EFFECT OF EARTHQUAKE RISK ON THE REAL ESTATE MARKET

An application to Lisbon

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Effect of earthquake risk on the real estate market – an application to Lisbon

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Motivation

- Real Estate is the largest store of value; Prices have been increasing in recent years increasing the value at risk;
- Lisbon considered to be of moderate seismicity due to proximity to Azores-Gibraltar fault, with two significant earthquakes in 1531 and 1755
- Unawareness of risk to investors and homeowners; How is it valued?
- 63,9% of Lisbon's building stock built before any seismic code

Main Goals of this PhD Work

- Understand how the real estate market values natural hazard risks
- Quantify the risk perception by investors and its impact on property prices
- Analyzing natural hazard value-at-risk on the real estate market in Lisbon

Pratical application:

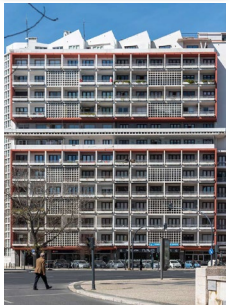
- Homebuyers
- Investors and Developers
- Insurance Companies
- Policymakers

Case Study – Lisbon's Real Estate Market | Housing stock

< 1755

1870-1930

< 1961 / 85



>2000

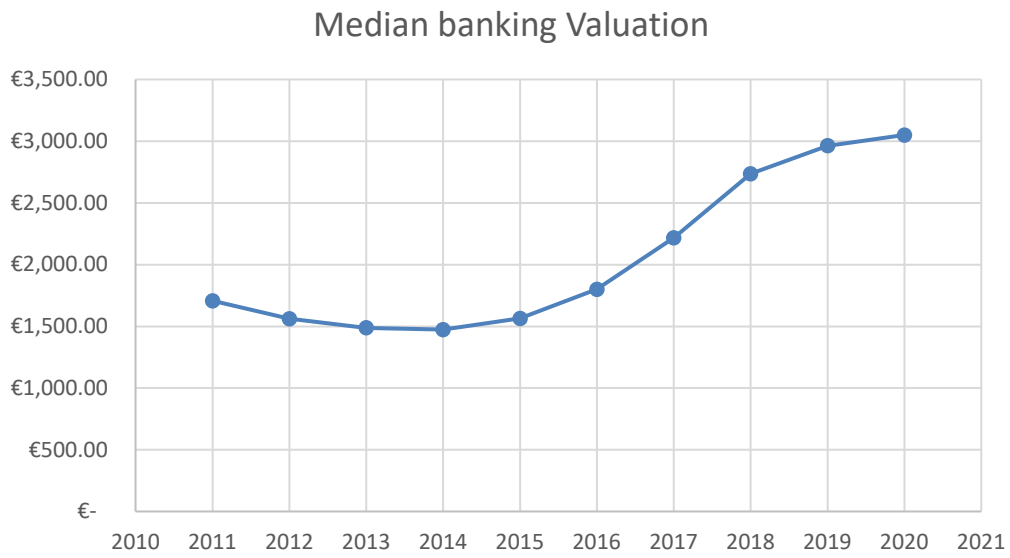
Pre-pombalinos | Pombalinos | **Gaioleiros** | "Placa" | Early RC | Modern RC | Modern RC II

> 1755

1930-1960

1985-2000

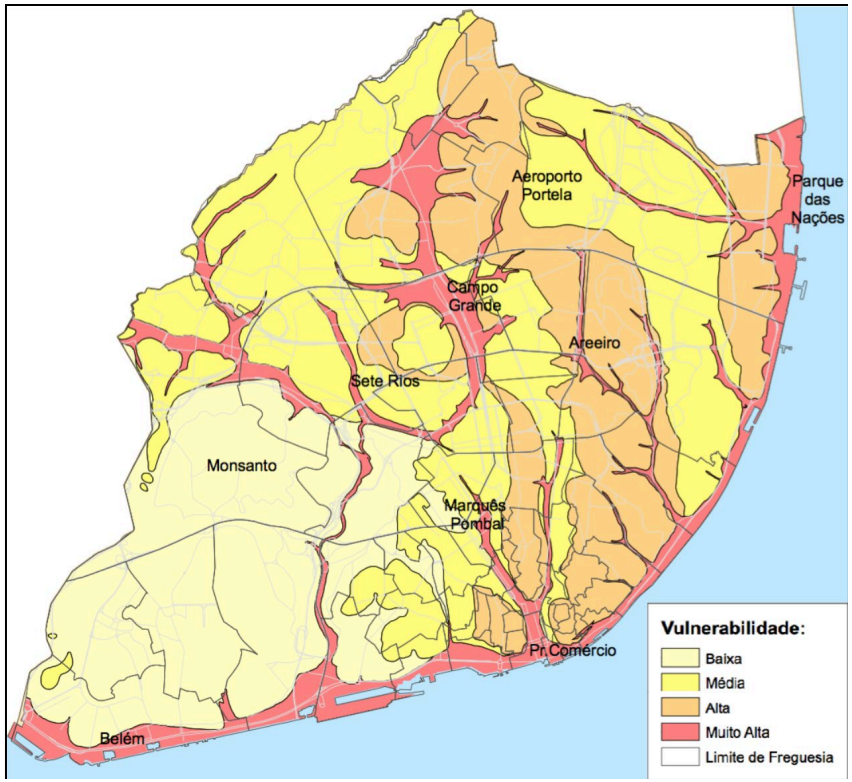
Case Study – Lisbon's Real Estate Market | Price Increase



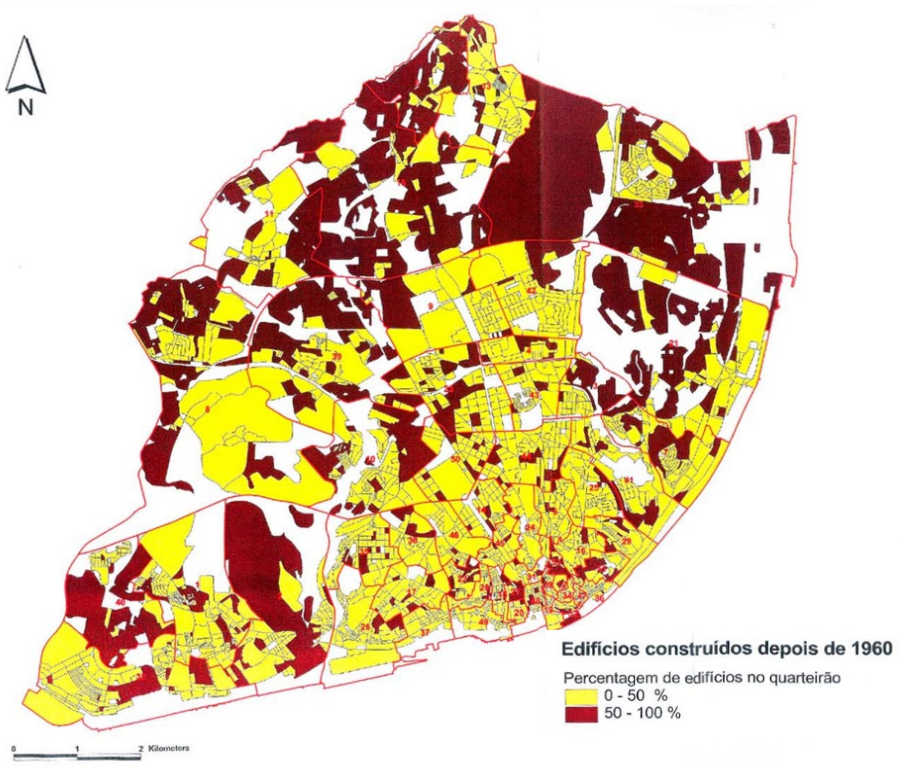
Median Banking Valuation for Lisbon County. Source: INE

As of 2018, according to the Portuguese Insurance Association, **only 16% of dwellings have an insurance coverage for earthquake risk**

Case Study – Lisbon's Real Estate Market | Vulnerability



Lisbon Seismic Vulnerability Map (CML 2008)

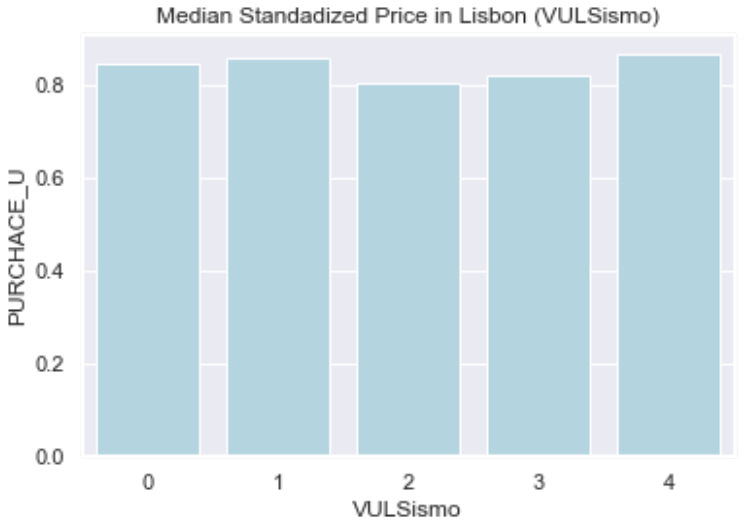


Percentage (%) of buildings (per block) built after 1960. Source: CMLisboa

↑ VALUATIONS + ↑ VULNERABILTY + ↓ AWARENESS = **HIGHER VALUE-AT-RISK** ⚠

Exploratory Data Analysis

| Overview

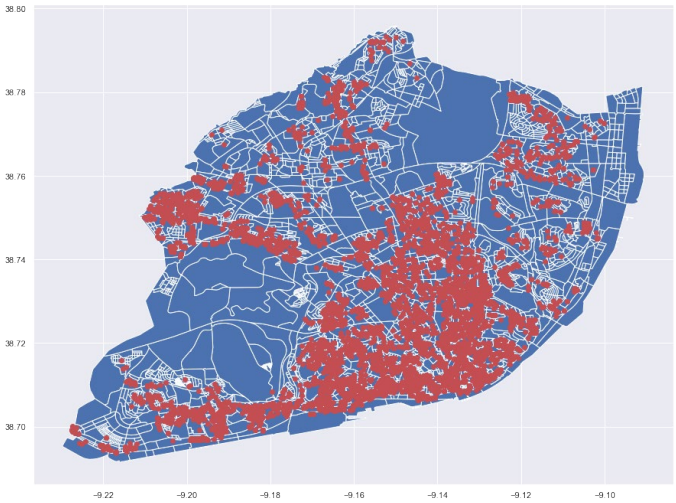


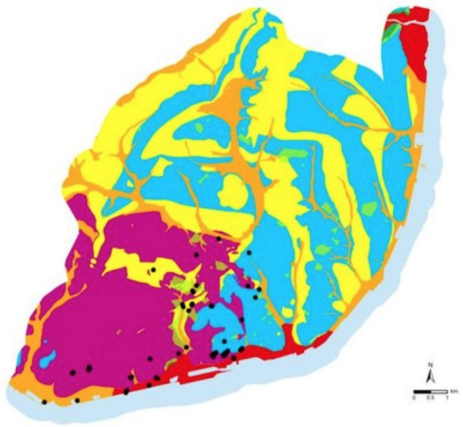
PARISH (VULSismo)	
Santa Maria Maior	20.007315
Arroios	14.374543
São Vicente	11.082663
Penha de França	9.473299
Misericórdia	6.949525

During EDA, a spatial distribution of values, spatial correlation analysis (Moran-I and LISA indicators) and a Principal Component Analysis (PCA) were also conducted

Methodology

| Steps taken





(Oliveira et al. 2019)

All data georeferenced

New and Old Parishes

Crossed data with old and new (2012[1]) administrative limits

Setting #Floors

Crossed data with altimetry map, containing the number of floors (3m floor to floor)

Setting PGA

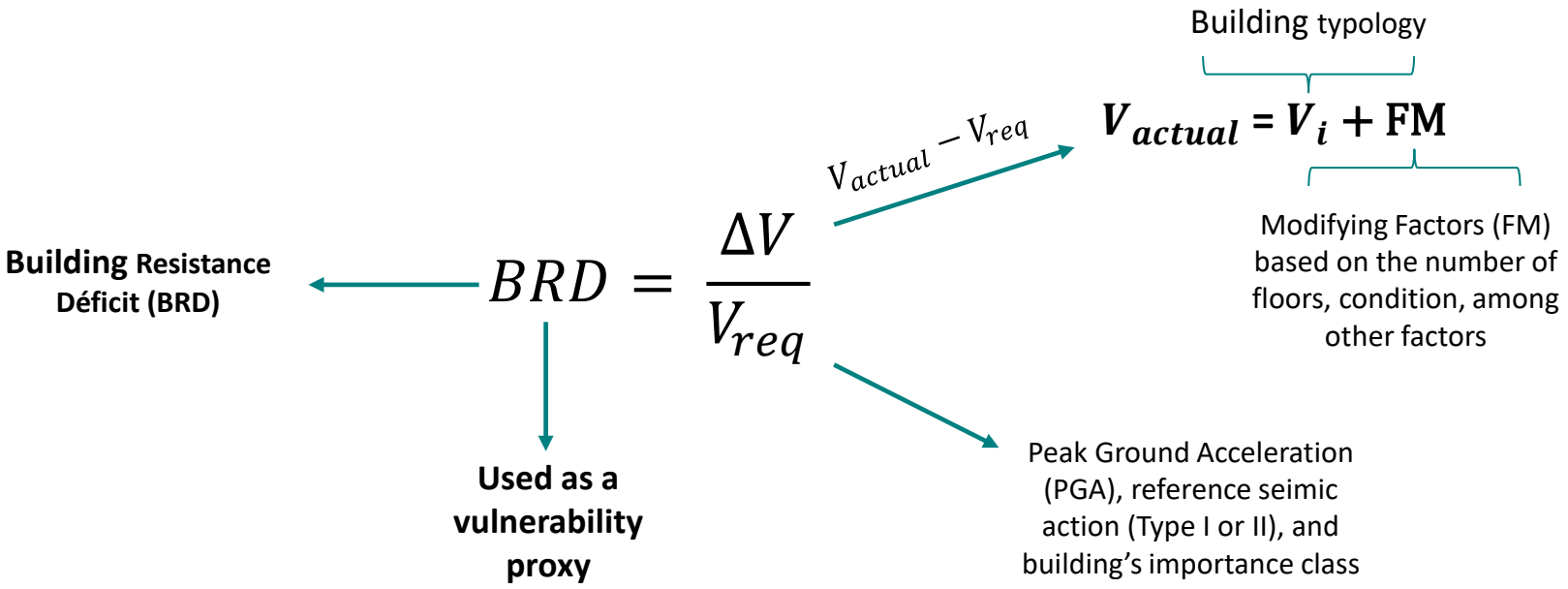
Crossed data with soil type to determine Peak Ground Acceleration (PGA)

[1]Law n.º 56/2012, 08-11

Methodology | Steps taken

Building Resistance Déficit index (BRD)

Based on existing literature, a Building Resistance Déficit index (BRD) was developed, which indicates the expected behaviour of a building for a given level of seimic activity. It compares it expected behaviour to the ideal vulnerability (requirement of no collapse) (Sá, Oliveira e Ferreira 2010; Ferreira 2012; Sá, Oliveira e Ferreira 2013).



References: (Lagomarsino and Gionvinazzi 2006; Sá, Oliveira e Ferreira 2010; Ferreira 2012; Sá, Oliveira e Ferreira 2013)

Methodology | Steps taken

Two approaches to assess vulnerability

$$V_{actual} = V_i + \text{FM}$$

Building Typology	V_{actual}
Masonry (<1945)	0,70
RC (1946-60)	0,60
RC (1961-85)	0,50
RC (1985-...)(≦ 5 floors)	0,40
RC (1985-...)(>5 floors)	0,44

(Ferreira 2012)

Drilling down vulnerabilty classes

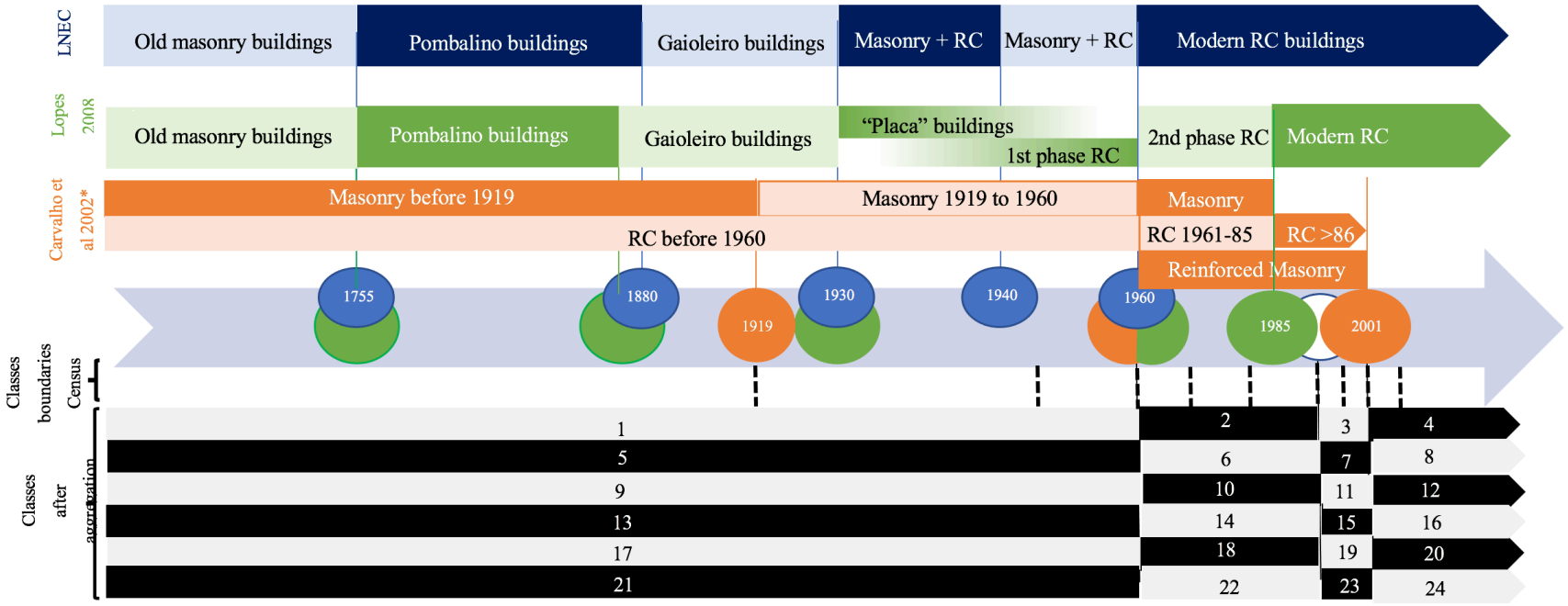
- Epoch according to censos 2011
- Structural materials used

Estimated vulnerabilty class (EMS-98)

- Aggregated to 24 classes from 60
- Attributed vulnerability value

References: (Lagomarsino and Gionvinazzi 2006; Sá, Oliveira e Ferreira 2010; Ferreira 2012; Sá, Oliveira e Ferreira 2013)

Methodology | Steps taken



*Primary classes. Each one is subdivided into seven other subclasses

**weighted values from distance to class limits

References: (Lagomarsino and Gionvinazzi 2006; Sá, Oliveira e Ferreira 2010; Ferreira 2012; Sá, Oliveira e Ferreira 2013)

Methodology

| Steps taken

Base Fixed-Effects Model (Space and Time)

Building Resistance Deficit (BRD)

Dummy for spatial unit (parish)

$$p_{it} = \alpha + \delta X_{it} + \beta BRD_{it} + \mu_i + \phi_t + \varepsilon_{it}$$

Error for parish i *at time t*

Mean sale price, for parish *i* at time *t*

Set of explanatory variables (number of rooms, useful area, construction year, distance to POI)

Dummy for time (year)

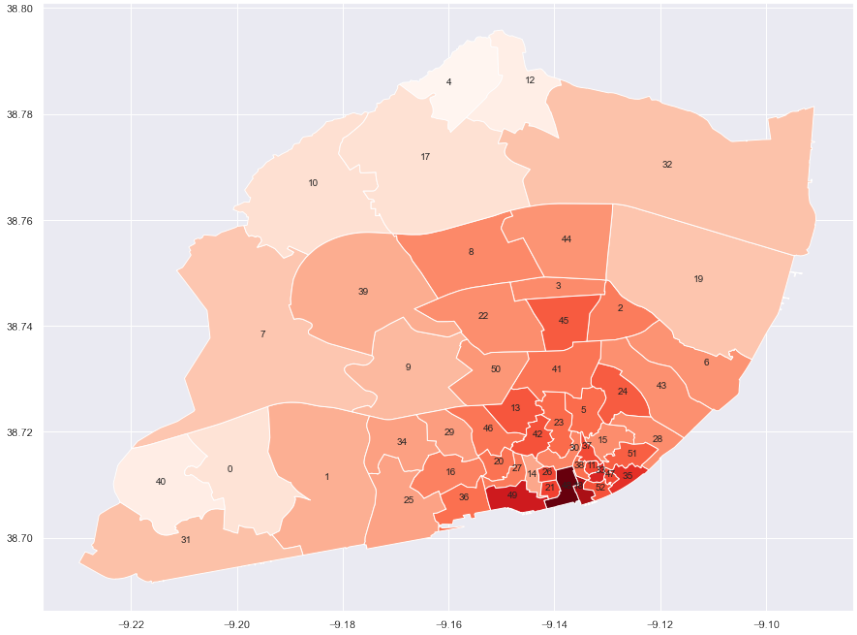
Besides the Fixed-Effects model, a Feasible Generalized Least Squares (FGLS), PooledOLS and an Extreme Gradient Boosting Tree model (XGBoost), were also conducted

References: (Lagomarsino and Gionvinazzi 2006; Sá, Oliveira e Ferreira 2010; Ferreira 2012; Sá, Oliveira e Ferreira 2013)

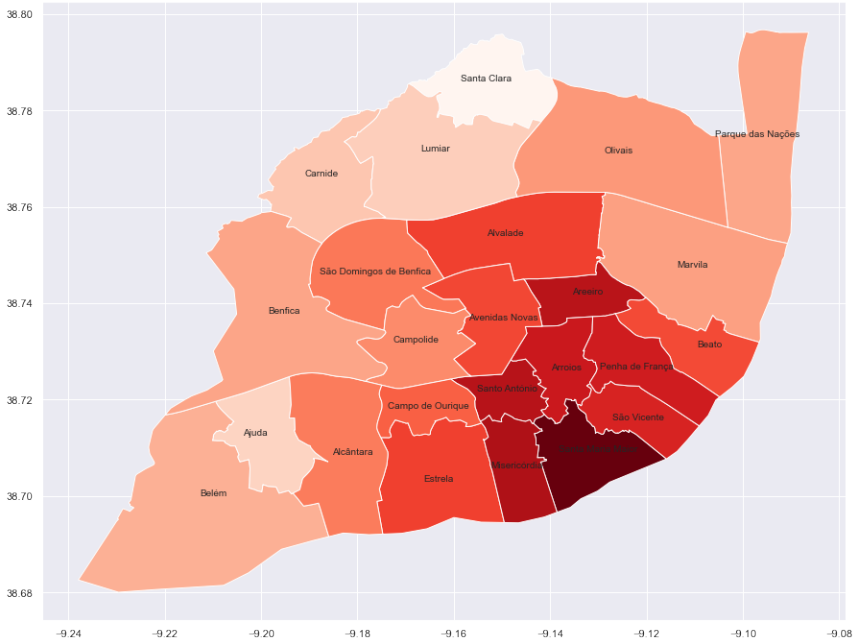
First Results

| BRD Distribution

BRD – Old Parishes (53)



BRD – New Parishes (24)



First Results

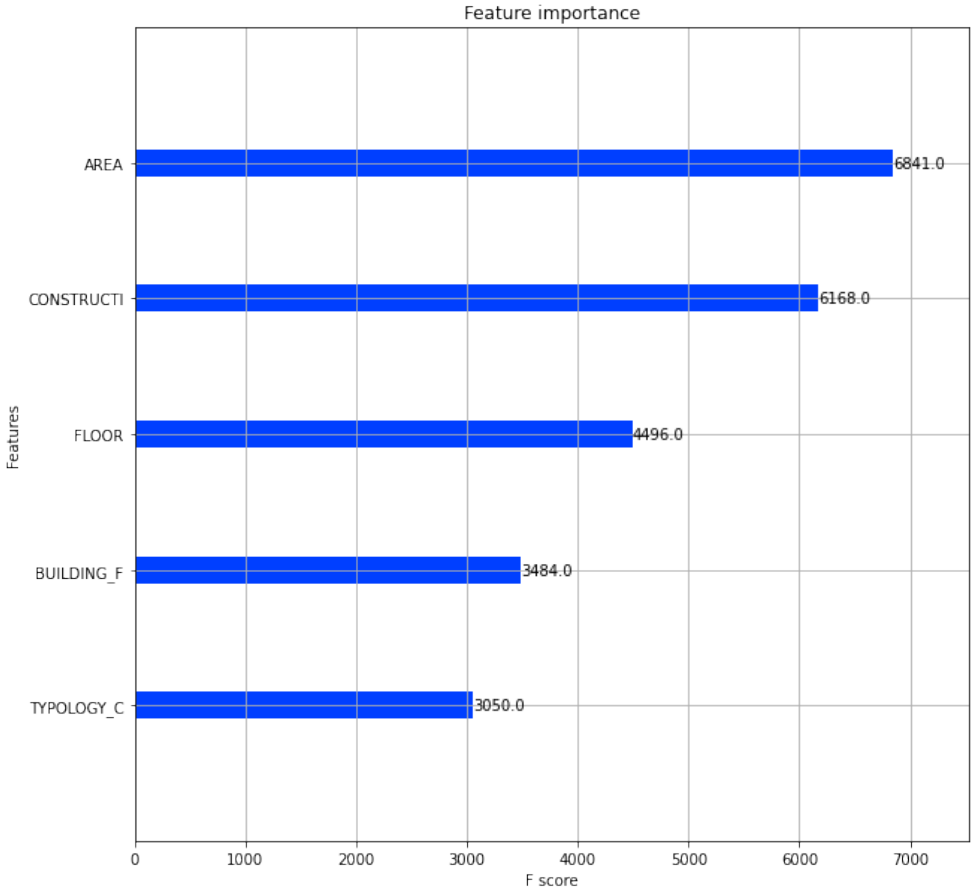
| Fixed-Effects Results

	BRD - First approach				BRD - second approach			
	Old Parishes		New Parishes		Old Parishes		New Parishes	
const	0.597***	0.519***	0.662***	0.594***	0.475***	0.403***	0.578***	0.484***
BUILDING_2	0.159***	0.155***	0.075**	0.083**	0.151***	0.153***	0.095***	0.108***
APARTMENT1	0.078**	0.076**	0.051*	0.049*	0.112***	0.112***	0.052*	0.052*
AREA	-0.001	--	-0.0001	--	-0.0005	--	9.18e-5	--
FLOOR	0.022*	--	-0.0005	--	0.020	--	-0.012	--
BRD_PROXIMO	-0.436***	-0.427***	-0.177	-0.207	-	--	--	--
BRD_PROXIMO_POND	--	--	--	--	-0.223**	-0.221**	-0.0002	0.002
BUILDING_F	--	0.014***	--	0.011***	--	0.014***	--	0.009*
Entities	53	53	23	23	52	52	23	23
Periods	11	11	11	11	11	11	11	11
R^2	18.86%	19.13%	8.49%	10.61%	20.48%	21.39%	9.54%	10.57%
Spatial Autocorrelation of Residuals	No	No	Yes	Yes	No	No	Yes	Yes

***p-value<1%; **p-value<5%; *p-value<10%

First Results

| XGBoost



Parameters	XGBoost Regression 1	XGBoost Regression 2	XGBoost Regression 3	XGBoost Regression 4
n_estimators	1000	500	100	100
learning_rate	0.08	0.08	0.08	0.04
sub_sample	75%	75%	75%	75%
Metrics				
RMSE	0.394	0.389	0.386	0.389
R^2 Score	72.00%	72.70%	73.20%	73.20%
Cross Validation				
#Folds	10	10	10	10
Mean cross-validation score	0.46	0.47	0.5	0.5

Area, construction year, floor number, number of total floors and number of rooms have been found as the most importante features to explain valuations

Remarks

1

The vulnerability of Lisbon's building stock is non-neglectable and should be addressed

2

Buildings located in the city centre, namely in the parishes Santa Maria Maior, Misericórdia and Santo António present the highest resistance deficit values

3

Despite the importance to BRD given by some models, a deeper analysis reveals that the preference is for newly built (high correlation)

4

Location, useful area, construction year, floor and number of rooms are the most impactful features to the property's valuation

5

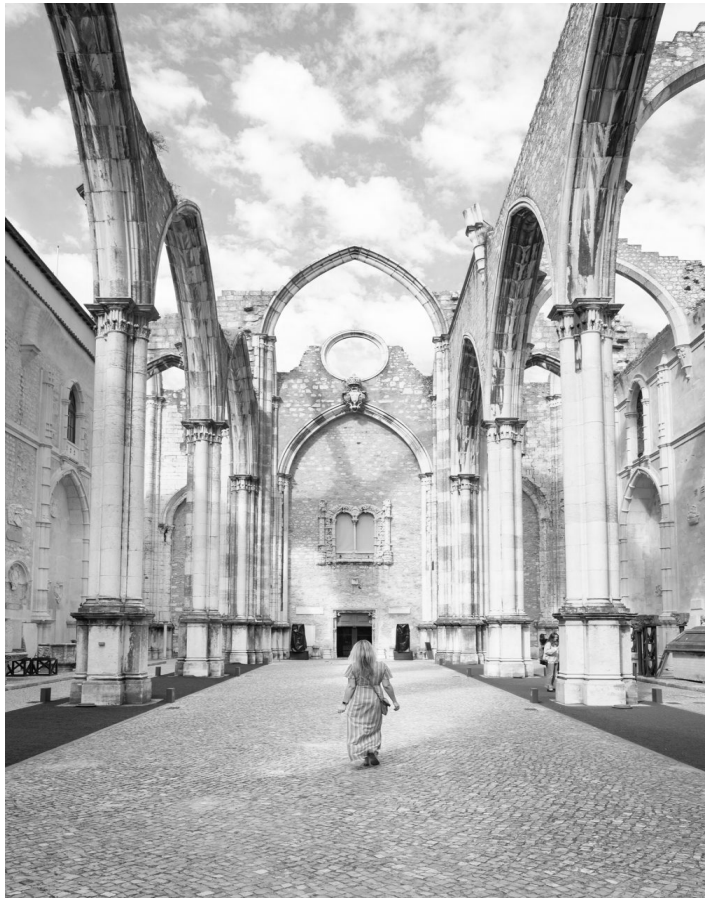
Based on the first results, we may point out a distortion of property market values, given that vulnerability is not directly valued. This distortion may result in added financial and physical risk to families and investors.

6

The direct model approach will be complemented by indirect methods of Contingency Valuation (CVM).

Next Steps

1. Conduct survey
2. Apply statistical models
3. Analyze the results



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Thank you!

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