Hurricane Risk Management in Florida

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Abstract

Florida, due to its geographic location, and the ever increasing population on its coastline, is subject to potentially devastating hurricane damage. To remedy this situation, the State has embarked on an aggressive program of mitigation which includes predicting and evaluating the risk. As part of this effort, the State commissioned an interdisciplinary team of researchers to develop a risk model, the so-called Florida Public Hurricane Loss Model. This paper describes key elements of the Model, and how the Florida experience might be extended to other areas.

1 INTRODUCTION

Econometric models failed to predict the insured building losses produced by hurricane Andrew, which hit Florida in 1992. A series of intense hurricanes in the subsequent years further exacerbated the resulting crisis in the American property insurance market, particularly the homeowner insurance market, in Florida and along the Gulf coast. Rates have increased dramatically with adverse impact on homeowners, businesses, mortgage industry, banks, and the real estate market. The result was a change in the loss projection paradigm with the adoption of computer-based catastrophe models (Pielke et al, 1999), and increased regulation at the State level, including the creation of the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM) (AAA, 2008). The Florida Public Hurricane Loss Model (FPHLM) is part of that change in paradigm providing a state-of-the-art loss projection model with a transparent rationale opened to public scrutiny (Hamid et al., 2010).

2 FLORIDA PUBLIC HURRICANE LOSS MODEL

The Florida Office of Insurance Regulation contracted an interdisciplinary group of university researchers to develop the FPHLM. The first module of the FPHLM focused on single-family residential homes and has been consistently certified every year by the FCHLPM since 2006. Currently a new module of the FPHLM is underway, which focuses on projecting losses of commercial-residential multi-family buildings, either condominiums or rental apartments. In addition, the commercial residential module is divided into two almost independent sub-modules: one for low-rise buildings and one for mid/high-rise buildings (4 stories or more). All three modules contain a meteorology model which defines the hazard, i.e. hurricanes, an engineering or vulnerability model which defines the damage to the structures due to the hazard, and, an actuarial model which converts the damage into monetary losses. In addition, a computer platform integrates the three models into one functioning program.

3 VULNERABILITY MODEL

3.1 Description

Historically, the engineering component of the first catastrophe risk models were based on empirical curve fitting techniques, where vulnerability curves were fitted to available claim data.

By contrast, the FPHLM uses an engineering approach in the treatment of different types of damage. The prediction of exterior damage is based on the modeling of wind pressure effect and debris impact on the building envelope, while interior damage to single-family and multi-family buildings at low to moderate wind speeds is is modeled as the result of the ingress and propagation of water through breaches in the building envelope.

Accordingly, the computation of damage is a 3 stage process as described in Fig. 1. The first stage corresponds to the external damage assessment through Monte Carlo simulations of wind pressure and debris impact damage on the building envelope of different types of buildings. Each type is modeled separately with different strength capacities assigned to each of its components (roof cover, deck, connections, walls, etc). The process is summarized in Fig. 2. The results are so-called damage matrices. Each row of a damage matrix lists results of one model simulation, the amount of damage to each of the 15 modeled components for a simulation being listed in 15 columns of the row. Each damage matrix gives the results of 5000 Monte Carlo simulations. A separate matrix is created for each peak 3-s gust wind speed between 50 and 250 mph in 5 mph increments (50, 55,…, 250 mph) at angles between 0 and 315 degrees in 45-degree increments (50 mph at 0°, 50 mph at 45°, 50 mph at 90°,...).

The second stage corresponds to the computation of internal and utilities damage. Damage to the interior and utilities occurs when the building envelope is breached, allowing wind and rain to enter. In the first version of the FPHLM, this damage was extrapolated from the exterior damage through empirical equations validated against claim data. The most recent version of the FPHLM predicts the interior damage through Monte Carlo simulations of the water penetration through the breaches. This process is based on estimates of rainfall intensity and duration as shown in Fig. 3.

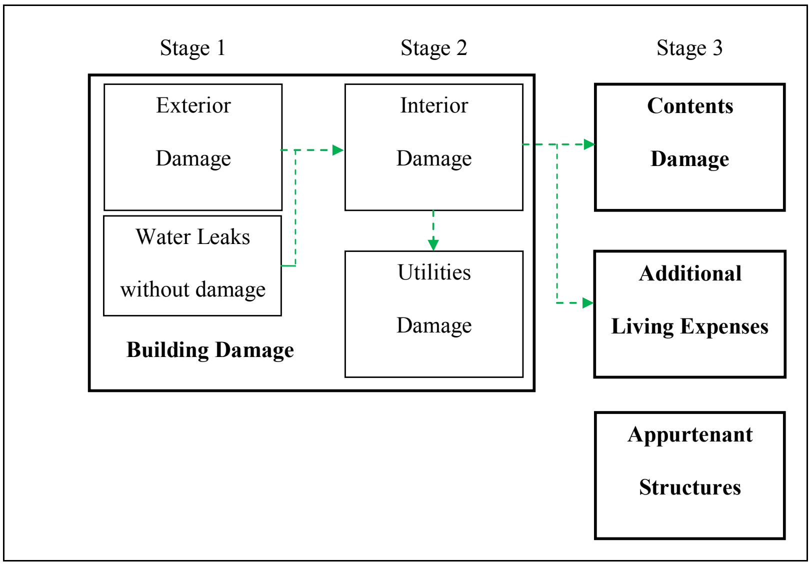

Fig. 1: components of the vulnerability model

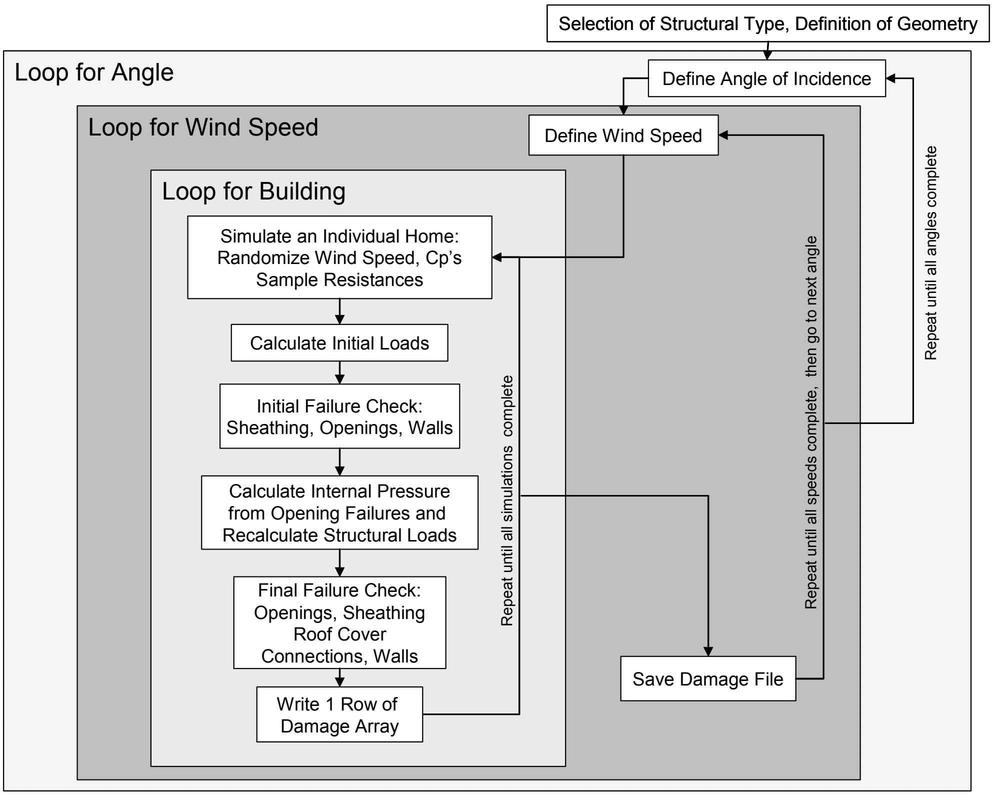

Fig. 2. Monte Carlo Simulation procedure to predict external damage

Finally, in the third stage, contents damage and time related expenses are estimated from the interior damage. Damage to appurtenant structures, which are all structures detached from the main building are estimated independently.

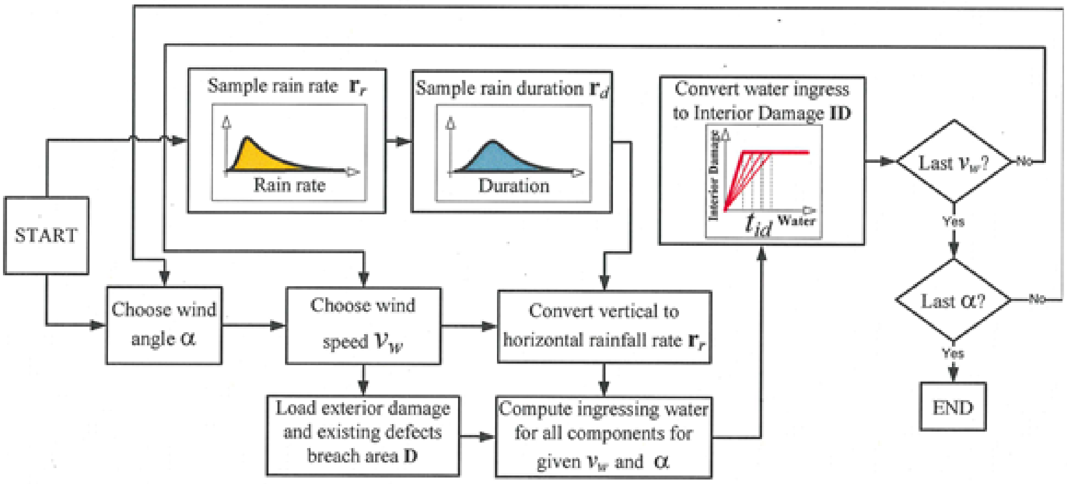

Fig. 3. Water penetration model

3.2 Vulnerability Matrices

For each Monte Carlo model in stage 1 described above, 5000 simulations are performed at 8 different angles and 41 different wind speeds. This is 5000 x 8 x 41 = 1,640,000 simulations per model, which are expanded to cover interior, utilities, contents, time related losses, and appurtenant structures, as explained above. The simulation results are then transformed into vulnerability matrices. A large number of matrices for site built homes are created for different combinations of wall type (frame or masonry), region (North, Central, South), sub-region (high wind velocity zone, wind borne debris region, other), roof type (gable vs. hip), roof cover (tile vs. shingle), window protection (shuttered or not shuttered), number of stories (1 or 2), and strength (weak, medium, strong).

A partial example of a vulnerability matrix is shown in Table 1.

Table 1. Partial example of vulnerability matrix

Damage\Wind Speed (mph)	47.5 to 52.5	52.5 to 57.5	57.5 to 62.5	62.5 to 67.5	67.5 to 72.5
0% to 2%	1	0.99238	0.91788	0.77312	0.61025
2% to 4%	0	0.00725	0.0805	0.21937	0.36138
4% to 6%	0	0.000375	0.001375	0.007	0.0235
6% to 8%	0	0	0.000125	0.000375	0.0025
8% to 10%	0	0	0	0	0.000375
10% to 12%	0	0	0	0	0.000375
12% to 14%	0	0	0	0	0.000625
14% to 16%	0	0	0	0	0.0005
16% to 18%	0	0	0	0	0.000125

The cells of a vulnerability matrix for a particular structural type represent the probability of a given damage ratio occurring at a given wind speed. The columns of the matrix represent the different wind speeds from 50 mph to 250 mph in 5 mph increments. These are 3-s gust wind speeds at a 10 m height. The rows of the matrix correspond to damage ratios (DR) in 2% increments up to 20%, and then in 4% increments up to 100%. At each wind speed, the number of instances of damage within each damage range is counted. For example, if a damage ratio is DR= 15.3%, it is assigned to the interval 14%<DR<16% with a midpoint DR=15%. After all the simulations have been counted, the total number of instances in each damage interval is divided by the total number of simulations per wind speed to determine the percentage of simulations at any damage state occurring at each speed. These percentages are the conditional probabilities of occurrence of a level of damage, given a certain wind speed.

One important plot derived from the vulnerability matrix is the vulnerability curve. The vulnerability curve for any structural type is the plot of the mean or average damage ratio per wind speed vs. wind speed. The model can also generate fragility curves for each vulnerability matrix, although these curves are not used in the model. Fragility curves are curves that represent the probability of exceedance of any given damage level, as a function of the wind speed.

3.3 Vulnerability Models

One of the first issues a modeler is faced with is which building should be modeled. Given the fact that the development resources are always finite, a selection of the most representative building types is necessary. Not all building types in a building population can be covered. In addition, it must be kept in mind that a catastrophe model is not intended to analyze the risk of a particular structure, with unique characteristics. On the contrary it is intended to analyze the risk of large groups of buildings, from a generic point of view. In other words, the structures to be modeled will be generic structures, representative on average of certain types of structures, but not of any structure in particular.

In the case of the FPHLM, the researchers did a detailed survey of the building stock in Florida, thanks to the availability of the databases of the tax appraisers in 32 countties in the State. From the information contained in these databases, it was possible to get statistics on key structural parameters including type of wall structures, type of roof shape, type of roof cover, age of buildings, number of stories, and areas. Based on these statistics, generic models of masonry and timber structures were developed that cover roughly 90% of the building stock.

The State was divided in four regions, North, Central, South, and the Keys, and the models take into account some regional characteristics like areas, and cost of repairs, so that there are different variants of the models for the different regions.

3.4 Models distribution in time

Over time, engineers and builders learned more about the interaction between wind and structures, more stringent building codes were enacted, and when properly enforced, resulted in stronger structures. Consequently, for each type of building modelled in the FPHLM, the developers created a weak model, a medium strength model, and strong strength model. These models represent the evolution in time of relative quality of construction in Florida. The different strength model differ by their roof to wall connections, the quality of their roof cover, the strength of their roof decking attachemnent, the bracing of their gable ends, and their opening protection.

Each set of models is representative of the prevalent wind vulnerability of buildings for a certain historical period in time. It is therefore important to define the cut-off date between the different periods, since the overall aggregate losses in any region are determined as a mixture of homes of various strengths (ages). The cut-off dates do not depend only on the evolution of the building code, but also on the prevailing local builder/community code enforcement standards in each era.

This issue of code enforcement has also evolved over time, and it is only recently that the State of Florida took an active role in uniform enforcement. Thus a given county may have built to standards that were worse than or exceeded the code in place at the time. After consulting with a variety of building code development experts, the team concluded that the load provisions had some wind provisions since the 1970's, and the issue is not only the code, but also enforcement of the code. For example, Southern Florida construction practice recognized the importance of truss to wall connection as early as the 1950's, when it became common to use clips rather than toe nails. The clips were not as strong as modern straps, but an improvement over nails only. However, an influx of population and construction boom in the 1980's lead to poor code enforcement and a decline in quality. Northern Florida construction suffered from the lack of impact from severe hurricanes over a long period. This sense of safety was compounded by a more localized approach to decision making. Thus northern construction is expected to be weaker than southern in general. The use of clips became relatively standard state-wide by the mid 1980's, while they were well used in the south prior to this time. The use of rated shingles and resistant garage doors became common after Andrew. Therefore, the classification shown in Table 2 was adopted for characterizing the regions by age and model.

Table 2. Distibution of different strength models over time

	Pre-1960	1960-1970	1971-1980	1981-1993	1994-2001	2002-pres.
South	½ W, ½ M	M	M	½ W ½ M	S	S
Keys	½ W, ½ M	M	M	M	1/3 M, 2/3S	S
Coastal	W	M	1/3 W, 2/3M	1/3 W, 2/3M	½ M, ½ S	S
Mainland interior	W	M	½ W, ½ M	½ W, ½ M	½ M, ½ S	S

3.5 Advantages and Limitations of the Engineering Approach

The engineering approach, where computer models of the buildings are developed and subjected to wind effects, is a vast improvement over the simpler curve fitting methods of the past. Fitting a vulnerability curve to past claim data can only yield a representation of the vulnerability of past construction, at best. On the contrary, through the modelling of the building, the engineer can study the interaction between its different components, and can evaluate the vulnerability of new improved structures as well as older weaken ones. In particular the benefits of mitigation measures can be evaluated at different wind speeds.

For example, the FPHLM includes weak and medium strength models with different combinations of mitigation features, like different deck attachment strengths, different quality of roof covers, or different opening protection. These features can be activated in different combinations, and their effect on the predicted hurricane loss investigated.

However, a model is dependant on the availability of engineering data regarding the strength of its different components and their behaviour under wind loads. Such data can be available in the literature, in manufacturer's catalogs, or from test results. Engineering judgment can also be used.

4 TREATMENT OF INCOMPLETE OR MISSING DATA IN INSURANCE PORTFOLIO FILES

The quality of the results of a portfolio analysis using a cat model is limited by the quality of the input data available in the portfolio files. Historically in Florida, insurance company collected only very partial data concerning the structural characteristics of the insured buildings, and that information was mainly concerned with fire resistance. Therefore, although a vulnerability model can become quite sophisticated, it is sometimes difficult to make full use of its capabilities. For example, the shape of the roof, whether gable or hip can have a strong influence on the wind vulnerability of a building. However, most of the time, this information is not available in a policy record of an insurance portfolio file.

Actually, many times, the only information of value, from a vulnerability point of view, in a policy record, would be the location, the year built and the type of exterior wall (e,g, masonry or timber). To make up for the missing information, the solution lies in getting statistics on the building population from external sources, like tax appraisers, or even internet utilities like Google Earth. Then, based, on the location, a weighted vulnerability can be assigned to the policy with missing information.

For example, from the insurance files, we can easily determine the region, sub-region, construction type, and year built. However this leaves the roof type, roof cover, and shutter options still undefined. But we know from previous exposure studies, the distribution of different roof types, and to some extent of roof cover per region. Also, some estimation of the percentage of homes with and without shutters in each sub-region can be made. Based on these statistics and estimates, we can define a general matrix for each construction type in each region and sub-region. The general matrices are simply the sum of the model matrices weighted on the basis of their statistical distribution. For example, if we know that a home is masonry construction and is in the windborne debris region of central FL, we also know that 66% of the masonry homes in central FL have gable roofs and 34% have hip roofs, around 85% have shingle cover and 15% tile, and 20% have shutters while 80% do not. Weight factors can be computed for each model matrix based on these statistics. For example, the Central FL, gable, tile, no shutters, masonry matrix would have a weight factor of 66% (masonry percent gable) x 15% (percent tile) x 80% (percent without shutters) = 7.9%. This is the percentage of that home type that would be expected in this region. Each model matrix is multiplied by its weight factor, and the results are summed. The final result is a weighted matrix that is a combination of all the model matrices and can be applied to an insurance policy if only the ZIP Code, year built, and wall classification are known. As a result, for each sub-region (standard, windborne debris region, and high velocity zone) of each region (Keys, South, Central, and North), there will be a set of weighted matrices (masonry, wood, and others) for weak, medium, and strong structures. Fig. 8 shows the weighted matrices for the masonry structures in a Central sub-region.

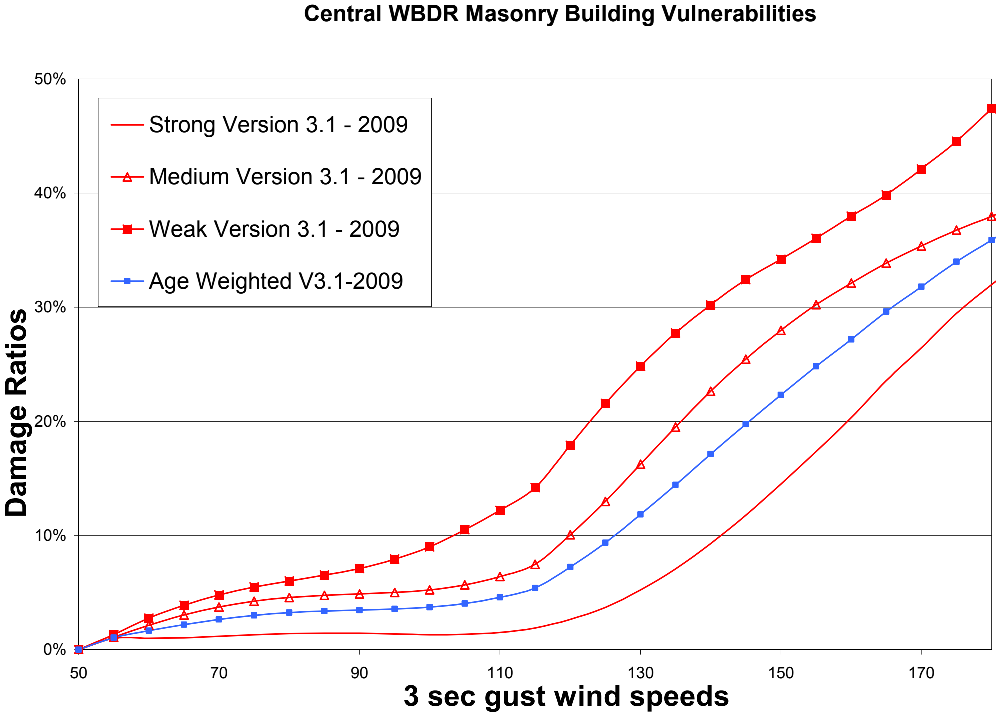

Fig. 4. Weighted masonry structure vulnerabilities in the Central wind borne debris zone

5 DISCUSSION AND CONCLUSIONS

Several cat models currently exists, with the vast majority of them being proprietary commercial models. Although these private models are state of the art models, they are subject to market forces, and more importantly, the science behind the results of these models is not publicly available. On the contrary, the Florida Public Model provides an independent and unbiased assessment of hurricane loss. Because of its public nature, market forces do not shape the outputs of the public model, since it is not in a fight for market share and customers. The method leading to the output is truly transparent to all stake holders, like citizens groups, insurance industry, government regulators, and legislators. Consequently, the use of the Public Model, promotes open discussions of the hurricane risk, based on verifiable scientific and engineering facts.

The methodology presented here could form the basis for the development of similar models adapted to the needs of other insurance markets. Some of the lessons learned include:

- The advantage of leveraging research efforts in academia, for the development of an independent public model, not subject to special interests or commercial constraints. The advantages include access to state of the art research, substantial reductions in costs, and transparency.

- The importance of access to reliable, consistent, and complete data at every stage of development of the model, including meteorological data, exposure data, laboratory data, cost data, and very importantly claim data for validation. The sponsorship of a governmental entity, and the collaboration of the insurance industry are crucial for access to some of these data.

- The need for a long term sustainable effort which reflects the fact that cat models are constantly being updated and improved, and can become rapidly obsolete if not properly maintained.

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