VALIDATION TEST AND BACKTEST ON EARTHQUAKE MODELS FOR TWO INSURANCE COMPANIES IN ROMANIA

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Abstract
The present paper presents a practical example of methods and tests which are used by companies in the Romanian insurance market with regards to choosing the most feasible model in order to validate their partial internal model and to use it for internal calculation of solvency capital requirement. The focus of the analysis carried on by the author was on earthquake model and content of the paper presents the validation of individual components in the model starting with the exposure and its processing. The back test considers how the rare past catastrophes are described in the models. The validation tests show that the used model – Impact Forecasting – is the best to be chosen of the available models.

Keywords: *earthquakes, insurance, insurance companies, natural peril, portfolio analysis, risks*
JEL Classification: *D81, G22, Q54*

Introduction

Earthquake models as well other typology of catastrophes are requesting a high amount of data in order to construct the model properly and finally to validate it. In order to be considered as reliable, any model is significantly dependent on the deep understanding of the underlying physical mechanisms that might influence or control the occurrence and modality of evolution as well the behaviour of earthquake or any other natural hazard.

While one or even more employees of any insurance company or other risk carrier do not have such wide and deep knowledge of all the implications and very technical data and information, the insurers are using already consecrated systems at the international level. They simulate with their systems and specialists in order to choose the best solution which is answering the needs of the insurance company.

For Romania, a major earthquake seems to be a horror scenario or a nightmare that people and authorities hope this will never come true. Remembering the 1977 earthquake from time to time, especially around 4th of March – the date it happened –, creates emotion in the society, fuelled by a never tired mass-media in search of articles to attract readers.

For the insurance market, in particular, this kind of event does not represent a nightmare that may come true, but an actual "it's going to happen" event. Thus, taken into account the provisions of the law, and the degree of insurance coverage, the actuaries of the Insurers that underwrite this kind of natural catastrophe are constantly analysing scenarios.

In Romania, there are two kind of policies that cover the possible effects of an earthquake: (i) PAD - Natural Disaster Insurance Policy – that is a compulsory insurance policy that covers damage caused by floods, earthquakes or landslides on homes, and (ii) Facultative policies that cover this kind of disaster among other risks related to housing.

While PAD is compulsory by law for the natural persons and covers 20.000 euros or 10.000 euros per year, depending on the type of home, the facultative policies cover up the full value of the houses/buildings. In present, 17 Insurers in Romania are involved in the distribution of PAD policies, and there are underwritten 1,7 million policies, with an aggregated sum insured of 33 billion euro.

This article presents the findings of the research the author carried upon the data of two important Insurer companies in Romania for the earthquake's insurance coverage area. Due to competition issues, the two Insurers were not named in this article but referred an 1st Insurer and 2nd Insurer.

The research took into account four models used on large scale to evaluate and manage catastrophic risks – IF, RMS, AIR and EQE – and focused on the validation test and back test for the two insurer companies mentioned above.

Validation tests on selected earthquake models

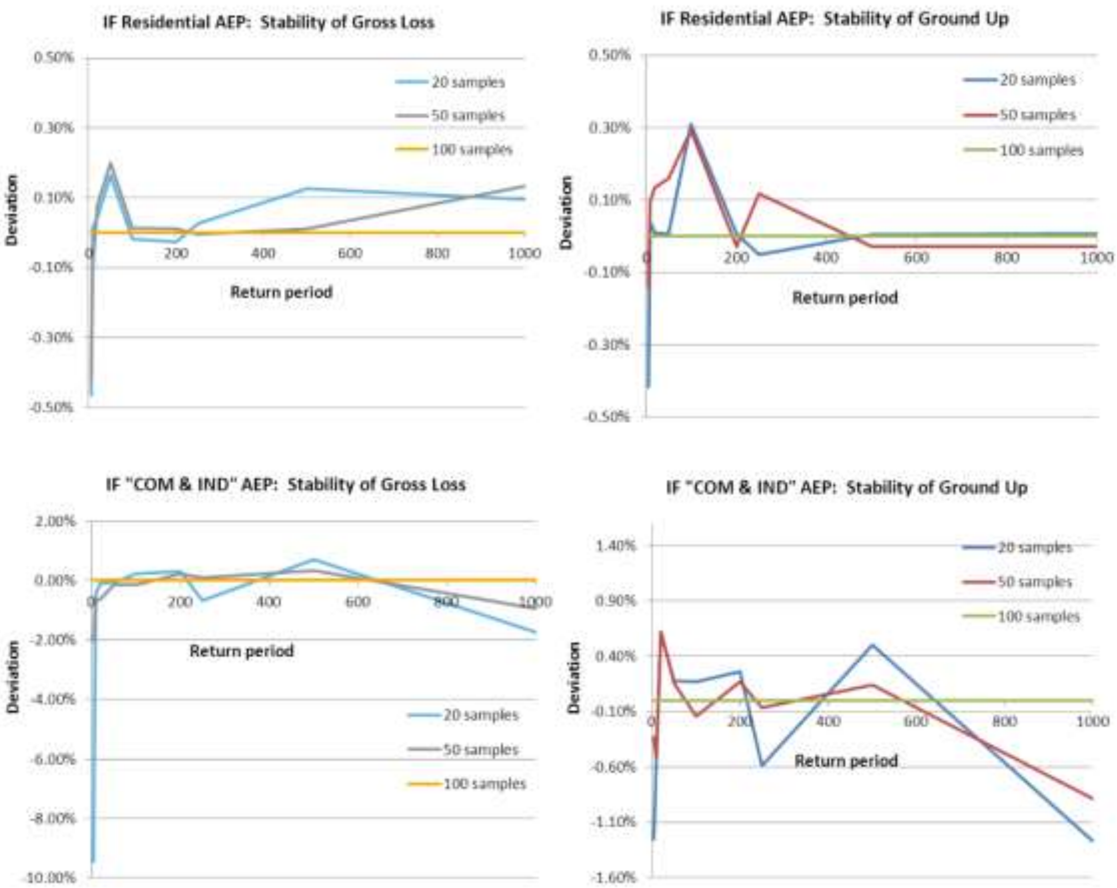
This research starts from the point in that the two Example Insurers perform detailed validation tests for the IF model as it is regarded to be the most appropriate model. Certain tests were also performed for the other available models in order to illustrate the differences and show that the IF model fits the best.

The graphics below are mostly shown for 2nd Insurer's portfolio, which tends to be the representative of the Romanian market

Stability testing

The two Example Insurers tested the stability by using a different number of samples. 2nd Insurer's portfolio demonstrates relatively good stability in ground-up losses, even if it is a little bit restored after the application of limits and deductibles. All deviations are still in a reasonable ranch of maximum about 1% at the 200-year level. For the stability of 2nd Insurer's portfolio, there were tested about 384.382 residential risks, 48.591 commercial and industrial risks. 1st Insurer's portfolio is tested on 287.213 residential risks and 20.225 commercial and industrial risks.

Figure no. 1 – Stability testing



Source: author's research results – data processed with Impact Forecasting - Aon Benfield Analytics

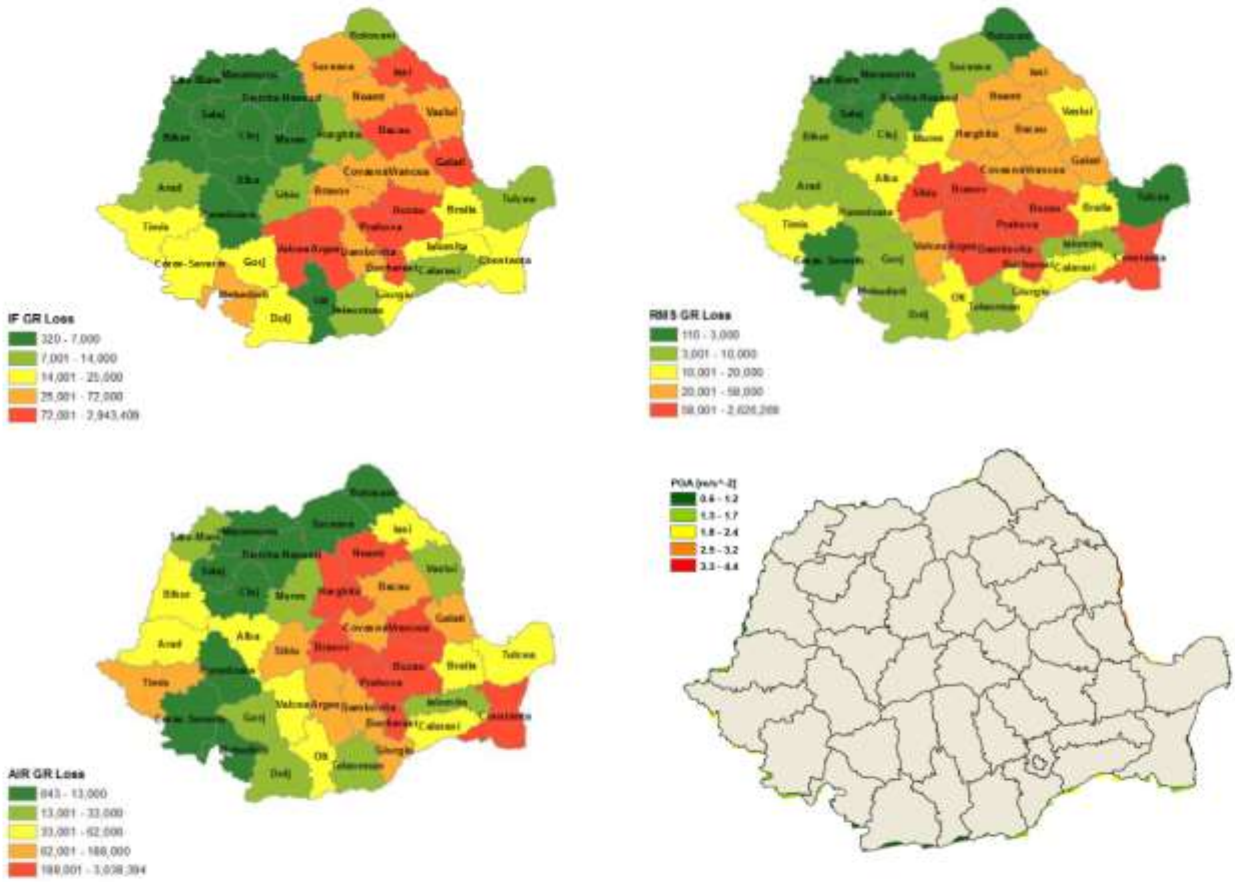
Sensitivity testing

The following figures show the sensitivity tests of the two Example Insurers performed by changing material assumptions of the exposure. The two Example Insurers performed the sensitivity test on CRESTA[1] zone level and compares hazard exposure of Annual Average Loss (AAL) with 1 in 200 loss expectation for models of IF/ RMS/ AIR. We can observe a material difference in respect to individual models.

All Lines of Business (LoBs) combined were analysed (residential, commercial, industrial) and the AAL on CRESTA level was extracted in order to quantify the geographical spreading of earthquake risk used in the simulation of each model for comparison purposes.

[1] CRESTA (Catastrophe Risk Evaluation and Standardizing Target Accumulations) is a *"system for the accumulation risk control of natural hazards - particularly earthquakes, storms and floods"* (www.wikipedia.org).

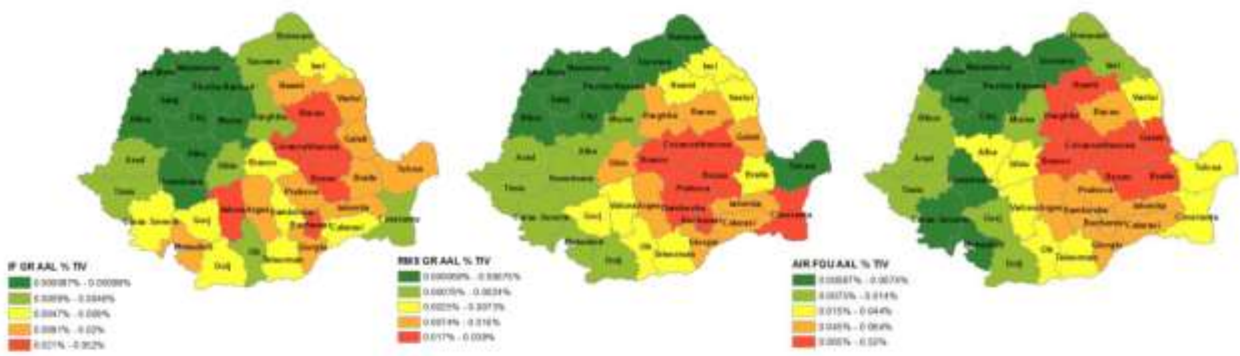
Figure no. 2 - GSHAP Hazard map



Source: (Global Seismic Hazard Assessment Program 1992 - 1999)

It is important to underline that GSHAP is a global project and it does not reflect all local specifics, like local ground-shaking amplification in Bucharest.

Figure no. 3 – Sensitivity testing

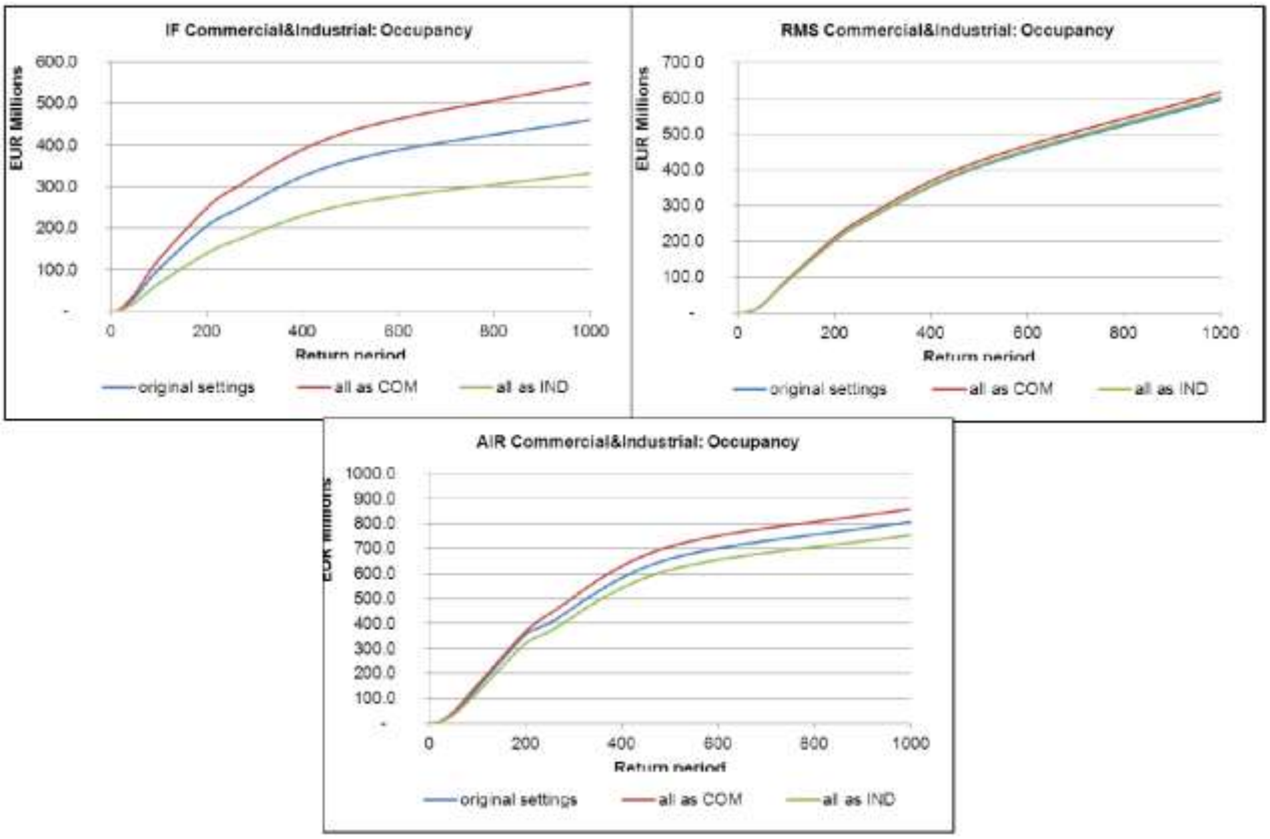


Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

To observe the effect of occupancy allocation, we analysed the two Example Insurer's commercial and industrial portfolio as assumed under different occupancy expectations as recorded in the system.

To assess the impact of uncertainty in the allocation of non-residential occupancies, we modelled non-residential lines once as all commercial and once as all industrial and compared the results with those using the original allocation of occupancies, as used for renewal modelling. The analysis is shown by the Exceedance probability curve for pre-defined return periods of gross loss.

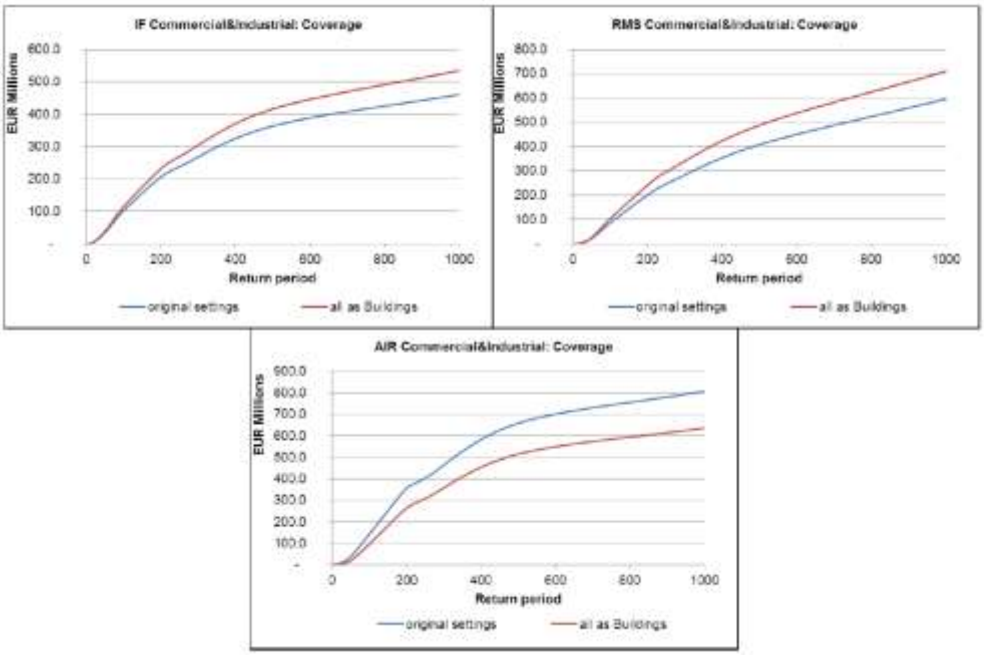
Figure no. 4 - Sensitivity of vulnerabilities – occupancy



Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

The sensitivity impact of non-residential lines (commercial and industrial) is assessed once with the original split to buildings, contents and BI and once with buildings only. This analysis clearly shows the impact of the high vulnerability assumptions for content in the AIR model.

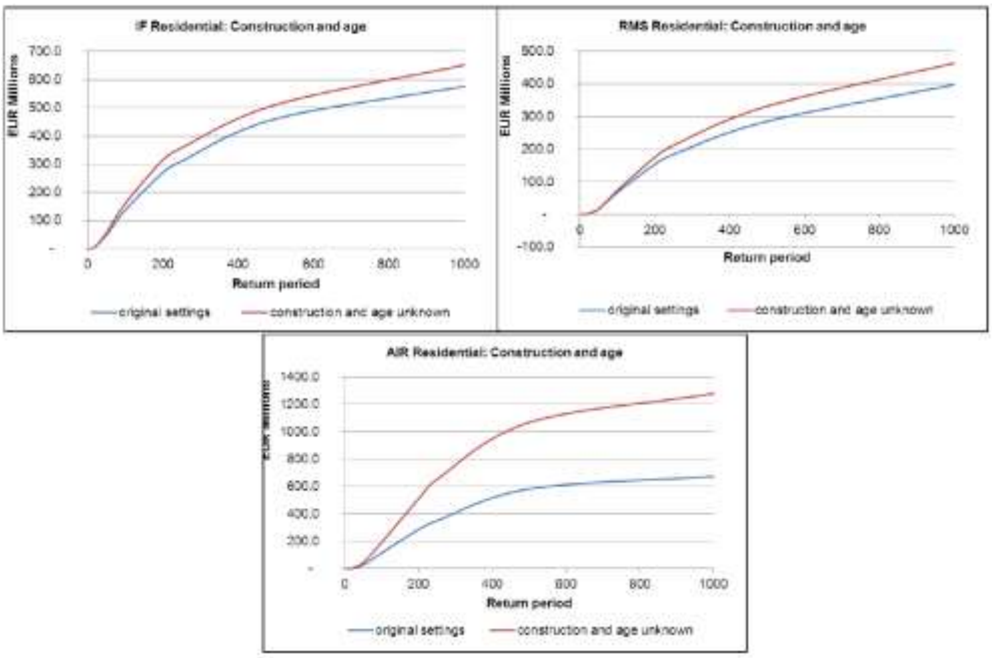
Figure no. 5 - Sensitivity of vulnerabilities – coverage



Source: author's research results – data processed with Impact Forecasting - Aon Benfield Analytics

With regards to construction and age, the assessment of the position of the model defaults when compared to the results based on company specific information. For the two Example Insurers, we assessed the potential impact of uncertainty by coding the constructions in original data.

Figure no. 6 - Sensitivity of vulnerabilities - construction and age

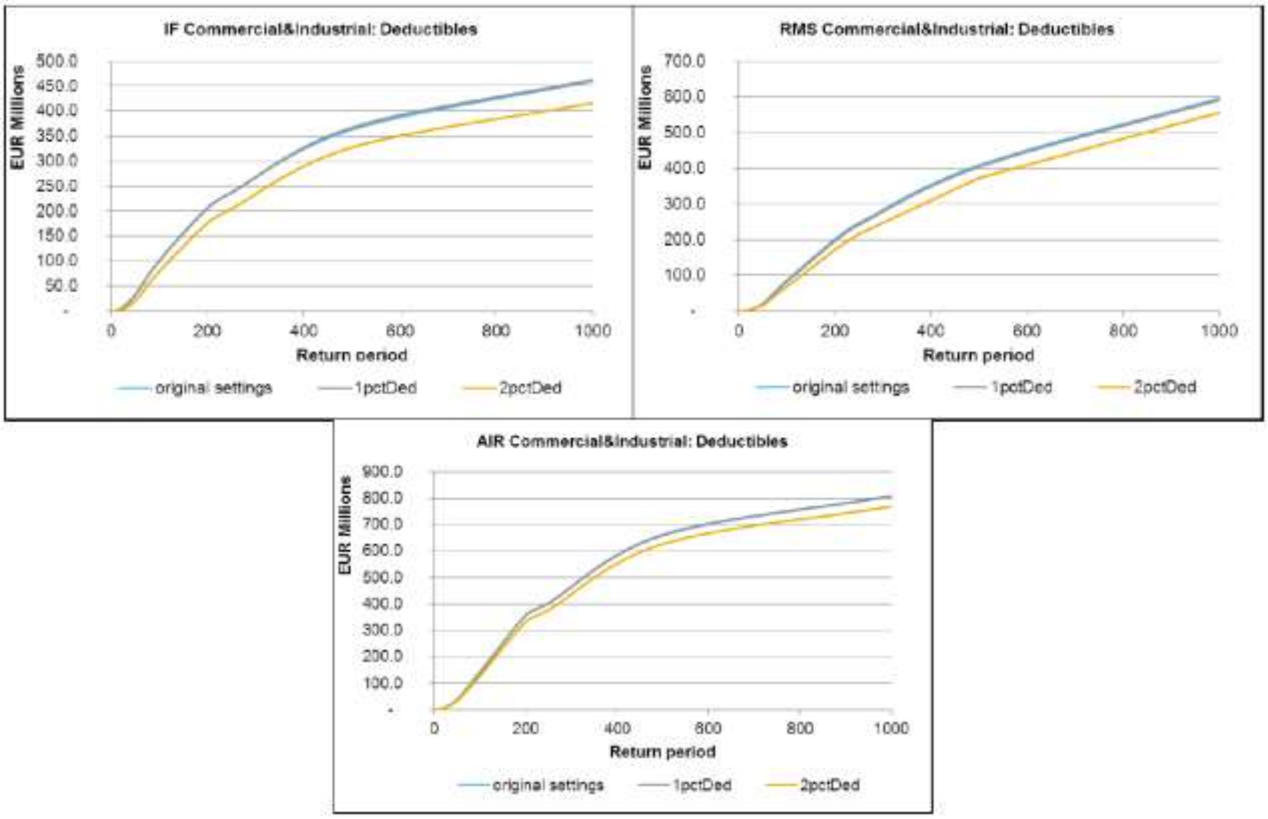


Source: author's own research results– data processed with Impact Forecasting - Aon Benfield Analytics

The sensitivity impact of "Construction and Age" vulnerability was assessed by the two Example Insurers in order to model the non-residential portfolio (commercial and industrial lines) with the deductibles as assumed for the renewal modelling and with the following deductible alternatives: 0%, 1%, 2%. We demonstrated individual Exceedance Probability curves for pre-defined return periods of the gross loss.

For a large part of 2nd Insurer's portfolio, the deductibles are withdrawn by the system as 'unknown'. Unknown values are replaced by the average values that are based on the remaining part of the portfolio. The aim of the sensitivity test is to quantify the impact of the assumptions for the unknown deductibles.

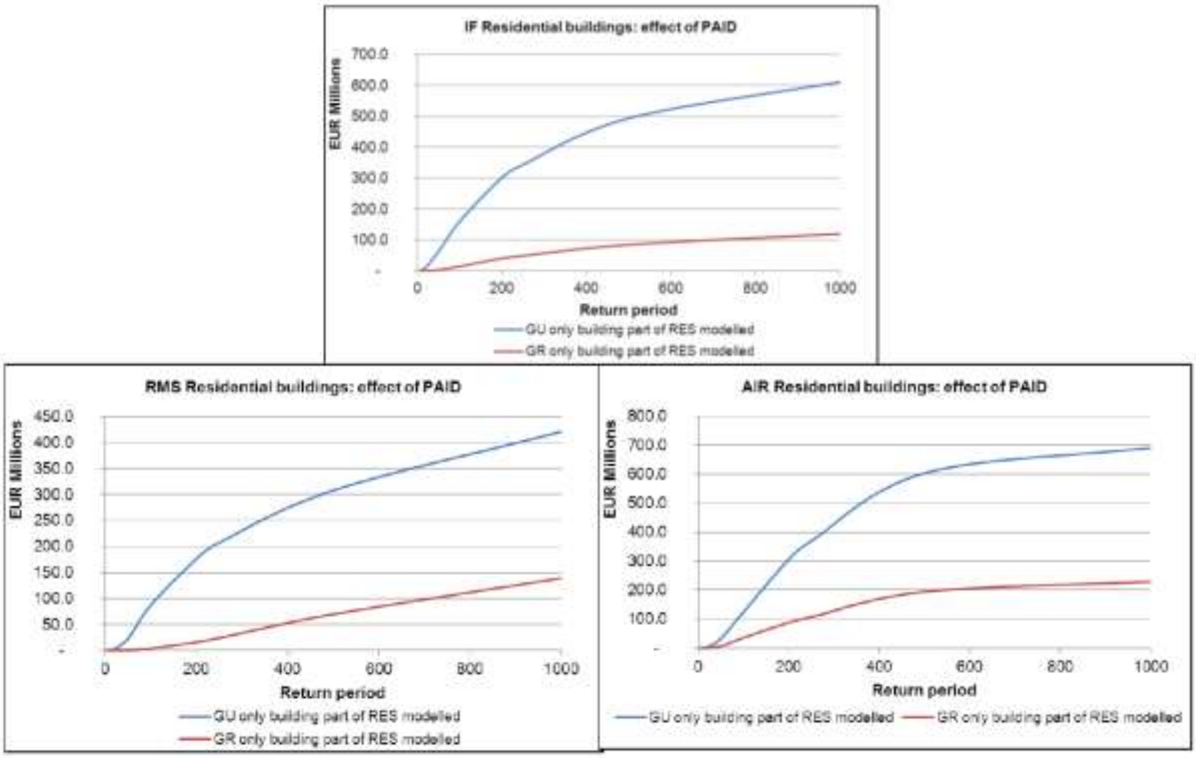
Figure no. 7 - Sensitivity of financial component – deductibles



Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

To be able to assess the impact of PAID pool, which is obligatory in Romania, there were carried out a sensitivity test which shows the influence of PAID deductibles. Therefore, the building part of the residential portfolio (w/o contents) is separately modelled with PAID (20,000/10,000) deductibles and without any deductibles. The Exceedance Probability curves demonstrate for pre-defined return periods of ground up loss (w/o application of deductibles) and for gross loss (PAID deductibles applied) perspective. For the two Example Insurers, we decided to assess the impact of PAID deductibles on building losses only due to observe the impact of PAID. PAID pool does not apply for commercial and industrial treaties. Another exclusions of PAID deductibles are the subLoBs of BI, contents and building annex (e.g. garage).

Figure no. 8 - Sensitivity of financial component - paid deductibles



Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

Backtest

For the two Example Insurers, we analysed the impact on the portfolio if the same seismic intensity occurs as happened in the year 1977 (magnitude of 7.4, depth 94 km). The analyses are shown for 2nd Insurer and 1st Insurer. The loss at that time was measured by USD 2 billion of overall damage. The city of Bucharest contributed more than 50% of the overall loss, the damage was also observed in Bulgaria and Moldova.

Figure no. 9 - 2nd Insurer Backtest, Data as at 30th April 2014, in EUR, Residential losses assumed PAID deductibles of EUR 20.000/10.000

Gross Losses, Model / Company / Line of Business

Division	IF		RMS		AIR	
Peril	Earthquake		Earthquake		Earthquake	
Sub peril	None	PML	None	PML	None	PML
Loss amplification	None	as %	Yes	as %	None	as %
Loss perspective	Gross	TSI	Gross	TSI	Gross	TSI
Total Sums Insured (TSI)	28,179,890,031		28,179,890,031		28,179,890,031	
Event						
Vrancea 1977	447,721,655	1.59%	287,872,664	1.02%	121,360,679	0.43%
*Vrancea 1977 (PAID)	232,392,517	0.82%	187,517,140	0.67%	85,746,803	0.30%

Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

Without the PAID pool IF model generates approximately 180 year event of the expected loss. AIR, however, would generate approximately lower loss under the same condition, but expects to repeat every 63 years. RMS lies with Return Period of 170 years in between.

Figure nr. 10 - 1st Insurer Backtest, Data as at 30th April 2014, in EUR, Residential losses assumed PAID deductibles of EUR 20.000/10.000

Gross Losses, Model / Company / Line of Business

Division	IF		RMS		AIR	
Peril	Earthquake		Earthquake		Earthquake	
Sub peril	None	PML	None	PML	None	PML
Loss amplification	None	as %	Yes	as %	None	as %
Loss perspective	Gross	TSI	Gross	TSI	Gross	TSI
Total Sums Insured (TSI)	9,210,351,945		9,210,351,945		9,210,351,945	
Event						
Vrancea 1977	184,951,224	2.01%	109,754,310	1.19%	63,216,812	0.69%
*Vrancea 1977 (PAID)	53,965,977	0.59%	41,378,513	0.45%	28,105,622	0.31%

Source: author's research results– data processed with Impact Forecasting - Aon Benfield Analytics

Analogical study and comparison are performed for 1st Insurer's portfolio. In the test, 1st Insurer suffers approximately from a 1 in 200 RTP loss from IF model (RMS very similar RTP 193) and only RTP 68 from AIR, when PAID pool should not come into force. By resuming of PAID deductibles, the expected loss is substantially lower.

Results, recommendations and limitations

By the result of the detailed evaluation of the four available models for earthquake, the two Example Insurers decided to use the IF model for earthquake's risk quantification in Romania. Reasoning including main aspects of the four models are listed below.

IF model

The main aspects of the IF model we considered to be as follows:

- IF has a credible hazard component, based on the scientific data provided by local experts. It properly reflects the frequencies of historical events as well as the geographical distribution of the earthquake risk. Depth distribution of Vrancea events reflects the real historical observations, also an advantage regarding the hazard component;
- IF vulnerability component, even if simpler compared to other models, is calibrated based on the real damage data (approx. 18,000 damaged risks are inspected after the past earthquakes);
- IF model has wide acceptance in the Romanian market (IF 1 in 250 PML is used as a general standard for Cat capacity purchase) and long continuity and consistency of the results;
- Sensitivity testing of coverages shows realistic behaviour in IF (similarly RMS);
- The IF documentation describes the technical model in a transparent way, so that a third person understands the model.

The limitations of the IF model we considered to be as follows:

- Construction type and year built in the IF model need to be mapped by a user into EMS vulnerability classes. This is certainly a limitation of the model, but the EMS curves are calibrated using the 1977 earthquake's loss data.

RMS model

Main aspects of the RMS model we considered to be as follows:

- Sensitivity testing of coverages shows realistic behaviour in RMS (similarly IF)
- Construction type and year built are directly applicable in RMS and AIR in the models' inputs.

The limitations of the model we considered to be as follows:

- RMS hazard component is rather simplified and tends to underestimate the hazard, not only in comparison with other models, but also in comparison with historical evidence. Following limitations are identified:
    - RMS stochastic catalogue underestimates frequencies of stronger (Mw > 6.5) events, not only compared to the other models but also compared to the historical data.
    - Modelling of the depth of Vrancea events is rather simplified, assuming the same probability of earthquake occurrence everywhere between 70 and 170 km.
- No additional damage amplification in Bucharest can be seen based on the sensitivity testing;

- Sensitivity testing for the main occupancies shows realistic behaviour of all three models of IF/AIR/EQE, the only arguable point is almost no differentiation between the commercial and industrial occupancy in RMS;
- The documentation of RMS can rather be seen as a user guide (not transparent enough).

AIR model

Main aspects of the AIR model we considered to be as follows:

- AIR hazard component is much more realistic compared to RMS, especially because of the following:
    - Geographical distribution of stochastic events reflects the historical data very well.
    - Frequencies of stochastic events correspond to the historical data for all magnitudes.
    - Similar to IF, positive match of the depth distribution of Vrancea events with historical observations
- Construction type and year built are directly applicable in RMS and AIR models'
- A significant weak point identified in AIR hazard is the fact that the model doesn't reflect additional damage amplification in Bucharest. This results in a relatively low contribution of Bucharest to the total PMLs in AIR, despite being the highest model for Romania.
- Very arguable relativities between individual coverages in AIR, where contents return the highest losses and BI the smallest. This is not supported neither by engineering assumptions nor by loss observations across Europe.
- Model default settings for unknown construction and year built are extremely conservative in AIR, producing approximately 70% higher losses compared to company specific information. This is a significant limitation of the model, as it cannot be used for simple data without additional information about property details.
- Documentation transparency

EQEmodel

Main aspects of the EQE model we considered to be as follows:

- One of the most extended available models on the market

The limitations of the model we considered to be as follows:

- Lack of documentation transparency
- Last model development changes which are not explained and translated for the public transparently and understandably, trustworthiness in the model is

Europe wide on a very low level, thus the detailed validation tests not even performed for EQE model

Overall limitations of earthquake modelling

With respect to the data used, we emphasise the following:

- Location assessment – in all insurance portfolios, there are policies without the specified location of the insured objects. This is one of the most important NatCat modelling limitations; there are several sources of the problem:
    - Unknown location – there are always some policies in the portfolio with missing information which can be further processed by using expert judgment/market know how or grossed up in the final results;
    - Wrong geocoded location – wrong address/ X-Y geocoding in data systems, e.g. for the address of the insured object the policy owner's address is stated and not the address of the object;
    - Multi-locations – all insurances underwriting industrial business have lots of multilocation contracts which cover multiple risks located on the different addresses. These risks are not always of the same size. Moreover, a lot of the locations are constantly changing (e.g. shops which are closing/reopening new store, similarly to casco business);
- Multi-location policies as mentioned above, also include a problem of the "imprecise size allocation", as the exact sums insured are not stated for all risks under one policy. Therefore, an expert assumption must be even met in this case;
- Occupancy/Coverage classification – missing/wrong inputs of the data used can imply incorrect processing of the model for the occurred loss (expert judgments/market data must replace real company's data);
- Property modifiers (age, structure, no. of stocks – if missing or incorrectly applied property modifiers can cause limitations of the results (expert judgments/market data must replace real company's data).

Related to the testing of the catastrophic events, there is to underline that the Back Test it can be only correctly performed in case of an available recent catastrophic event. Some events are too small to be compared to or too much time has passed by. In case the event is too old, the observed losses are not easily comparable with the current insurance exposure that is exposed to the present losses. It is the case of the individual adjustment to adapt the loss to the current values. Therefore, in such cases/ or in case of no catastrophic event for a given country and peril, it is possible to perform only a limited comparison of the past hazard (if occurred) with the model's hazard definition.

Also, for the stability test – some NatCat models (not the case of selected Romanian IF model) – use predefined number of events set in their event catalogue with a predefined fixed number of samples per each year of simulation. Therefore, any alteration of the stability conditions in regards to the hazard or simulation numbers is inexecutable.

Not least, about the scope of the model (application), the earthquake risks in the two EXAMPLES's RO portfolio cover the LoBs of property.

Conclusions

Within the validation test carried on the two Example Insurers we decided to take 2nd Insurer as a core country/driver of Romanian earthquake exposure. Therefore, all main tests are performed on their portfolio.

The researcher is aware of the fact that no special stress tests were performed, although lots of tests can be seen as stress tests as found in the sensitivity/ backtest presented. For future periods one improvement to be addressed is to add the stress tests to the validation process.

With regards to the model used (hazard scope, software), The lack of the historical catastrophic events that derive the damage functions (known as vulnerability curves), not always based on one's own claim experience (the damage functions are calibrated upon available claim experience that occurred in the recent past).

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U.S. Geological Survey - *https://www.usgs.gov/*