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Natural Catastrophe Modelling for Construction Risks

Viaduct collapse following Kobe Earthquake - http://www.fhwa.dot.gov/publications/publicroads/96fall/p96au17.cfm

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The present paper is based on the experience of the working group's members in the insurance industry. The opinions expressed hereunder are solely those of the authors for the respective chapters each member has composed and do not in any way reflect the views of any insurance company or any other legal entity involved in the insurance industry.

The paper is not meant to be exhaustive and other aspects may exist, presumably affecting the profitability of an insurance policy, which may not be described in this paper.

All the authors are serving in their personal capacities.

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Executive Summary

Natural catastrophe Modelling is a vital tool for underwriters writing risks in areas exposed to natural perils. Models tend to be very complex and understanding how they work is vital to understanding their limitations and deciding how much reliance can be placed on the guidance they provide.

A number of models are commercially available. They were developed by universities originally and scientists in the late 80s for the older ones and have since evolved taking into consideration the actual losses occurred after NATCAT events. Nevertheless, in the majority of the cases, the objects at risk are standing-by completed structures as opposed to construction sites. The buildup of values and the vulnerability of structures and buildings are time dependent through the lapse of construction and are not presently taken into account by the models studied.

We need as well to state that not every model is good for everything. They are very region dependent, some being more advanced in a particular region than others and some perils have a better holistic view for one particular model than for the others. A blend of available models might be the best option for a robust and consistent result.

Traditionally, model usage is devoted to underwriting and reserve level control. They have not really been develop to determine the pure premium or the Maximum Possible Loss of a particular location. Among future use, they could help in allocating the right emergency relief teams in number and location and limit dispersing the effort of the Insurance sector in trying to get as quickly and efficiently possible to its affected customers.

Purpose of this document

This document gives an overview of the most important commercially available Nat Cat models. Such models are typically designed for Property business and have significant gaps for Engineering business. The document discusses how such models can still add value in Engineering business and it outlines the most urgent development needs in order to make these models more relevant for this business segment.

Possible further developments

To summarise the development needs for existing models to make them more suitable for engineering business include;

- More accurately reflecting the buildup in value over time.

- More accurately reflecting the change in vulnerability over time.

- Combining these two to more accurately quantify the financial loss

1. <u>Introduction</u>

Natural Catastrophe Modelling is a vital tool for underwriters writing risks in areas exposed to natural perils. The NATCAT models are very complex and it is understanding how they work is vital to understanding their limitations and deciding how much reliance can be placed on the results they produce.

This paper covers:

1. The nature the NATCAT and how they work

2. Commercial products available

3. Limitations on the information provided and how much reliance should Underwriters place on these results

4. Likely future developments

5. Use of NATCAT models for claims management after events.

2. **The Nature of NATCAT Models and how they work**

A NATCAT model is a computerized system designed to simulate NATCAT events such as earthquake, cyclones, winter storms, post-tropical storms, flood, tornadoes… and estimate the magnitude, intensity and location of an event to calculate the potential loss. These models may be extensively used today for;

- Risk pricing

- Portfolio management

- Capital requirements

There are five essential elements to a NATCAT Model.

Example for windstorm

Define windstorm event	Access wind speeds	Apply exposure	Calculate damage	Quantify financial loss
1 **Stochastic Event Module**	**2** **Hazard Module**	**3** **Exposure Module**	**4** **Vulnerability Module**	**5** **Financial Analysis Module**
Location of event, intensity and frequency		Location of risk	Building characteristics, extent of damage	What is magnitude of loss

1) Stochastic Event Module - This comprises two elements

    i)   Historical events – a collection of historical events are used to draw conclusions on the pattern and to derive predictions on a particular event.

    ii)   Stochastic events – computer generated events based on stochastic information, like, for example, wind speed and direction, to produce a probabilistic model. A large number of theoretically possible events may be included within the model software using the computer. They generally complement historical events.

2) Hazard Module

    i)   For a given area or location this will determine the intensity of the event. For a hurricane this would be wind speed and potential storm surge.

3) Exposure Module

    i)   This is the consideration of the exposure to the NATCAT event. For this the location is fundamental so accurate geocoding is essential. In addition insurance coverages and the value of the risk are important if the model is used to determine the possible loss in financial terms.

4) Vulnerability Module

    i)   This will determine the vulnerability of the risk to the NATCAT event and so defines the relationship between a measure of hazard and the measure of damage that a location could sustain.

As an example for buildings the vulnerability curve can be drawn as this for windstorms as the following example:
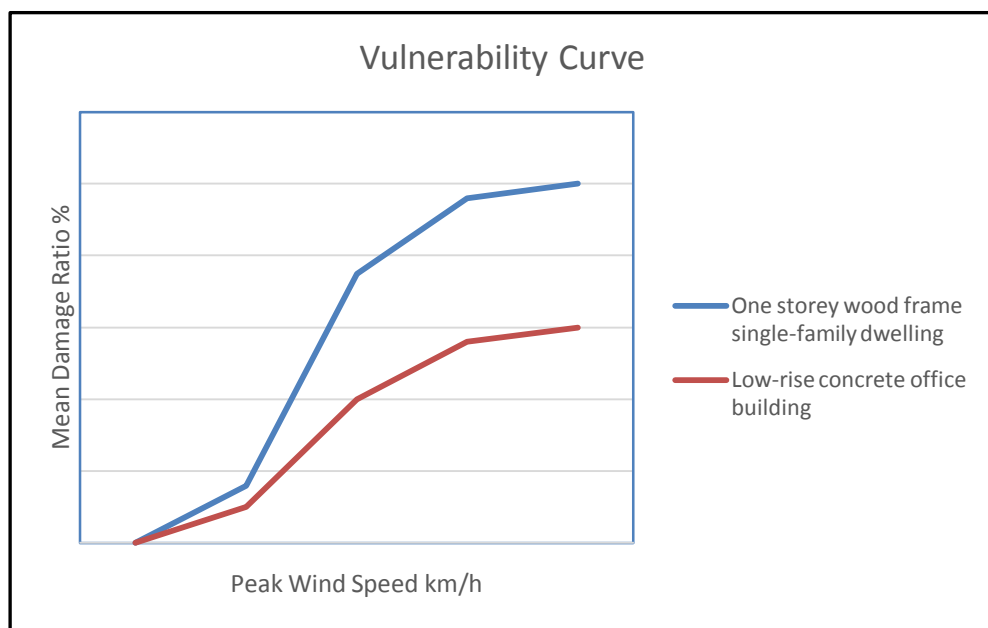
The damage curve is determined by factors called the Primary Characterisitcs. For a building this could include;

    i)   Occupancy type

    ii)   Construction class

    iii)   Building height

    iv)   Year of construction

Secondary modifiers can be used to adjust the Damage Curve further.

To understand how the models work and the accuracy of their results it is necessary to understand the inputs into the model.

Primary Characteristics

i)   Occupancy Type

E.g. road, railway, bridge, tunnel, refinery, building

ii)   Construction Type

E.g. Timber frame, steel frame, concrete frame

iii)   Year Built

The age is important as construction standards and design have change over time

iv)   Number of stories / height

This will influence exposure to wind as wind speed is generally lower nearer ground level because of surface friction. Other considerations are exposure to flooding and earthquake.

Secondary Modifiers

There are a large number of secondary modifiers according to the structure at risk and the model used but an example of those relevant to construction would include;

i)   Cladding type and roof type

ii)   Construction quality

iii)   Flood protection, flood defense elevation

iv)   Opening protection and wind resistance.

5) Financial Analysis Module

Once the ground up loss has been calculated the module will now apply the insurance policy coverage conditions to calculate the actual exposure to the account.

The models were originally developed for the property insurance market where the structure (essentially a building) remains in the same state and almost the same sum insured throughout the period of insurance. For a construction project the location based Modules - Stochastic, Hazard and Exposure will remain constant and applicable throughout the construction process as the location will not vary. However the Vulnerability Module used in most modules is applicable to a

completed structure and does not replicate the vulnerability of a partially completed structure. Additionally the value at risk will be minimal at the start of a project and increase to the full value at the end of the construction period.

The Financial Analysis Module will therefore have to be run at the beginning and the end of the period of insurance or anytime a significant variation in the sum to be insured arises along the project to model the change in state of the project over time.

3. <u>Commercial Products available</u>

3.1. RMS

RMS was created in 1988 at Stanford University. It is a private company headquartered in the Silicon Valley (Newark, CA). From the beginning, RMS has modelled risk. Today its model works in 100 countries. From the beginning its models have been widely used by insurance and re-insurance carriers worldwide. Its customer base has largely widen and RMS provides its services to non-insurance corporation and governmental agencies.

RMS works with a number of partners worldwide to refine its model:

- ARA Applied Research Associate which operates HurLoss, a certified model by the Florida Commission on Hurricane Loss Projection Methodology to model hurricane catastrophe
- CATALYTICS, Singapore based company, developing an earthquake (EQ) model across the ASEAN region and particularly in poorly modelled area/countries such as Indonesia, Philippines, Singapore, Malaysia, Brunei, Thailand and Vietnam
- CATRISK, a London based modeller specializing in earthquake modelling. This model now includes North Africa and the Middle-East
- COMBUS from Australia, modelling the low-return period perils affecting the country such as bush fires, storm, flood and hail
- ERN, a Mexico-based modelling firm, well known for developing its earthquake model for Mexico after the deadly 1985 quake in Mexico City. ERN was created at the UNAM (Mexico Autonomous University) and is the Mexican Government approved EQ modelling insurance institutions have to use to come up with a reserve level. The EQ model has now expanded in many Latin American countries. ERN is also developing a Hurricane model for Mexico (both Atlantic and Pacific sides)
- JBA RISK MANAGEMENT, a data provider which provides hazard maps and models for catastrophe modelling
- RISK FRONTIER, founded in 1994 at Macquarie University in Sydney, Australia. This lab at the university provides hazard maps and models for the Asia-Pacific region. Hazards include cyclones, EQ, hailstorm, bushfire, flood, tsunami and volcanic ash. Risk Frontier is the preferred research supplier of the New South Wales (the state where Sydney in located in) State Emergency Services
- QUAKERISK, a pan-European EQ model developer

- ANALYZE RE, regrouping software engineers, statisticians and economists with a background in reinsurance risk pricing
- SPATIALKEY, an IT company delivering agile visualization and analytics to improve and speed up the understanding of accumulation and exposures.

Current RMS offer encompasses such perils as: earthquake, severe convective storms (tornadoes and hailstorms), cyclones, windstorms, winter storms, flood, tsunamis but also cyber risks, terrorism, life risks (pandemic risks), risks affecting marine cargo. RMS claims to offer modelling for EQ, pandemic and terrorism worldwide while the other perils are only offered in part of the world, where they apply or where RMS has enough partners to offer something. For instance, flood is modelled in Europe only and RMS provides flood hazard data for the US on a 30 m resolution.

RMS model is a 3-step tool, modelling the event using stochastic events to complement historical data and rely on more robust data sets, determining the damage and deriving the loss.

The EQ modelling is the most advanced model for RMS and will model ground motion as well as ground displacement like fault ruptures, landslides and soil liquefaction. The takeaways will include secondary effects such as fire ignitions or tsunamis.

For hurricanes (North American Cyclones), the second best advanced model for RMS, the model will estimate damages based on a 3 s peak wind gust and water surge depth. The model will calculate wind fields on-shore coping with the terrain roughness that is also calculated based on topography and constructions. The surge depth is modelled based on a hi-resolution topography and bathymetry on and off-shore. The model has been accredited by FEMA (the US emergency management agency) as one of 2 accredited models for surge depth prediction. The hazard resolution for surge is the same as the flood one and goes down to 100x100 m in some areas.

The vulnerability curves are internal design with help for RMS' partners and literature reviews. RMS does not specifically addresses structures of non-completed buildings but mainly addresses buildings of various construction type, age and following building codes.(RMS does have a builders risk model, but it is limited in scope at this time)

The model gives the OEP (Occurrence Exceedance Probability) and AEP (Aggregate Exceedance Probability) loss exceedance curves, the AAL (Average Annual Loss a.k.a. pure premium) and the TVAR (Tail Value at Risk). Results are given for buildings, contents and BI, provided an adequate insurance policy structure is given at time of modelling.

All RMS models are available through a software platform called RMS (one)®. RMS (one) is a software in the making, it is not commercially available yet. Risk Link is its current software

Some highlights per geographical areas.

RMS has developed a high resolution flood model for Europe (for 13 countries: Austria, Belgium, Czech Republic, France, Germany, Hungary, Liechtenstein, Luxembourg, Monaco, Poland, Slovakia, Switzerland, the UK including Northern Ireland and the Channel Islands) with a granularity of 5x5 m, even down to 2x2 m in the UK. The event set covers 18 river basins with over 8000 catchment areas. The set holds some 800000 events corresponding to some 50000 simulated years. Flood defence are included in the mapping and include some temporary ones. RMS uses a stochastic defence failure model and its partners for accurate data. Floods include inland phenomena, groundwater and snowmelt driven events.

RMS has developed a hi-resolution model for EQ in New Zealand, following the Canterbury Earthquake Sequence in 2010-11 (including the Christchurch event, a 6.3 magnitude on Richter scale). This model is also integrating a soil liquefaction model which played a key role in the damage and losses that occurred during those events. The model uses the 2014 Geological Map of New Zealand from GNS Science and has been built after data has been collated on sites. The local building stock has been embedded in the model and vulnerability curves reflects construction practices, building codes followed and damaging results, built from the consequences of the actual EQs in New Zealand. A fully probabilistic tsunami event generating model has also been designed, something new for the area. It is also a hi-resolution model.

The model for Hurricanes is valid for the North Atlantic only and covers the US, Canada, Mexico, Bermuda, Central America and the Caribbean and oil rigs in the Gulf of Mexico (some 40 countries in total). The storm surge is also

modelled with a dynamic time-stepping engine but for the US, the Bahamas, Cayman Islands and Turk and Caicos only. This model is one of the oldest RMS operates. Damage and losses spanning 20 years have been collated. The granularity of the model is 15 m and over 500 vulnerability functions are included.

Another model is available for Typhoons affecting China.

RMS proposes a hail storm modelling for Europe within its severe convective storm model. This complement the windstorm model available for the same locations simulating 100000 years of activity. The event catalogue includes 135 real storms.

The tsunami model accounts for large earthquake 8.9 to 9.6 magnitude in subduction zones known to have produced large tsunamis in the past (like the 2011 Japan event of the 2004 event in the Indian Ocean). It also considers ground subsidence and variable land friction across multi-country coastlines.

Winter storm modelling is proposed for the United States and Canada. The events modelled are snow falls, ice, freezing temperatures and extra-tropical winds. Data sources are mainly from the NOAA (National Oceanic and Atmospheric Administration) National Weather Service and Canada's Meteorological Service. Vulnerability curves have been constructed based on damage observation from past events.

3.2. EQECAT

EQECAT Eqecat was owned by the ABS Group until late December 2013, a marine and offshore classification body based in Houston, TX. The new owner is CORELOGIC®, a California based company specializing in providing data and analytics to the real estate sector. Before buying Eqecat, Corelogic already had in-house capabilities for flood exposure determination, based on data. Corelogic claims to have the more comprehensive property and related financial databases in the US, Australia, New Zealand and developing its databases in the UK, Canada, Mexico and India. The Eqecat perimeter is now known as Catastrophe Risk Management within the Corelogic products. RQE® (Risk Quantification & Engineering) is Corelogic's full simulation catastrophe modelling solutions.

The model operates for a number of hazards in a number of locations:

Flood

- Europe, mainly Austria and Germany
- US except islands and possessions

Earthquake

- Australia
- Canada
- Europe with a focus for Italy
- US
- Mexico
- Caribbean
- All of Central America
- Argentina
- Brazil
- Chile
- Colombia
- Peru
- Venezuela
- Japan including Tsunamis
- China
- India
- Indonesia
- Malaysia
- New Zealand
- Pakistan
- Philippines
- South Korea
- Taiwan
- Thailand
- The gulf peninsula
- Israel
- Lebanon
- Kenya
- Malawi
- South Africa
- Turkey

Cyclone

- Asia
- Australia
- Pakistan
- Oman
- Reunion
- UAE
- Yemen
- North Atlantic (US, Caribbean, Bermuda)
- Gulf of Mexico
- Some Central American countries and northern South America

Tornado and hail (severe convective storm)

- US

Winter storm (blizzards)

- US

Extra-tropical cyclone (mainly windstorms)

- Europe (24 countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Monaco, Netherlands, Norway, Portugal, Spain, Romania, Slovakia, Poland, Sweden, Switzerland, UK)
- Argentina
- Brazil
- Chile

Corelogic is not very specific for regions it does not cover currently although not excluding those formally.

Corelogic proposes records of natural events that have affected a particular building and possibly the suffered loss. Once the event and affectation is known, Corelogic also proposes for that particular building a repair/reconstruction estimate based on building permit databases and assessor's data. This is mainly available for buildings (residential, commercial, industrial) as opposed to structures and other civil works. It

does not specifically apply neither on non-completed buildings or structures at time of the event.

The model is a classic 3-step engine, determining the hazard with a stochastic set of events, sometimes including historic data, determining the damage or vulnerability, based on vulnerability functions and finally the loss by applying insurance policy structures. Regarding this third step, it does not necessarily mean that the model will automatically apply the variation of capital exposed to loss with time as found in construction projects. Vulnerability functions in the model are specific to constructions practices per country and are taken from literature reviews or based on Corelogic's experience from past events, engineering input and expert studies. There is no evidence other structure type than buildings are taken into account in the fragility curves.

The loss model gives results for building, contents and business interruption if details are provided in the insurance policy input step.

The stochastic event sets may be more or less large, depending on the hazard but are generally a few decade of thousands of events large.

Input data can be imported into the model by longitude and latitude, post or zip code where existing, place name, CRESTA zones or by country.

The model gives the OEP (Occurrence Exceedance Probability) and AEP (Aggregate Exceedance Probability) loss exceedance curves, the AAL (Average Annual Loss a.k.a. pure premium) and the TVAR (Tail Value at Risk).

More refinements or limitations can apply for the various sections of the model, according the peril and the hazard.

> The earthquake (EQ) in the United States uses the National Seismic Hazard Model developed by the USGS (US Geological Survey) and for California in particular (the most seismic prone area in the continental US) the UCERF3 (Comprehensive Uniform California Earthquake Rupture Forecast version 3). The model uses a time dependent frequency, being scientific consensual for this part of the world. This means that a fault late in its seismic cycle (relative to the average time between large EQs) is more likely to produce an EQ.
> Ground response is also modelled using ground motion prediction equations and adjusting for site amplification (in sedimentary basins for instance) or decaying.

Vulnerability functions are derived from engineering reviews and observations from EQ, in particular that of Northridge in 1994 and Loma Prieta in 1989. Those vulnerability functions in the RQE model are in particular addressing the wood-frame residential homes and foundation type and connection to the wood-frame structure.

The model also computes other perils such as fire following an EQ, sprinkler leakage or human losses and injuries to account for workers compensation. No detail has been given on how those derived perils are modelled.

The EQ in Australia is characterized by infrequent moderate events but highly variable losses. RQE uses the GA (Geosciences Australia) hazard model and includes 300000 years of simulated losses to avoid underestimating tail risks driven by infrequent events.

The European EQ model offers a better granularity in Cyprus, Greece, Italy, Malta, Portugal, Spain and Turkey, the most prone countries to EQ. Seismic sources have been taken from literature and have been incorporated in the stochastic model that has computed 300000 years of simulated loss to cope with infrequent yet highly destructive events.

Vulnerability functions are based on field investigations with engineering knowledge assessing local building codes.

The model also uses a soil-based attenuation function and not rock-based attenuation to better model urban areas, mainly built on soil and not rock.

The use of SHARE (Seismic Hazard Harmonization in Europe) for the hazard module for Italy has been chosen to include the latest scientific knowledge such as the hazard exposure in the Po river valley, considered low or irrelevant prior to the 2012 series of earthquakes.

In Japan and similarly to what has been done for Italy, the 2011 Richter 9 Tohoku-oki earthquake has triggered a new seismic source zonation which is now included in the model. Resolution is now down to 250 m country wide. A revised non-linear soil amplification model has been added and time-dependent probabilities are used in Japan as well.

Vulnerability functions include unique developments for structures with seismic protection systems and specific construction practices like seismic base isolation (considered in the model as secondary structure modifiers).

Additional perils are covered such as tsunamis with about 24000 stochastic events. It includes modelling of tsunamis height using the Cornell University

model. Fire following EQ and sprinkler leakage are also modelled but no detail is available on how those are obtained.

The United States flood models covers all US states with a high granularity: 10 m resolution elevation data. The hazard data is based on FEMA maps. The construction types producing the vulnerability curves are shared with the EQ construction type for the US.

The Europe flood model mostly covers Austria and Germany for both riverine floods for the following river basins: Rhine, Elbe, Oder, Weser, Ems, Danube, Salzach, Inn, Ager, Krems and Enns rivers, and off-plain floods.
Some 32000 stochastic precipitations events have been determined. For each event, the effective run-off of water per catchment area is calculated considering the local topography. Then the water height is determined at various points in the river system. Flood defence breach is computed probabilistically (sub-model built after engineering judgement has been given on a per defence basis) and water height is added according a digital terrain model having a granularity of 50x50 m.
Vulnerability functions are derived using ABS consulting (former owner of EQECAT) engineering data.

Corelogic uses Asia typhoons historical data coming from Hawaii's Joint Typhoon Warning Center, Japan's Regional Specialized Meteorological Center, the Hong Kong Observatory and China's Shanghai Typhoon Institute for the period 1945-2009. Model provides results for combined wind, storm surge and rainfall induced flooding. It includes cyclones, tropical storms and tropical depressions. Separate damage functions are created for each of the peril.
Main parameters for the fragility curve set are age and height of the buildings which appears to be limited parameters and will not account for dikes or embankments, cyclone panes or shutters for instance. In addition, Corelogic uses claims data and expert opinion to create vulnerability curves that relate wind speeds to damages.
The model includes some 150000 stochastic and 1800 historical events.

The United States tornado model is based on historical data from the 1950s from NOAA's records (National Oceanic and Atmospheric Administration). The

data includes the Fujita classification for each event as an indication of the severity of the loss. The stochastic set of events includes 840000 storms.

The vulnerability curves have been derived from a 20 year literature research. The granularity is 10 km² and the model is valid for the 48 contiguous states.

The United States winter storm model is a fully probabilistic model. It uses a 11500 stochastic event set. This set includes historical events.

3 hazard parameters are considered in the model: the snow depth, the ice thickness and the wind speed. The model considers 2 damage types: the roof damage or collapse due to weight and ruptured pipes due to freezing.

The model is available for the 48 contiguous states and does not cover Alaska.

The windstorm model for Europe also includes offshore wind turbine risks in the North Sea, the Irish Sea, the Baltic Sea and the Eastern Atlantic. The hazard set includes 384 historic and 23000 stochastic events. The frequency model uses a 1200 year simulation and a recorded frequency from 1960-2014 in over 4000 meteorological stations across Europe. Correlated storm surge is available for the UK, France and Sweden with a probabilistic coastal defence failure. Forestry vulnerability is included for Sweden and Finland based on tree type and height.

The model is clearly limited to building type of construction. The granularity is 500 x 500 m.

3.3. AIR Worldwide

Air Worldwide (AIR) was founded in 1987 in Boston, MA making it the oldest cat model in the market. It started very modestly until Hurricane category 5 Andrew hit Florida in 1992 which raised the global consciousness on how devastating those hurricanes could be. AIR was bought in 2002 by VERISK ANALYTICS®, a data analytics provider for many industries such as insurance and risk management.

As for its competitors, AIR is modelling various perils within the NATCAT (earthquake, extra tropical cyclone (winter storms), flood, severe thunderstorm (Tornadoes), hurricane, but also wildfire, cyber risks, terrorism, risks affecting marine and cargo, life and health of agriculture.

AIR covers some 90 countries overall but risk dependent.

AIR model is a stochastic model. It works classically with various modules and provides OEP (Occurrence Exceedance Probability), AEP (Aggregate Exceedance Probability) and AAL (Average Annual Loss or pure premium). CATRADER (Aggregate modelling tool) & Touchstone (Detailed modelling tool) are the modelling tools delivered by AIR. It is tailorable by the user to incorporate in-house models, loss adjustment factors or exceedance probability curve adjustments which are useful to incorporate varying deductibles or priorities. This capability could be of interest for the engineering line of business which often needs to managing varying quantities over the life of a project.

As for other models, earthquake is the most developed one. It includes the frequency and magnitude of tail scenarios although they are quite infrequent. Additional functions are included in the model such as Tsunamis, liquefaction of soils, landslide or subsequent fire. AIR is also the first modelling company to propose a probabilistic tsunami model. The vulnerability curves used are region-specific and time dependent to reflect the various construction practices and building codes in the countries where the model is available. Current covered countries include Canada, the US, Mexico, all of Central America, highly populated islands of the Caribbean, Chile, Colombia, Ecuador, Peru, Venezuela, Australia, Brunei, China, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Taiwan, Thailand, Vietnam, most of the European countries. In some countries like Japan, extensive loss data from the insurance market has been used to validate the model results. Regarding Japan and after the M9.0 Tohoku EQ that struck in 2011, AIR has incorporated new scientist data in the model to account for the changes in local seismology and new rupture probabilities due to the fault modifications occurred after the EQ. Still addressing Japan, AIR has developed a Tsunami model for theentire life of it, covering generation, uplift of water with changing height and forward speed, impact on the shore and inundation period. This model uses a high resolution terrain and coastline data (50x50 m).

The extratropical cyclone model is mainly addressing the winter storms in the US and Canada as well as the windstorms in Europe. Damage functions used by AIR for North America also allow modelling the losses due to snow, sleet, freezing and icing conditions which are often a result of a windstorm in that region. Supplier downtime, utility service interruption as well as contingency measures taken by authorities are also built in the model. For Europe, the model includes data from real events since Daria in 1990 and since 2000 a numerical weather prediction based on national centers for weather prediction. As opposed to Hurricanes, extratropical cyclones are far more complex systems thus requiring this type of modelling. This includes clusters of systems, i.e. several storms in rapid succession as history has proven it is often the case for storms in Europe. The local effects of terrain roughness are also incorporated

in the model. The vulnerability curves cover all types of construction found in Europe, including some specifics such as agriculture and greenhouses or forestry. Business interruption as well as content damage are also modelled.

Flood is modelled in the USA, Brazil, China, Thailand, Austria, Czech Republic, the UK, Germany and Switzerland. Data on levees and dikes acquired by AIR allow it to quantify the likelihood and impact of their failure. In the US, AIR uses its precipitation model to predict rainfall but also takes into account the saturation of soils due to prior rainfall and snowmelt. The model computes on a continuous basis. Custom modifiers can be used in the model like specifying the exact height of the floor of interest from ground level. Specific fragility curves are used to model the probability of failure of the complex and rather old levee system across the US. As most of the damage due to floods is for the contents and components of a building, the model integrates construction material for the inner wall to determine the probability of damage due to mold for instance. Off-floodplain floods are modelled by a specific module for the US and takes into consideration the construction and watertight surfaces in an area.

A severe thunderstorm modelling (or Tornado modelling) is available for Canada and the USA. It does include hailstorms for those two countries. In the US, with a 90x90m resolution, the model supports residential homes and a total of 40 construction classes as well as complex industrial facilities. The stochastic catalogue includes 10000, 50000 and 100000 year events.

The tropical cyclone model covers Canada, Hawaii and 29 continental state of the US, Mexico, all of Central America, the majority of the Caribbean islands, Southeast Asia, Australia, Korea, Taiwan and China. This model was AIR's first when it started in 1987. The Atlantic basin model is shared among the Caribbean, the US, Mexico and assets in the Gulf of Mexico. It includes the sea surge sub peril in coastal areas of the US. Secondary modifiers for the vulnerability curves take into account building features such as roof cover, roof attachment, type of siding, glass type.

A combination of the EQ model and the cyclone model is offered for offshore structures or near shore structures like marinas and piers. Main areas being modelled are the Gulf of Mexico, Eastern Asia and Southern America. The modelling does include damage to cargo whether in transit or at maritime ports.

3.4. CEECAT

CEECAT is a web based portfolio and data management tool designed to aid understanding of project construction exposures. CEECAT is run and operated by JLT

Re. It was specifically designed for (re) insurers writing construction and engineering business. The construction specific issues that it considers include the non-static nature of each risk both in time and space and the constantly changing vulnerability of risks.

The three elements of this tool include;

- Portfolio management, individual project exposure analysed on a day-by-day basis

- Catastrophe Modelling, natural catastrophe exposed risks modelled taking account of full construction and peril dynamics

- Online data management, web enabled facility that connects to current systems

3.5. OASIS Loss Modelling Framework

A few years ago, the London based organization has started to build a new platform which offers a simulation platform and financial module. Hazard and vulnerability information needs to come from other parties, such as academic groups or specialized engineering companies. It's still early days but the platform has the potential to become an important player to build on 'own view of risk'.

4. **Limitations on the Information provided – should Underwriters rely on a Black Box**

To understand the limitation of the models it is necessary to understand the importance of the input data, the calculations and assumptions behind outputs provided from the models.

4.1 Change in Vulnerability

The output will only be as accurate as the input provided. The Primary Characteristics and Secondary Modifiers are discussed earlier and the more details provided here the better. That said the models do not monitor the change in vulnerability of the structure during the construction.

4.2 Buildup of Value

To account for the buildup of value over time the models can be run at the beginning of the project and at the end and the exposure between these two dates pro-rated assuming a linear buildup of value. This might not be necessarily if you have the value at key steps of the construction. The difficulty here is that the buildup of value is rarely linear and so the assumed exposure mid-way during construction will not be accurate. See later for possible future development for models.

4.3 Unknown Location

Some construction insurance products include turnover and declaration policies and it can be difficult to model accumulation because the exact locations are generally not provided. Linear risks such as road, rail and tunnel projects are not well represented with existing models and assumptions have to be made about how the value is split over the length of the project.

4.4 Granularity of Geocoding

The initial exposure assessment in the models, ie the Stochastic, Hazard and Exposure Module are all related to the location. It is therefore important that the location is accurately inputted and on as granular level as possible. Coastal locations can have a large variation in ground level within a short distance and if we consider storm surge exposure the difference between being at the top or bottom of a hill can make a significance. It is therefore important that the actual coordinates not the post codes are used.

4.5 Seasonality of Hazard

Engineering projects oftentimes last for several years and not necessarily an integral multiple of one year. If the hazard – like floods or cyclones – has seasonality patterns, then this should be considered when simulating events and insured losses.

Figure 1 Hurricane climatology in the North Atlantic - cortesy NOAA, http://www.nhc.noaa.gov/climo/

4.6 Key Outputs

Average Annual Loss (AAL) also called Pure Premium

This is the amount of premium required to balance the modeled catastrophe risk in average over one year, also referred to as pure premium or burn cost and equivalent to expected loss on an annual basis.

This is the expected loss when averaged over a very long period of time and the minimum premium you have to receive for the modelled NATCAT event. To also balance the other exposures of an all risk cover, plus to make some profit you would also need much more than the AAL.

Occurrence Exceeding Output (OEP)

This is the probability that the single largest event loss in a year will meet or exceed a loss threshold. OEP gives the probability of a loss of a given size or larger in a year.

The OEP is calculated from an exceedance probability curve. This enables an insurer to determine the Maximum Possible Loss (MPL) for a NATCAT event. The MPL

however relates to a return period determined by the underwriter or (re) insurer. The higher the return period the likelihood that the result will be more accurate but then also the MPL will be higher. So the results need to be considered in conjunction with the whole portfolio and the (re) insurers view on the risk and results of the MPL being exceeded. It is not totally absurd to have to consider a 1000 or even a 1500 year return period to achieve a comparable MPL result to one provided by a loss control engineer performing an assessment on site.

4.7 Use of modelling on a single location

The results from NATCAT modelling are more accurate on a portfolio basis where there are a large number of risks. For a single risk the results may not be so accurate because of the possible lack of historical data for that particular location. In this case, the modelling would be based on pure stochastic events which may never occur in that location. The results are appropriate for;

- Portfolio steering / risk accumulation control

- Calculating NATCAT RI protection requirements

- Risk capital allocations

- Regulatory reporting

- NATCAT pricing for individual policies.

It is clear therefore that underwriters should be informed by and not controlled by the model results.

5. <u>Likely future Developments</u>

There are two significant areas where the current models do not model construction projects accurately, the buildup of value over time and the changing in vulnerability during the construction process.
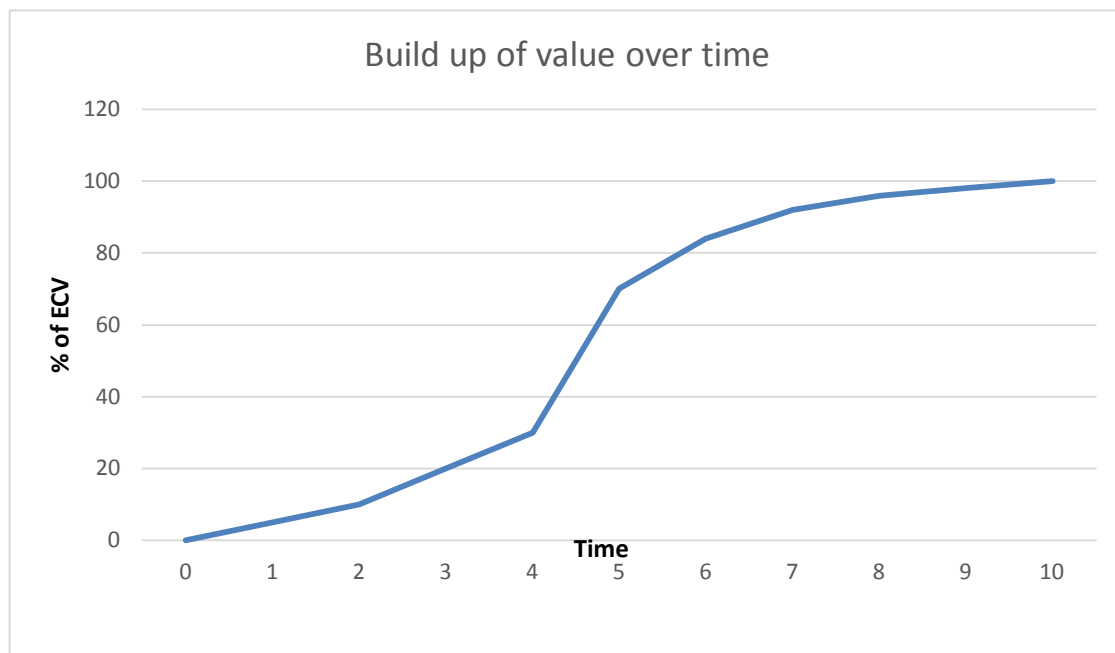
Buildup of value

Current assumptions are that the ECV will build up linearly over time.
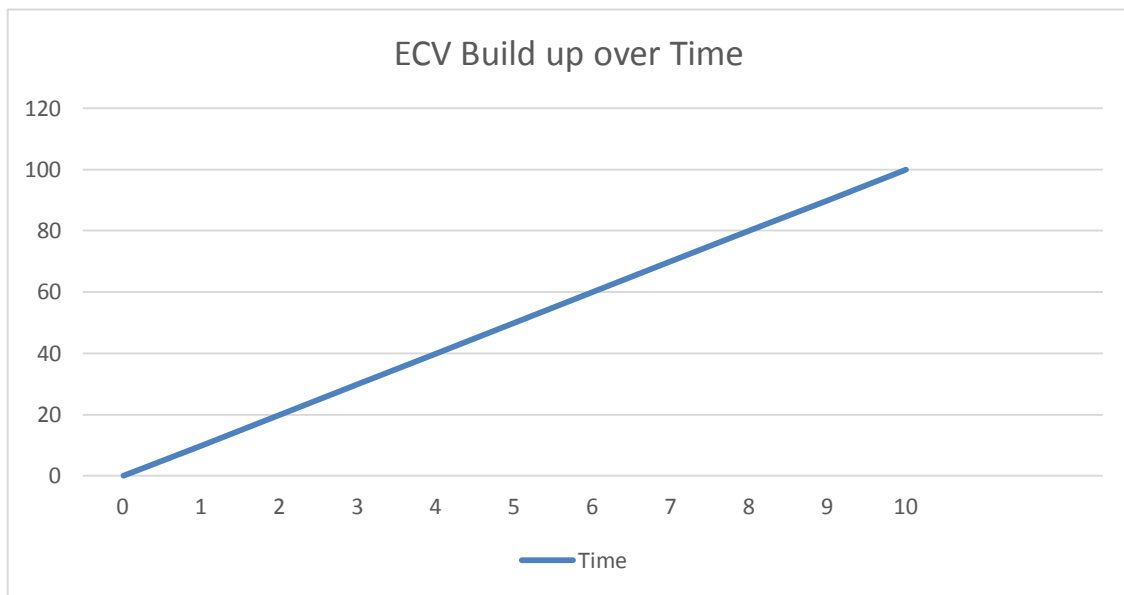
Typical buildup of value would probable follow am 'S' curve
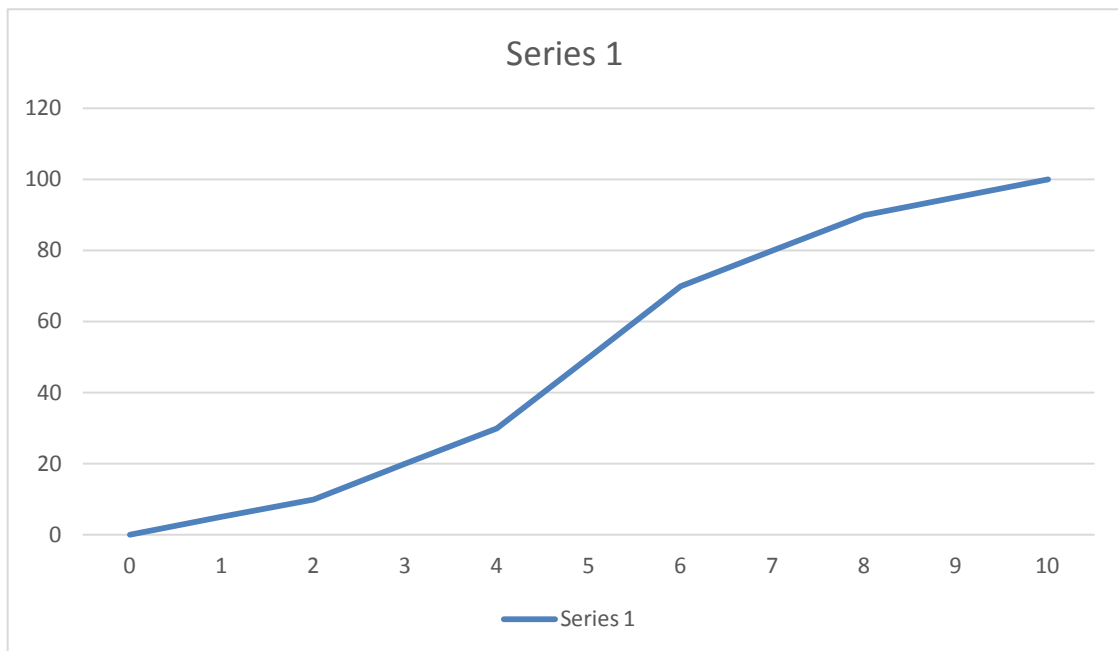
However where there is a degree of pre-fabrication or the use of modular units (EAR) it is possible that the increase in ECV may start earlier in the construction process.

If we consider that when the model is calculating the exposure for a construction portfolio at a particular point in time it currently assumes a linear buildup in the ECV there could be considerable inaccuracies built into this analysis.

During the underwriting process the underwriter will have access to a full submission including the Gant Chart and a breakdown of the sum insured. From this information he should be able to derive the buildup of value curve for that particular project. It is our suggestion that the existing models could be adapted to allow the underwriter to enter this information into the model and consequently improve the accuracy.

Vulnerability

The vulnerability of a structure to a NATCAT event will depend on the specific event, the nature of the structure and also the timing of the event when compared to the particular stage in the construction process.

If we consider a cable stayed bridge in a high earthquake exposed area. Bridge structures generally have design life in excess of 100 years and a robust design should mean that these structures are resilient to earthquake and the model should take account of this. The correct Primary Characteristics and Secondary Modifiers will be critical here to reflect the robustness of the design. However this analysis will not take account the different stages in the construction process.

Completed Cable Stayed Bridge

If we consider a completed cable stayed bridge this would normally be robust with resiliance to earthquake designed in.

Partially Constructed Cable Stayed Bridge

The partially constructed cable stayed bridge will be more exposed to earthquake during this phase of construction and this won't be represented during the modelling process. It is our suggestion that the existing models should be adapted to allow the underwriter to enter information reflecting the construction phases into the model and consequently improve the accuracy.

The vulnerability of this structure might be reflected by the following graph.

Change in vulnerability over time

Vulnerability

Time - Years
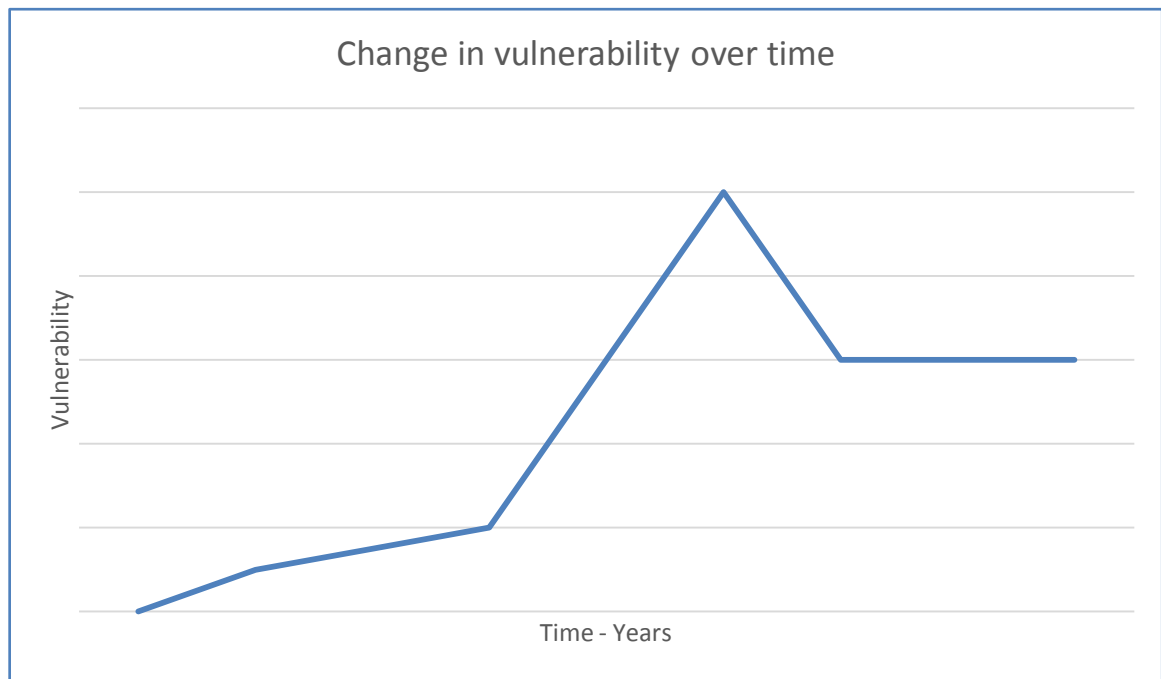
By using a combination of buildup of value and vulnerability graphs it would be possible to more accurately access the actual exposure of the structure to the NATCAT event. Consequently the financial loss can be more accurately calculated.

Summary

The development needs for existing models to make them more suitable for engineering business include;

- More accurately reflecting the buildup in value over time.

- More accurately reflecting the change in vulnerability over time

- Combining these two to more accurately quantify the financial loss.

6. <u>Use of NATCAT Models for Claims Management after Events</u>

NATCAT models have the ability to predict damages based on both recorded and stochastic events. They are quite good a defining what area/basin will be most likely affected and what will be the extent of the damage with associated likelihoods. Even if they do not address some specificities of the engineering line of business, the knowledge of the most affected areas can help insurers with their claim management after the event.

Without even having to recognize the extent of the loss using hi-tech satellite or drone imagery, the use of NATCAT models with the real event will produce an evaluation of the damage and the location of it. This might be quicker and more practical initially for an insurance carrier to dispatch its relief teams on the scene and address priorities. Additionally this is a tool which would be useful for aid agencies to assist them in focusing their efforts.