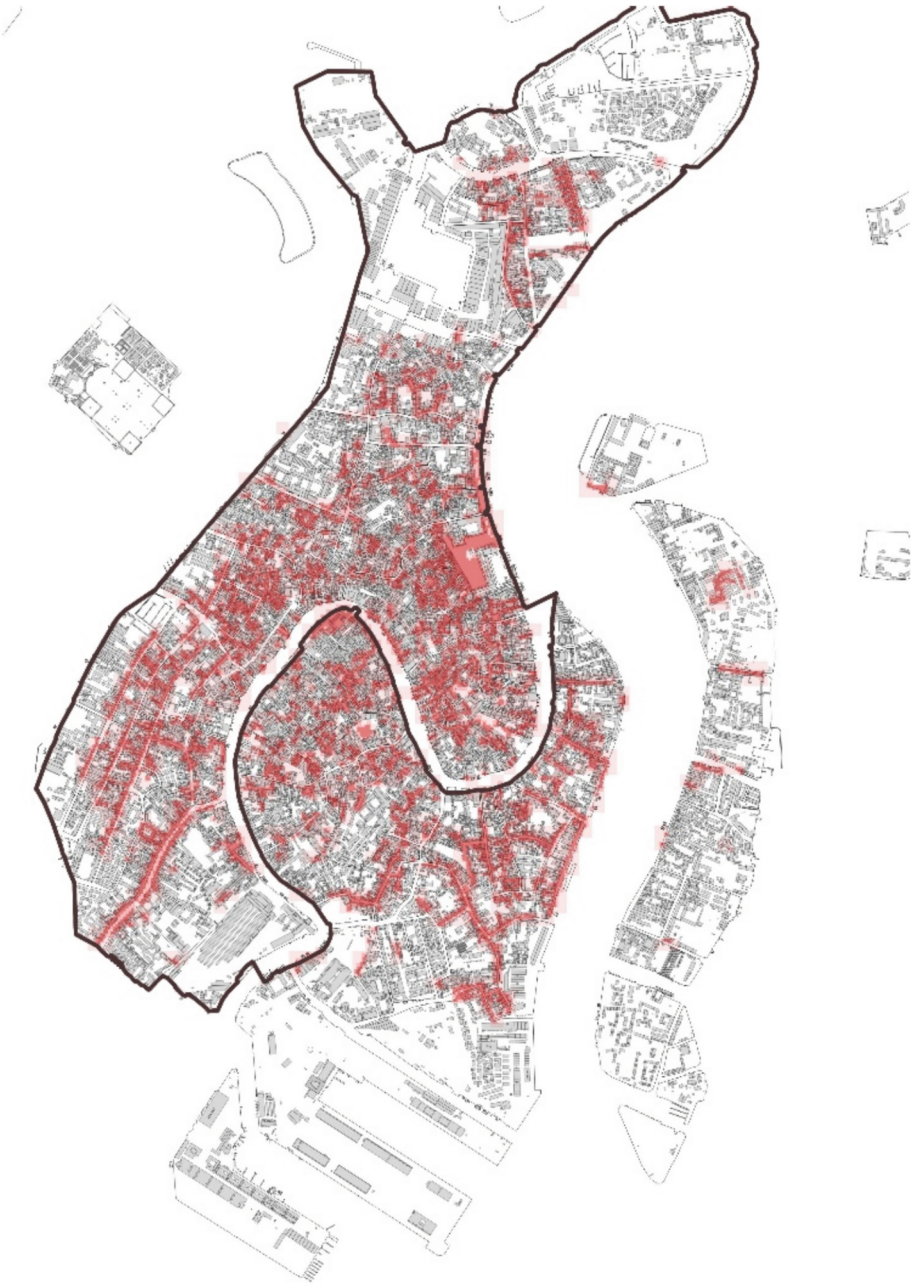

Fig. 4. Zones of the historic center at risk of flooding at tide levels of 110 cm or higher and selected area of analysis

The analysis was then performed using the natural logarithm of the 2018-homogenized unit price as the dependent variable and was carried out by progressively

excluding the independent variables that were found to be not statistically significant. The reduced specifications therefore include seven independent variables. In the first version of the model, the variable MoSE_21 is included among the regressors, whereas in the second version it is replaced by MoSE_22 in order to assess potential delayed effects of the Mo.S.E. activation on the Venetian real estate market.

Table 2. Results for the first model

	coeff	std err	t stat	p-value	vif	Sig.
Const.	9.2005	0.1320	69.7009	0.0000		***
MoSE_21	0.0492	0.0265	1.8560	0.0647	1.0217	*
Mc	0.1794	0.0218	8.2131	0.0000	1.0742	***
Upc	0.2978	0.0494	6.0301	0.0000	1.1631	***
St	0.1055	0.0312	3.3814	0.0008	1.0782	***
B21	−0.1443	0.0315	−4.5853	0.0000	1.0690	***
B17	−0.0991	0.0358	−2.7663	0.0061	1.0723	***
LN_Sa	−0.2860	0.0351	−8.1473	0.0000	1.1700	***
Adj. R^2 0.4862						
Significance level: *** $p < 0.01$; **$p < 0.05$; *$p < 0.1$.						

Table 3. Results for the second model

	coeff	std err	t stat	p-value	vif	Sig.
Const.	9.1678	0.1223	74.9796	0.0000		***
MoSE_22	0.0994	0.0259	3.8334	0.0002	1.0422	***
Mc	0.1772	0.0208	8.5226	0.0000	1.0721	***
Upc	0.2926	0.0482	6.0751	0.0000	1.1640	***
St	0.0901	0.0304	2.9633	0.0034	1.0931	**
B21	−0.1434	0.0307	−4.6645	0.0000	1.0680	***
B17	−0.1037	0.0342	−3.0289	0.0027	1.0738	***
LN_Sa	−0.2800	0.0328	−8.5400	0.0000	1.1740	***
Adj. R^2 0.5100						
Significance level: *** $p < 0.01$; **$p < 0.05$; *$p < 0.1$.						

Standard assumptions of regression are met by both models. The VIFs are always under the threshold of 2.5. In both models, the White Test does not detect heteroskedasticity at the 1% significance level (Model MoSE_2021: LM = 8.10, df = 2, p = 0.017; F = 4.14, df1 = 2, df2 = 237, p = 0.017; Model MoSE_2022: LM = 7,54, df = 2, p = 0,023; F = 3,84, df1 = 2, df2 = 237, p = 0,023). Furthermore, the D'Agostino–Pearson test does not indicate statistically significant departures from normality of residuals

(Model MoSE_2021: DA = 5.05, p = 0.080; Model MoSE_2022: DA = 4.21, p = 0.122).

Both models exhibit an adjusted R^2 of approximately 0.5. In the first specification, the variable MoSE_21 is significant at the 10% level and has a coefficient of 0.0492, whereas in the second specification the variable MoSE_22 is significant at the 1% level and displays a higher coefficient of 0.0994. All other variables in both models are statistically significant at least at the 5% level, and their signs are consistent with expectations (Table 2 and 3).

From an interpretative standpoint, the log-linear specification adopted here allows the coefficients of the independent variables to be read as percentage variations of the dependent variable. Accordingly, the results indicate that the activation of the Mo.S.E. system produced an immediate increase of approximately 5% in the unit values of ground and raised-ground floor properties in Venice, rising to nearly 10% one year after the system first became operational.

With regard to the remaining independent variables — and leaving aside variables whose effects are straightforward and consistent with basic real estate market dynamics — it is worth highlighting the influence on price of the two variables related to urban-planning compliance and the presence of septic tanks. Both have positive and economically meaningful effects on unit price: the presence of septic tanks is associated with an increase of roughly 10%, while full urban-planning compliance yields an estimated price premium of up to 30%.

4 Conclusions and Further Development

In order to assess the effect of the activation of the Mo.S.E. system on property values, using a hedonic price model, the study examined a sample of 240 real estate sale advertisements of housing units located on the ground or raised-ground floor level in selected areas of Venice's historic center that are at risk of flooding, published between 2018 and 2025.The results of the study reveal a positive influence of the Mo.S.E. system on the market value of ground and raised-ground floor housing units in Venice. This effect can be estimated as an increase of approximately 5% in property values starting from 2021, followed by a further rise of about 5% in the subsequent year. These findings are consistent with the estimates proposed by studies conducted both prior to or shortly after the activation of the flood-protection system. The delayed effect is consistent with the hypothesis that the real estate market requires operational and repeated evidence before capitalizing the value of such technological innovations. In other words, the reduction in perceived flood risk appears to have required a period of empirical confirmation before being fully capitalized into property values. Some limitations, however, concern the inability to geolocate the properties and therefore to verify their exact elevation with respect to flood risk, as well as the statistical significance, at the 10% level of the MOSE_21 variable.

It is nevertheless possible that the observed increase in value also incorporates other side effects, such as changes in the requirements for ground-floor units introduced into the municipal building code following the exceptional high tide of 2019. The Building Code of the Municipality of Venice contains a set of provisions specifically regulating ground-floor spaces and the conditions they must meet in order to be considered

suitable for residential use. The regulation stipulates that new constructions must have the ground-floor level set at 1.60 m above MRPS, whereas existing buildings — which constitute the vast majority of the housing stock in the Historic Centre of Venice — may have a ground-floor level as low as 1.00 m provided they are equipped with adequate flood-protection measures In 2019, in response to the extraordinary high tide, additional minimum standards were introduced for ground-floor units (e.g. positioning electrical outlets at least 1.10 m above the floor, installation of a bilge pump and an associated uninterruptible power supply with a minimum autonomy of six hours), which may have partly influenced the property values of ground and raised-ground floor houses after this year.

More broadly, the models highlight the strong positive influence of features such as the presence of septic tanks and full urban-planning compliance — both of which are requirements needed for properties to be used within the tourist-rental market. These aspects raise an important question regarding the true beneficiaries of the implementation of the Mo.S.E. system. While the benefits of Mo.S.E. in terms of safeguarding the city's architectural and artistic heritage are indisputable, the system may simultaneously exacerbate worrying urban dynamics, such as overtourism and depopulation. Indeed, the possibility of exploiting ground-floor spaces — made feasible by the activation of Mo.S.E. — appears to facilitate their conversion into tourist accommodations, thereby contributing to the growth of short-term tourism, a phenomenon associated with urban pressures and social tensions within the historic city.

Future research developments include extending the analysis to the full dataset by incorporating upper-floor properties. This will make it possible to assess whether these units also experienced price effects due, for example, to improved accessibility in areas of the city that were previously prone to rapid flooding. This type of analysis would make it possible to compare the cost of the public investment with the aggregate increase in property values for the city, thereby allowing verification of the results reported in the existing literature and providing useful information for the evaluation of public policies. Such analyses may also offer valuable insights for defining policy implications, particularly with regard to the risk that the entire value uplift could be captured by the short-term rental sector. This scenario would worsen the negative externalities imposed on the city by tourism characterized by very short stays, concentrated in specific periods of the year, which place additional strain on urban management (for example, public transport, waste disposal, and overall residential livability) without generating a commensurate economic return for the city itself.

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