Risk of Hurricane Damage and Evaluating the Economic Viability of Strengthening New and Existing Residential Construction

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1. Introduction

Losses from wind and hail in the U.S. averaged $1.6 billion annually for the period 1950-1989 and then more than $6 billion annually for the period 1989-1995. The potential for even larger losses exists given that the population and property at risk is increasing dramatically. There is increasing importance on estimating probable maximum losses (i.e., expected insurance losses) and the effect that changes to existing structural vulnerability have on building damage and expected insurance (and societal) losses. Surveys of existing vulnerability provides only a 'point-in-time' or a snapshot of housing as it was at that time and so may not be a good indicator of future vulnerability. Hence, over time this 'point-in-time' structural vulnerability will vary due to changes in housing types or styles; new materials; age profiles; code specifications, compliance and enforcement; changes to exposure categories and so on. The present paper will propose a scenario-based model for changes in the structural vulnerability of residential construction due to improvements in building envelope performance, for both existing (retrofitting) and new construction. The hurricane damage risk-cost-benefit analysis model developed herein will assess the influence of the time-dependent changes in structural vulnerability on expected insurance losses. One scenario may include, for example, retrofitting existing houses immediately after they experience hurricane damage. The cost of retrofit can be included in the hurricane damage risk-cost-benefit analysis to help assess the economic viability of this and other scenarios. The model will also aid decision-makers by determining when a particular retrofit strategy will be economically viable.

2. Prediction Of Expected Losses

Expected losses to be calculated herein are based on the GIS-based hurricane hazard risk analysis framework developed by Huang, et.al. (2001). This study used event-based simulation to generate hurricanes; namely: (i) Hurricane arrival time generated from a Poisson arrival model; (ii) Gradient wind field generated; (iii) Gradient-to-Surface conversion factor used to determine surface wind speed; (iv) Hurricane moved to next location and the wind field is regenerated taking into account spatial changes such as decay. A similar process also calculates wind speeds in nearby zip-codes; and (v) After the hurricane has degraded to a point where wind speeds are no longer significant the simulation randomly generates the next hurricane event.

Models that related claims and damages to surface wind speed allowed the claim and damage ratios at each zip code to be determined for each hurricane event, summed for each hurricane event, and then divided by 50 at the end of each 50-year period to obtain expected annual claim and damages ratios for zip codes in North and South Carolina and Florida. The Monte-Carlo simulation analysis considered 1000 simulated 50-year exposure periods.

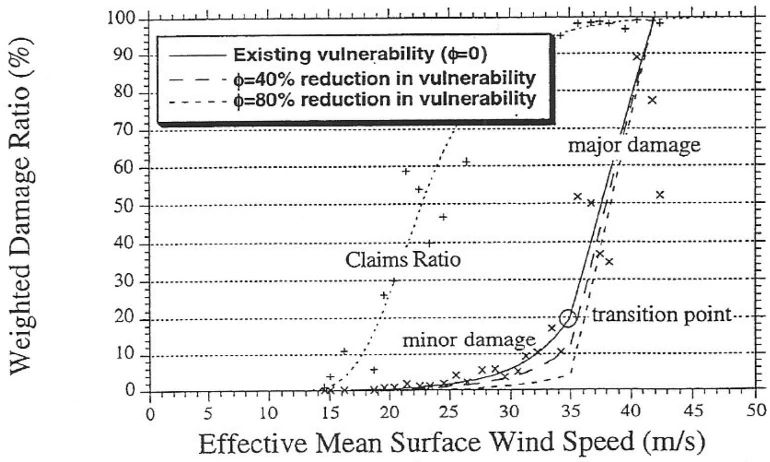

Figure 1. Claims Ratio, Model of Existing Structural Vulnerability and Effect of Reduced Vulnerability to Minor Damage.

3. Hurricane Structural Vulnerability Models

The claim ratio is defined as the total number of claims in a zip code divided by the total number of insurance policies in that zip code. The damage ratio is defined as the amount paid out by the insurer (in

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damages) divided by the total insured value (including contents). It is assumed herein that changes in structural vulnerability will not influence the number of insurance claims but rather the value of such claims (i.e., damage ratio). Thus, the term 'structural vulnerability' subsequently refers to the effect of effective surface wind speed on the damage ratio of residential construction. This structural vulnerability model is shown in Figure 1. If it is assumed that improvements to building construction will mostly affect the vulnerability to minor damage then the conditional structural vulnerability may be as shown in Figure 1 where ϕ is the reduction in existing structural vulnerability. In other words, the transition point is reduced by $20\times(100-\phi)\%$.

4. Future Residential Construction Scenarios

There are many possible scenarios for time-dependent changes to structural vulnerability of new and existing residential construction. However, for the present study scenarios associated with strengthening (retrofit) and changes to population mix of new construction are considered. If a house is damaged by a hurricane then this would probably be a convenient time to retrofit (strengthen, upgrade) the house since a builder is already on site conducting repairs. It is quite likely that the additional cost of retrofitting will only be incrementally greater than the costs of simply restoring the house to its initial (undamaged) condition. Some form of financial assistance is generally needed to encourage retrofitting. This scenario therefore assumes that the insurer fully covers the cost of retrofitting. The hurricane damage risk-cost-benefit analysis to follow will help assess if such an investment strategy will prove to be economically viable to the insurer.

The analysis assumes that retrofitting is a one-off process conducted after the first hurricane-induced incidence of damage. The cost of retrofitting is expressed as a percentage of the value of the structure. The damage ratio for subsequent events will then be influenced by the proportion of retrofitted housing and this proportion in turn is affected by the peak mean wind speed experienced by the site up to this time. The claims ratio (Figure 1) provides an indication of the proportion of houses retrofitted after each hurricane-event. If the next hurricane-event is of lesser intensity then no additional houses are retrofitted, otherwise, a hurricane-event of greater intensity will lead to additional houses damaged and retrofitted.

Another scenario considers the effect of the rate of growth of new housing assuming that such new housing is constructed with reduced structural vulnerability. Clearly, the rate of growth of new housing may also be seen to represent the rate of growth of retrofitted houses or other strategies that result in houses of reduced vulnerability.

For both scenarios it is assumed that the wind speed characteristics are constant across an entire zip code and that the structural vulnerability of an individual house in its initial (undamaged) condition is time-invariant and deterministic. Thus, a low wind speed event will only cause damage to a sub-set of houses previously damaged by a higher intensity wind event. See Stewart, et.al. (2000) for more details of this analysis.

5. Results of Hurricane Damage Risk-Cost-Benefit Analysis

The Monte-Carlo simulation method is similar to that described in Section 2 except that structural vulnerabilities are modified and retrofit costs included in the analysis as discussed in Section 4. Expected annual costs are then annualised for a 50-year exposure period.

5.1 Existing Structural Vulnerability

The expected annual damage ratios based on the existing structural vulnerability (ie. 'do nothing') are shown in Table 1, for typical coastal and interior (several hundred km) locations in South Carolina (US). Naturally, these results are near identical to those reported by Huang, et.al. (2001). It is observed that the expected annual damage ratio may be as low as 0.08% for sites far inland (Columbia) and as high as 2% for exposed coastal sites (Folly Beach). An expected annual damage ratio of 2% implies that houses will experience losses totalling 100% of the insured value, on average, every 50 years.

Site	Existing Vulnerability	Reduced Vulnerability to Minor Damage		% of Houses Retrofitted
		ϕ=40%	ϕ=80%	
South Carolina:				
Charleston City	0.541	0.409	0.276	88.0
Columbia	0.080	0.058	0.035	50.9
Folly Beach	2.088	1.754	1.420	96.6

Table 1. Annual Expected Damage Ratios for Existing Structural Vulnerability and Retrofit During Repair to Hurricane Damage (Excluding cost of retrofit).

5.2 Retrofit During Repair to Hurricane Damage

The expected annual damage ratios (excluding costs of retrofit) for this scenario are shown in Table 1 and in all cases at least 50% of houses will be retrofitted over the 50-year exposure period. In some cases this reduction in damage ratios is up to 55% for an 80% reduction in vulnerability to minor damage. As such, the expected annual damage ratio decreases dramatically for the retrofit scenarios considered herein.

Zone of Economic Viability

The cost effectiveness of the retrofit scenarios may be assessed by comparing the insurer costs (damage ratio for a particular reduction in structural vulnerability + retrofit cost) with the 'do nothing' scenario. There are a large number of combinations of reductions in structural vulnerability and retrofit costs. Hence, an 'envelope' of these combinations producing expected annual insurance costs lower than the 'do nothing' expected annual damage ratio is developed – this is referred to herein as the 'zone of economic viability'. Figure 2 shows the zones of economic viability for Columbia (interior) and Folly Beach (coastal). The zone of economic viability is much smaller for Columbia due to its reduced exposure to hurricanes; however, Figure 2(a) shows that retrofitting is still cost-effective if a 60% reduction in vulnerability can be achieved for a retrofit cost not exceeding 5% of the initial building cost. For Folly Beach, retrofitting is cost-effective even if retrofit costs for the same reduction in vulnerability (ϕ=60%) reach 40%. Clearly, the zones of economic viability (particularly for coastal or exposed regions) show that for the scenarios considered herein retrofit costs may be cost effective even if they achieve modest reductions in structural vulnerability.

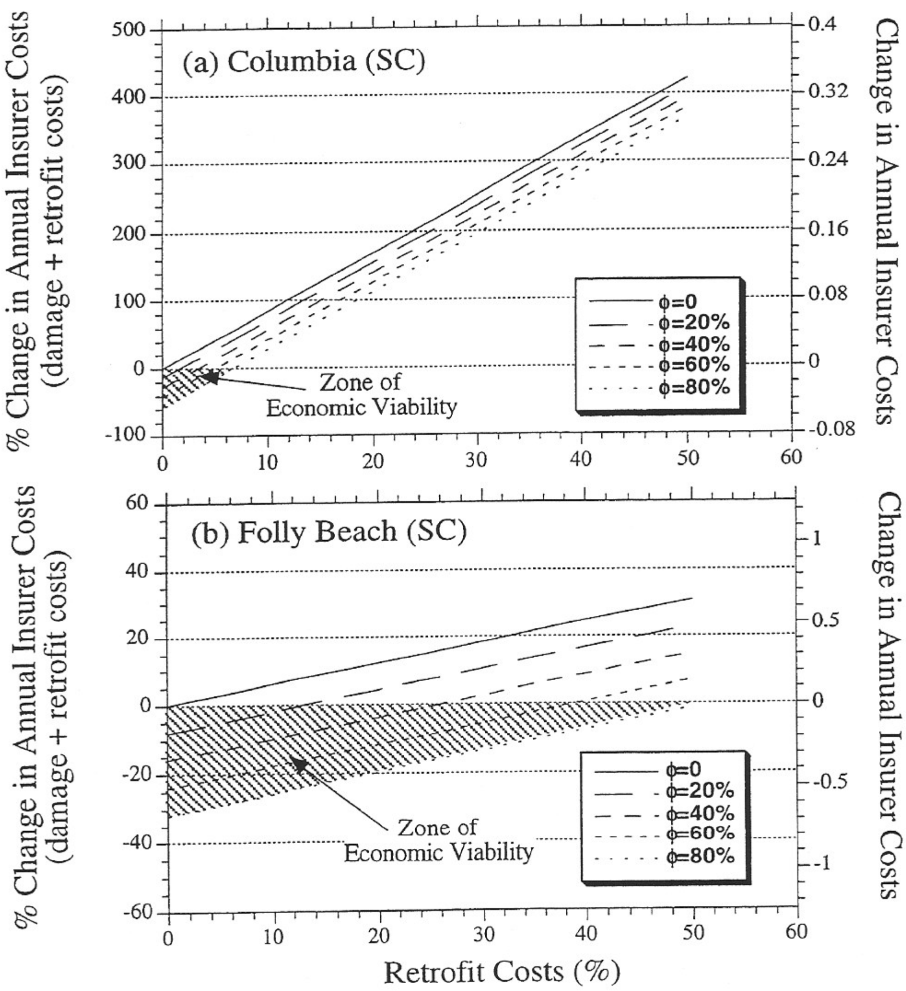

Figure 2. Zone of Economic Viability for Retrofit During Repair to Hurricane Damage (Reduced Vulnerability to Minor Damage), for (a) Columbia and (b) Folly Beach.

Time to Economic Viability

The preceding analyses have considered costs annualised over a 50 year exposure period. However, it may also be useful for decision-makers to monitor changes in costs over time as this will give an indication when a particular retrofit strategy will be economically viable. This is achieved by comparing the 'do nothing' strategy (existing vulnerability) with cumulative insurer costs for all years up to year T annualised over this time period. For example, annualised costs up to year T are shown in Figure 3, for retrofit during repair to hurricane damage (ϕ=60%, retrofit cost=5%). The intercept of the cumulative costs for all years up to year T annualised over this time period and the 'do nothing' expected damages shows the time needed for this particular retrofit strategy to be economically viable. In this case, this particular retrofit strategy becomes economically viable after four years for Folly Beach.

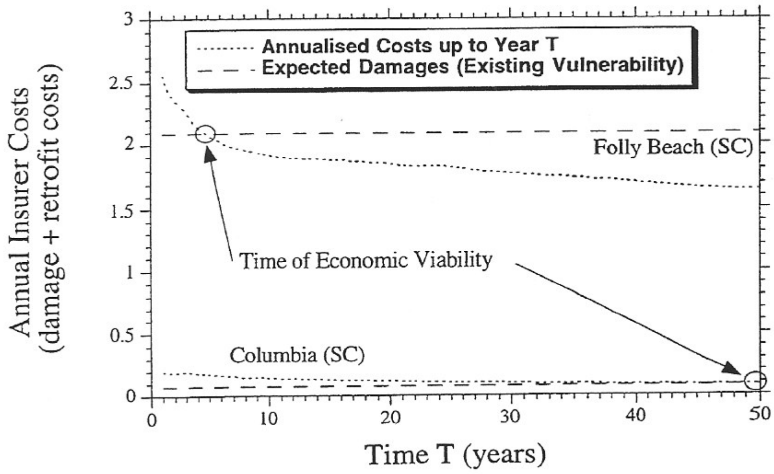

Figure 3. Time to Economic Viability for ϕ=60% and Retrofit Cost of 5%.

5.3 Rate of Growth of New Construction

Any increase in the proportion of new construction (designed and constructed to reduced vulnerability) will reduce expected annual damage ratios. For example, assuming a ϕ=40% reduction in vulnerability for all sites shows that even a 1% annual increase in the proportion of new housing can reduce expected annual damage ratios by at least 6% and in some cases up to 20%. It is possible to determine the cost effectiveness of a range of possible strengthening requirements for new design and construction. This might include combinations of rate of new construction, reduction in vulnerability and additional cost of strengthening. Figure 4 shows the changes in total costs for one such combination of parameters. In this case, strengthening causes a reduction to minor damage (ϕ) and the additional cost of construction is 10%. It is assumed that insurers will pay for hurricane damage and the owner for the additional cost of construction; hence, these costs are essentially societal costs. In this particular case it appears that strengthening of new houses is cost-effective for a exposed regions such as Folly Beach.

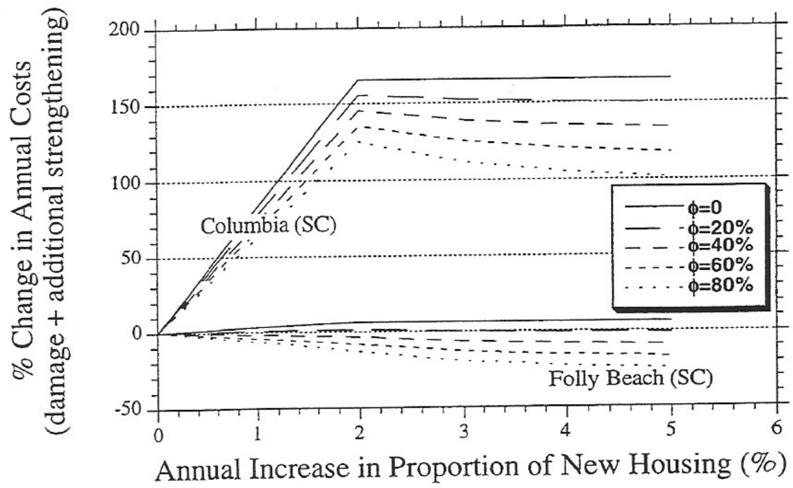

Figure 4. Percentage Change in Expected Annual Costs for Retrofit Causing Reduction to Minor Damage (ϕ) and an Additional Cost of Construction of 10%.

See Stewart, et.al. (2000) for more details and results of the hurricane damage risk-cost-benefit analysis. This also includes the consideration of other scenarios, such as how structural vulnerability may be reduced for a 'fully engineered' design (ie. building designed to withstand design specified wind loads).

6. References

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