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Methodological proposal for the development of insurance applicable to building construction elements

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1 Introduction

The application of durability models in the insurance sector is still in an embryonic phase. The Portuguese insurance market, although recognizing the housing stock's degradation problem, has not addressed this area mainly due to the lack of understanding of the natural degradation phenomenon and the associated risks.

This study intends to help the industry's development by analyzing the phenomenon and proposing a viable methodology to cover that risk. In this work a methodology was created for the design of insurance policies covering construction elements, based on their progressive degradation performance data. The analysis of existent insurance policies related to the construction industry is very important to understand and describe, at national and international level, the current scope and the main differences between the currently available insurances and the proposal of this work.

An essential part of this work is the development of probabilistic models related to service life prediction that can be applied in the insurance market and define costs and premium rates. The final objective is to apply the methodology to a case study with natural stone cladding, in order to validate those models.

2 Methodological proposal for insurance design

The diagram below (Figure 2.1) details the insurance policy lifespan. A process of an insurance subscription (AIA, 2016) covers the following areas:

- Application: The insurance company is contacted by the customer to gather information about the types of coverage and the associated costs. An application is filed and sent to the insurance company underwriter;
- Underwriting: A risk evaluation is made by the insurer, based on objective actuarial factors, the amount of coverage requested and the policyholder's insurance history, and the decision about the application's acceptance and the subsequent premium is made;
- Policy issue: Delivery of the policy to the policyholder, which includes an insurance agreement, a declarations page, endorsements and modifications;
- Claims: During the insurance policy period, most policyholders do not submit claims caused by suffered losses. In the event of loss, company's claims department is contacted by the policyholder and a claim is filed. The loss claims will be investigated by a representative, who will verify the particular risk's coverage, determine the policy's application and, if approved, define a repair evaluation;
- Renewal: The duration of most policies is 12 months. The policyholder can choose to cancel the policy during the policy period or to renew it with the same insurer (or move to another insurer) at the end of the policy period.

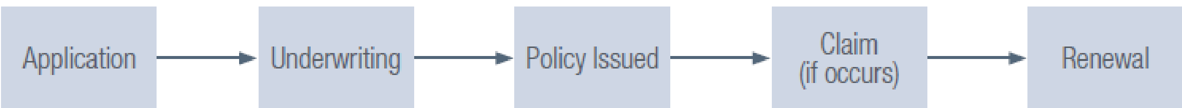

Figure 2.1 - Insurance policy's life cycle (AIA, 2016)

The main issue to overcome in the traditional life cycle is the underwriting topic. Degradation models were applied to help the evaluation process. These represent the evolution of degradation in function of the building's age, which is useful to identify the building elements' expected condition in each instant and end of its service life. Table 2.1 identifies the degradation levels of natural stone based on the anomaly and the area affected.

Table 2.1 - Degradation levels for natural stone claddings (Silva et al., 2011; Mousavi et al., 2017)

Degradation level	Anomaly		% area of cladding affected
Level 0 ($S_{w,\,rp} \leq 1\%$)	No visible degradation		-
Level 1 Good (1% < $S_{w,\,rp} \leq 8\%$)	Aesthetic degradation anomalies	Surface dirt	> 10%
		Moisture stains	≤ 15%
		Localized stains	
		Colour change	
		Flatness deficiencies	≤ 10%
	Loss-of-integrity anomalies	Material degradation (*) ≤ 10% plate thickness	≤ 20%
		Cracking width ≤ 0.2 mm	
Level 2 Slight degradation (8% < $S_{w,\,rp} \leq 20\%$)	Aesthetic degradation anomalies	Moisture stains	> 15%
		Localized stains	
		Colour change	
		Biological growth	≤ 30%
		Parasitic vegetation	
		Efflorescence	
		Flatness deficiencies	> 10% and ≤ 50%
	Joints anomalies	Joints material degradation	≤ 30%
		Loss of material - open joint	≤ 10%
	Fastening to the substrate anomalies	Scaling of stone near the edges Partial loss of stone material	≤ 20%
	Loss-of-integrity anomalies	Material degradation (*) ≤ 10% plate thickness	> 20%
		Material degradation (*) > 10% and ≤ 30% plate thickness	≤ 20%
		Cracking width ≤ 0.2 mm	> 20%
		Cracking width > 0.2 mm and ≤ 3 mm	≤ 20%
		Fracture	≤ 5%
Level 3 Moderate degradation (20% < $S_{w,\,rp} \leq 45\%$)	Aesthetic degradation anomalies	Biological growth	> 30%
		Parasitic vegetation	
		Efflorescence	
		Flatness deficiencies	> 50%
	Joints anomalies	Joints material degradation	> 30%
		Loss of material - open joint	> 10%
	Fastening to the substrate anomalies	Scaling of stone near the edges Partial loss of stone material	> 20%
		Detachment	≤ 10%
	Loss-of-integrity anomalies	Material degradation (*) > 10% and ≤ 30% plate thickness	> 20%
		Material degradation (*) > 30% plate thickness	≤ 20%
		Cracking width > 0.2 mm and ≤ 3 mm	> 20%
		Cracking width ≥ 3m m	≤ 20%
		Fracture	> 5% and ≤ 10%
Level 4 Generalized degradation ($S_{w,\,rp} \geq 45\%$)	Fastening to the substrate anomalies	Detachment	> 10%
	Loss-of-integrity anomalies	Material degradation (*) > 30% plate thickness	> 20%
		Cracking width > 3 mm	
		Fracture	> 10%
(*) - Material degradation is meant to be every anomaly that involves loss of volume of the stone material			

S_w is obtained as the ratio between the extent of the façade degradation, weighted as a function of the degradation level and the severity of the defects, and a reference area, equivalent to the maximum theoretical extent of the degradation for the façade in question (Equation 1):

$$Sw = \frac{\sum(A_n * k_n * k_{a,n})}{A * k} \qquad (1)$$

where S_w is the weighted severity of degradation of the facade (%); A_n is the area of coating affected by a defect, in m^2; k_n is the defect's nth multiplying factor, as a function of its condition (between 0 and 4); $k_{a,n}$ is the weighting coefficient corresponding to the relative importance of each defect based on the cost of repair; k is the weighting factor equal to the highest degradation level in the façade and A is the total area of the cladding, in m^2. The coefficient $k_{a,n}$ takes into account the relative importance of each defect, concerning their repair cost. The cost of repair is calculated as the ratio between the sum of the costs of each operation within the required intervention and the cost of replacing the cladding. If no further data are provided, it is assumed that $k_{a,n} = 1$ (Silva et al., 2016d).

3 Proposal of actuarial models

The insurance methodology exploits four different model types, of increasing complexity: single-parameter deterministic model, multi parameter deterministic model, single-parameter stochastic model and multi parameter stochastic model. The first model is represented in Figure 3.1. Its degradation curve is exclusively in function of the cladding's age (single-parameter model). It was obtained through a simple non-linear regression, where a third grade polynomial equation adjusts to the scatter plot graph with the analyzed claddings.

The results of the estimated life service obtained with the first model can be summarized in Table 3.1. These values are fixed independently of the building to which the model is applied.

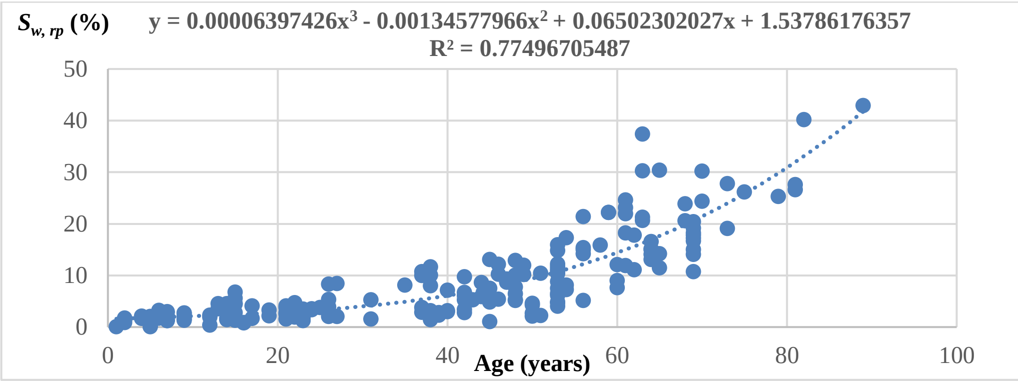

Figure 3.1 - Degradation's evolution using the severity of degradation level for the 142 stone claddings inspected (Silva et al., 2011)

Table 3.1 - Estimated life service of the severity of degradation levels chosen (single-parameter deterministic model)

S_w (%)	Age - estimated service life (years)
10	52
20	68
40	88

The second model (multi parameter deterministic model) utilizes a generic exponential function indicated in Equation (2) (Silva et al., 2016a):

$$Sw = Ae^{B_1*I+B_2*M+B_3*H+B_4*A+B_5*TP} \quad (2)$$

Where S_w represents the claddings' severity of degradation level, I age, M distance from the sea, A area of the cladding, H exposure to humidity, TP type of stone and the estimation parameters are: A = 7,478, B_1 = 0,035, B_2 = -1,501, B_3 = -1,756, B_4 = -1,777 and B_5 = -1,062. Depending on the building's characteristics, the values M, A, H and TP change (Silva et al., 2016b). It is intended, for S_w values of 10%, 20% and 40%, to obtain the respective values of I, like in the previous model.

In reality, buildings have an associated probability of reaching the end of service life before expected, which increases with age. The objective of an insurance company is to transform those probabilities into costs to be able to include unexpected situations during the buildings' service life, whatever the origin of the unforeseen events. Figure 3.2 presents the curves obtained through logistic regression. The analysis is made directly: P (S_w > 10%) reaches 20% at 43 years of age, but at 51 years that probability increases to 50%. As expected, the probability of loss grows with the constructive elements' aging. On the left's graph, the growth of risk takes off at year 30 while on the right one the growth only starts at year 60. The claddings' service life, for each of the S_w levels, can be determined by risk thresholds (Table 3.2). Since only two previous case studies presented an S_w greater than 40%, the ages associated with that degradation level were obtained through a numerical manipulation with physical sense. Analyzing Table 3.2, the reduction of the risk assumed by the insurance company results in an anticipation of the planned maintenance activities, since the degradation threshold is expected to reach the insured asset sooner.

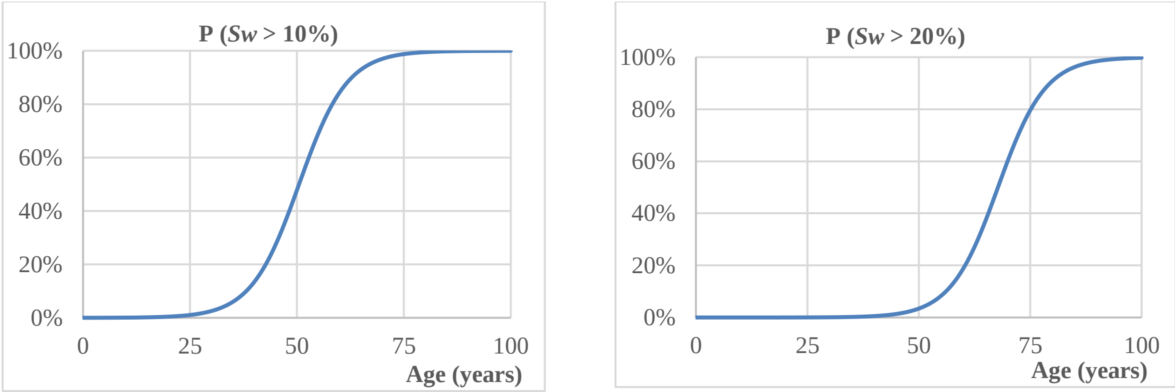

Figure 3.2 - Single-parameter stochastic models for the first (left) and the second (right) defined degradation levels (Silva et al., 2016b) (Silva et al., 2013)

Table 3.2 - Estimated service life for the defined S_w and risk margins (single-parameter stochastic model)

		Risk margin			
		5%	**10%**	**20%**	**50%**
***S**w* **(%)**	**10**	34	39	43	51
	20	53	57	61	68
	40	74	80	85	94

The multi parameter stochastic model follows a similar logic to the single-parameter stochastic one and was developed directly with the case study's data.

3.1 Models' similar aspects

The main coverage of the proposed insurance policy is described below. The claim's filing process occurs in three different S_w thresholds and includes a specific maintenance action:

- S_w reaches 10% → cleaning;
- S_w reaches 20% → major intervention;
- S_w reaches 40% → replacement.

The definition of each level of degradation is based on the information present in Table 2.1. The first one amounts to the cladding's entry on the level 2 (slight degradation), the second one coincides with the limit between level 2 and 3 (conventional end of service life) and the third one corresponds to a late stage of level 3 (moderate degradation). During the periodic assessments, the insurance company registers the S_w value, justified with comments and pictures. Based on the results, the insurance entity decides whether to approve the repairs budget. The maintenance actions previously mentioned include the following:

- Cleaning: includes scaffolding installation, cleaning with water jet, brushing and detergent (Madureira, 2011), correction of cracking ≤ 1 mm and "deep" reposition of 20% of joints;
- Major intervention: includes all the previous action's contents but with a deep reposition of 30% of joints. Additionally, it includes a "light" reposition of the remainder 70% joints and the substitution of 20% of the cladding;
- Replacement: includes scaffolding installation and the complete substitution of the cladding, with the application of the new cladding and the transportation to a landfill of the old cladding included.

Some observations regarding the limitations of these services:

- For each policy (building cladding), each of the described actions is made only once. After a cleaning action, if the element reaches a S_w value of 10% again, the insurer will not interfere. When the degradation levels reach 20%, the company will accept to do a major intervention;
- It was considered, as a simplification, that the maintenance actions have no effect on the value of S_w. The repaired claddings present the same estimated service life as in the moment previous to the intervention;
- It was assumed a total absence of periodic building maintenance by the insured;
- In case of several apartments in the same building, the insurance is shared equally and each one pays the same premium.

An annual policy with renewal option is proposed. When the client accepts to pay for this protection, his premium is fixed as long as he continues the subscription, independent from the rate's volatility. This is beneficial for the insured as he knows how much he/she is going to pay each year without surprises, hassles or extra calculations.

3.2 Calculations

The difference between the expected service lives and the cladding's age result in the different time periods in which the maintenance actions take place (t_{10}, t_{20} e t_{40}). In those periods, money has different present values. The insurance entity expects a replacement cost (negative cash flow) of C_t euros at the end of year t, with a discount rate r (Brealy et al., 2010). The present value of this future payment is calculated by (3):

$$PV = \frac{C_t}{(1+r)^t} \quad (3)$$

The advantage of present values is that they are all expressed in current euros - so one can add them up. For the designed insurance product, the total present value is given by Equation (4):

$$PV = \frac{C_{t,nom(10)}}{(1+r_{nom})^{t_{10}}} + \frac{C_{t,nom(20)}}{(1+r_{nom})^{t_{20}}} + \frac{C_{t,nom(40)}}{(1+r_{nom})^{t_{40}}} \quad (4)$$

The terms $C_{t,\ nom(10)}$, $C_{t,\ nom(20)}$ and $C_{t,\ nom(40)}$ correspond to the nominal costs of the maintenance actions of the different degradation thresholds, t_{10}, t_{20} and t_{40} indicate the year in which those costs occur and r_{nom} represents the nominal discount rate, which includes the global inflation risk, opportunity costs and other costs. In Equation (3), the $C_{t,\ nom}$ terms account for the effect of inflation. The way inflation affects the nominal discount rate can be explained through Fisher's theory (Brealy et al., 2010), in Equation (5):

$$1 + r_{nominal} = (1 + r_{real}) * (1 + i) \Leftrightarrow r_{real} = \frac{1 + r_{nominal}}{1 + i} - 1 \quad (5)$$

It is critical to be consistent utilizing nominal or real values when working with cash flows and discount rates. If $r_{nominal}$ is at 6%, either convert the cash flows to nominal terms and discount at 6%, or convert the discount rate to real terms and use it to discount the real cash flows. To work in nominal terms, it is necessary to take into account trends in equipment, labour and material costs. For that reason, a construction inflation rate (i_s) of 3% and a global inflation rate (i_g) of 2% were adopted. To simplify the case study's result presentation, real values were utilized. Equation (6) and (8) are Equation (4) applied to the expected costs and premiums outlooks respectively.

$$PV, cost = \frac{C_{t,real(10)}}{(1+r_{real,cost})^{t_{10}}} + \frac{C_{t,real(20)}}{(1+r_{real,cost})^{t_{20}}} + \frac{C_{t,real(40)}}{(1+r_{real,cost})^{t_{40}}} \quad (6)$$

The terms $C_{t,\ real(10)}$, $C_{t,\ real(20)}$ e $C_{t,\ real(40)}$ correspond to the real costs of the maintenance actions of the different degradation thresholds, equal for all the presented models. Terms t_{10}, t_{20} e t_{40} indicate the year in which those costs occur. The $r_{real,cost}$ represents the real discount rate, equal for all the models and obtained through (5). The discount rate applied to the cost is presented in Equation (7), which solely accounts the inflation rate i_s:

$$r_{real,cost} = \frac{1 + r_{nominal}}{1 + i_s} - 1 = \frac{1 + 0.06}{1 + 0.03} - 1 = 0.029 = 2.9\% \quad (7)$$

In Equation (8), $C_{t,\ premium}$ corresponds to the annual premium in €/m^2 and is the main result of these models.

$$PV, premium = \frac{C_{t,premium}}{(1+r_{real,premium})^1} + \frac{C_{t,premium}}{(1+r_{real,premium})^2} + \cdots + \frac{C_{t,premium}}{(1+r_{real,premium})^{t_{40}}} \quad (8)$$

The $r_{real,premium}$ also represents a real discount rate equal for all the models. However, this rate accounts not only for the rate i_s but also the rate i_g and is presented on Equation (9):

$$r_{real,premium} = \frac{1 + r_{nominal}}{(1+i_s) * (1+i_g)} - 1 = \frac{1 + 0,06}{(1 + 0.03) * (1 + 0.02)} - 1 = 0,0089 = 0,89\% \quad (9)$$

Equaling (6) and (8), the premium value ($C_{t,prémio}$) is obtained. That value is converted to euros paid per household through the product of the premium by the cladding's area of the building and then dividing by the number of existing apartments. At this stage the model has not considered the insurance company's profit margin. Based on the obtained results on each model, it is possible to translate each obtained probability into a certain profit margin.

4 Case study

An analysis of the proposed models was performed using a real building as a case study. The process started with an information gathering through visual inspection and interviewing the building's Architect. Then, the data was applied in each model and the final results analyzed. The case study is located in Parque das Nações in Lisbon (Portugal). It has 15 apartments and 606 square meters of cladding. The cladding's area was obtained through the product between the area of one stone plate and the number of plates present in the cladding. Table 4.1 presents the building's inputs for the model and Table 4.2 the fixed costs on each of the maintenance actions.

Table 4.1 - Case study's characteristics relevant to the model

Characteristic	Input	Observations
Age of the cladding	14 years	Built in 2003 (the last intervention was a joints' treatment in 2013, no greater interventions have occurred in the cladding)
Colour of natural stone	Light colours	It is a moleanos limestone
Type of finishing	Smooth	-
Area of the stone plate	Medium	Approximately 0.6 m by 0.4 m
Thickness of the stone plate	Up to 2.5 cm	The thickness is close to 2,5cm, but inferior to the one used in stone plates fastened indirectly
Facade area of the cladding	Entirely clad	-
Orientation	NW/W/S/E	Northwest and West - main facade; South - lateral facade; East - backyard facade
Distance from the sea	Up to 5 km	Parque das Nações is an area facing Tagus river
Exposure to wind/rain	Severe	Although it isn't a tall building, the building's surrounding area is considered clear
Exposure to damp	High	-
Use of the building	Residential + commerce	-
Ease of inspection	Normal	The building has 5 stories, near the limit of the normal condition

The cladding's substitution is more expensive than its original replacement (Mousavi et al., 2017). For that reason, a coefficient of 1,1 multiplies the limestone's price.

Table 4.2 - Case study's fixed costs, in prices of 2017, by maintenance action (CYPE, 2016) (Mousavi et al., 2017) (Orçamentos e Orçamentação, 2017)

S_w index	Details of the maintenance task	Costs (Year 0) (€/m^2)
10%	Scaffolding	3.69
	Cracking	8.28
	Cleaning	19.03
	Joint's reposition (20%)	0.2 * 10.26 = 2.05
	Total	**33.05**
20%	Scaffolding	3.69
	Cracking	8.28
	Cleaning	19.03
	Joint's repos. (30%) + Light joint's repos. (70%)	0.3 * 10.26 + 0.7 * (0.5 * 10.26) =6.67
	Cladding's substitution (20%)	0.2 * 1.1 * 51.04 = 11.23
	Total	**48.90**
40%	Scaffolding	3.69
	Cladding's substitution (100%)	1.1 * 51.04 = 56.14
	Total	**59.83**

4.1 Result's analysis

With the building's characteristics, the application of the multi parameter models for the case study is feasible and the comparison between the resulting service life values and the ones obtained through the single-parameter models. That knowledge paired with the costs previously presented allows the calculation of the risk premium for each model.

Table 4.3 presents each one of the independent variables, with the values of the case study corresponding to the shaded ones. Those values were introduced in (2) and from them the estimated service life values for each defined S_w presented in Table 4.4 were obtained. For the multi parameter stochastic models, the obtained curves are represented in Figure 4.1 and its interpretation is in every way similar to the Figure 3.2.

Table 4.3 - Variables of the multi parametermulti parameter deterministic model and values

Independent variables	Variables' quantification		
Distance from the sea	≤ 5 km: 0.96	> 5 km: 1.03	
Dimensions of stone plates	Medium dimensions: 1.04	Large dimensions: 0.94	
Exposure to damp	Low: 1.03	High: 0.91	
Type of stone	Limestone: 1.04	Marble: 0.96	Granite: 1.39

Table 4.4 - Estimated service life for the chosen degradation thresholds (multi parametermulti parameter deterministic model)

S_w (%)	Age - estimated service life (years)
10	48
20	68
40	87

Comparing the above left graph with the left graph of Figure 3.2, one can conclude that these are approximately equivalent; thus for P (S_w > 10%) the model that distinguishes the different characteristics produces results aligned to the one that does not distinguish them. However, matching the right graph above with the right graph of Figure 3.2 results in considerable differences. When the characteristics are considered, the curve expands in the region between 65 and 80 years. The increase of information about the insured object translates in a greater expectation of the second maintenance work to happen in that service life interval. Like Table 3.2, Table 4.5 presents the cladding's service life for each S_w level in crescent order of risk margin. The last level's results were also obtained through a numerical manipulation due to the deficit of previous case studies in those conditions.

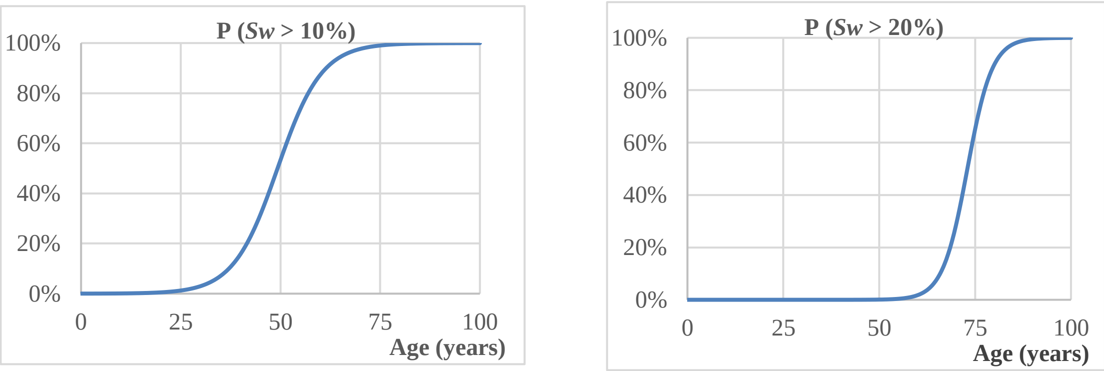

Figure 4.1 - Multi parameter stochastic models for the first (left) and the second (right) defined degradation levels

Table 4.5 - Estimated service life for the defined S_w and risk margins (multi parameter stochastic model)

		Risk margins			
		5%	**10%**	**20%**	**50%**
S_w (%)	**10**	33	38	42	50
	20	64	66	69	73
	40	84	86	90	95

In the multi parameter stochastic model, the risk's reduction equals an advancement on the maintenance action's schedule. This effect is less noticeable in the second and third degradation level. Table 4.6 displays the case study's remaining years until the proposed maintenance actions, for each considered model. The values were obtained by subtracting the different estimated service life values previously presented by the age of the cladding (14 years).

Table 4.6 - Case study's estimated service life for the defined degradation levels, by model

		Deterministic		**Single-parameter stochastic**				**Multi parameter stochastic**			
		Single-parameter	Multi parameter	Risk margins							
				5%	10%	20%	50%	5%	10%	20%	50%
S_w	10%	38	34	20	25	29	37	19	24	28	36
	20%	54	54	39	43	47	54	50	52	55	59
	40%	74	73	60	66	71	80	70	72	76	81

Table 4.6 highlights some aspects deemed important:

- For the deterministic models, the characteristics' differentiation has no influence. The age's difference observed between both models is nonessential. The service life comparison between single-parameter stochastic and multi parameter stochastic for the threshold S_w=10%, for any risk margin is also inconclusive;

- For the thresholds S_w=20% e S_w=40%, in both stochastic models, the less the assumed risk margin, the less the service life value remaining. This principle is more suggestive in the single-parameter model and for replacement actions (last line of the table) than in the multi parameter model and major intervention actions;
- For a fixed risk margin, in both the second and third degradation thresholds, the expected service life is higher in the multi parameter stochastic model than in the single-parameter one. The difference is substantial for less risk margins (5%) and in the major intervention maintenance action.

With the service life values defined, the premium calculations for each model can be done. The method is the same for every model, the aspects that change between them are the years in which the maintenance actions occur and the maximum duration of the policy through renewal. This duration corresponds to the period until the materialization of the last maintenance action associated with S_w=40%. The procedure will be exemplified with the single-parameter deterministic model. Equation (8) can be modified into Equation (10) (Brealy et al., 2010), that eases the calculation's interpretations.

$$PV, premium = C_{t,premium}\left(\frac{1}{r_{real,premium}} - \frac{1}{r_{real,premium}(1 + r_{real,premium})^{t_{40}}}\right) \tag{10}$$

Applying the data to Equation (6) results in Equation (11):

$$PV, cost = \frac{33.05}{1.029^{38}} + \frac{48.90}{1.029^{54}} + \frac{59.83}{1.029^{74}} = 28.63\ €/m^2 \tag{11}$$

Lastly, substituting the result of (10) with the $PV, premium$ of (9) produces the Equation (12):

$$28.63 = C_{t,premium}\left(\frac{1}{0.0089} - \frac{1}{0.0089(1 + 0.0089)^{74}}\right) \Leftrightarrow C_{t,premium} = 0\ 53\ €/m^2 \tag{12}$$

This result is the risk premium rate for this case study, when the insurance is subscribed in 2017 based on this model. The risk premium by household is obtained through Equation (13):

$$\frac{C_{t,premium} * Area\ of\ stone\ cladding}{N.º\ of\ households} = \frac{0.53 * 606}{15} = 21.45\ €/m^2 \tag{13}$$

The commercial premium is retrieved multiplying the result of (13) with coefficients that symbolize margins for administrative expenses and expected profit. In this methodology, a fixed coefficient of 1.3 universal to all models that intends to cover the fixed costs present in any financial institution is considered first. A safety margin of 1.2 for single-parameter and 1.1 for the multi parameter is also applied, accounting for the model's risks. The commercial premium by household of the case study's building, for the single-parameter deterministic model, is 33.47 €. Table 4.7 summarizes the same calculations for the remainder models.

Table 4.7 - Summary table with estimated service lives, estimated costs, risk premium rates, risk premiums by household, risk coefficients and commercial premiums by household for the different models

		Deterministic		Single-parameter stochastic				Multi parameter stochastic			
		Single-parameter	Multi parameter	5%	10%	20%	50%	5%	10%	20%	50%
S_w	10%	38	34	20	25	29	37	19	24	28	36
	20%	54	54	39	43	47	54	50	52	55	59
	40%	74	73	60	66	71	80	70	72	76	81
PV, cost (€/m^2)		28,63	30.19	45.26	39.35	34.85	27.82	38.81	35.15	31.63	26.59
$C_{t,\ premium}$ (€/m^2)		0,53	0.56	0.98	0.79	0.67	0.49	0.75	0.66	0.58	0.46
Risk premium by household (€)		21,45	22.84	39.55	32.02	26.90	19.75	30.26	26.86	23.26	18.72
Risk coefficients		1,3*1,2	1.3*1.1	1.3*1.2				1.3*1.1			
Commercial premium by household (€)		33,47	32.66	61.69	49.96	41.96	30.80	43.28	38.41	33.26	26.77
Final premium by household (€)		-	-	33.89	32.72	31.92	30.80	28.42	27.93	27.42	26.77

Table 4.7 shows the relation between the estimated service lives of each maintenance repair work and the resulting insurance's premium. The deterministic mode, although the simplest, has the same probability of not estimating correctly the

service life as the stochastic model with a risk margin of 50%. The simplification of using the average values issues a risk premium slightly higher. The obtained results grant some observations:

- In the deterministic models, the commercial premium's difference between the single-parameter and multi parameter models is not even 1€. This result reaffirms the lack of preponderance of the characteristics' differentiation in these models;
- In the stochastic models, the lesser the assumed risk margin, the greater the premium. This aspect is more evident for the single-parameter model;
- For a fixed risk margin, the premium is less in the multi parameter stochastic model than in the single-parameter one. The difference is significant for smaller risk margins (5%);

The insurance business is highly dynamic and competitive in which the clients' majority is driven by basic insurance products with the least premium possible (Vida Económica, 2015). An insurance product based on a deterministic model will not be able to compete against an insurance based on a stochastic model with a 50% risk margin because it provides the same coverage and risk charging a higher premium.

The risk premium is greater for an insurance product that predicts with greater prudence the expected intervention periods because the cost's increase is passed to the client. During the subscription to the product "multi parameter stochastic 5%", the insurance company considers that the client's building belongs to the 5% whose cladding will need a cleaning at year 19, a major intervention at year 50 and a replacement at year 70. Realistically, 95% of the clients' buildings will have those maintenance needs at a later stage of the cladding's life, which results in lower costs for the insurer.

In order to provide a greater balance to the commercial premiums, increasing their competitiveness and motivating a risk reduction, a further calculation was made in the stochastic model's results. For models with risk margins lower than 50%, the insurance company decreases 90% the difference between the premium of the considered model and the premium of the 50% risk margin model. In Equation (14) an example of the procedure for the multi parameter stochastic model with 5% risk margin is presented:

$$Final\ premium\ by\ household = 43.28\ - 0.9 * (43.28 - 26.77) = 28.42\ € \tag{14}$$

The methodology section responsible for the premium's valuation needs to be adjusted based on its portfolio and the market conditions. In this work, a proposal that fits in the observed context was presented, although it needs to be applied and readjusted over time.

After calculating the risk premiums for the various models and the adjustment and determination of the final premium per condominium, it is concluded that for the insurer, the best model to apply corresponds to the stochastic multiparameter 5 %. Increased knowledge translates into better information that enables the insurer's exposure to risk to be significantly reduced without making final premium amounts inaccessible to customers.

The implementation of a line of policies such as those proposed in this work would be particularly advantageous in the form of a building warranty for building management and maintenance companies, not only because the warranties format, analyzed at an international level, present greater value in this context, but mainly due to these entities' characteristics.

Compared to the private owners of a single dwelling, they present a superior risk because of the greater number of buildings for which they are responsible. This product offers both the risk's mitigation, fundamental to the activity of these companies, at a moderate cost, and the exchange of knowledge between both entities, that results in service gains for the client.

5 Conclusions

Unlike the deterministic models, the characteristics' segmentation in the stochastic models allowed risk and premium reductions through the increased knowledge of the insured object. The increase of the model's sophistication led to a decrease in the clients' premium and an increase in the company's safety, creating a beneficial situation for both parties. These measures can affect in the long term the profits per client, but with the service's improvement and a lower premium a greater number of clients in portfolio and globally a decrease in risk are expected. This product presents several advantages:

- In residential condominiums, insurance can be issued by sharing risks within the households and resulting in a lesser premium for each;
- It promotes quality construction, since the insurance protects against bad options in materials and construction practices;
- Insurance companies schedule and perform the "examination" when the claim is made, unlike what happens in the majority of housing. As they have no interest in delaying the building's maintenance, the insured housing gets a renewed look, benefitting the image of the neighborhood/city;
- The developed insurance product can be resumed in a service given to the clients, so its usefulness raises the global value of the covered building. This characteristic allows the commercialization of the insurance by real estate promotion, besides the usual distribution channels (Internet, banks, brokers, agents, amongst others).

The commercial premium for the inhabitants of the case study varies between 25 € and 35 € per year. These values, comparatively to the premiums presented by Dias (2014), represent a reduction over 60%. Considering the average apartment's real estate value, the yearly premium does not even get close to 0.1% of the cost of an apartment. The same cannot be said about vehicles' insurance, the most popular non-life insurance branch, where is unexpected that the premium equals 0.1% the value of the car. This difference shows the asymmetry in the way society values the building stock compared to other tangible assets.

In future research, it would be relevant to evaluate similar insurance products covering different facade materials such as ceramic cladding or rendered facades and covering other building elements like the roof and the structure. Variations in the maintenance actions and periods flexible with the building's needs, model's application to dwellings and real measurement of the S_w in future case studies are also solid aspects to cover in the future.

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