4.0 SUMMARY AND CONCLUSIONS

The goal of this report was to inform senior Caribbean government officials and senior insurance officials of some of the key issues involved in the emerging discipline of hurricane loss (or damage) estimation for buildings. To meet this goal, this report attempted to accomplish the following three objectives:

(1) To make senior government and insurance officials aware of the relevance, value, and importance of loss estimation tools and techniques in the Caribbean region;

(2) To provide the officials with an overview at a conceptual level of the specific tools, techniques, and skills needed to perform a loss estimation study; and

(3) By way of examples, to provide the officials with a knowledge and appreciation of how the tools are used in loss estimation.

In Section 1 of the report, an overview of the context of hurricane loss estimation in the Caribbean was presented. The relevance of the need for hurricane loss estimation to senior government officials and insurance officials was emphasized. Section 2 presented a development of what tools, techniques, and skills were needed in order to perform a loss estimation on buildings in a hurricane environment. Section 3 described these tools in more detail and presented several examples of the use of the tools in developing answers to the questions of interest to senior government officials and insurance officials. Brief discussions on the uncertainty associated with using such methodologies, the selection of potential hurricane loss estimation software products, and the effort, time, and cost needed to implement a loss estimation study were also presented in that section.

In conclusion, the application of the tools of hurricane loss estimation can simultaneously impact such important activities as the efficiency of hurricane disaster management process and the profitability of insurance risk management. More specifically, the application of these tools can lead to the following benefits:

(1) In the planning phases of the hurricane management process, the tools may provide government officials with the capability to identify, rationally potential, cost-effective, mitigative technologies,

(2) During the disaster and post-disaster phases, the utilization of the tools may lead to more rational decision making on the part of government officials by making available useful information regarding damage at the building level, the zone level, or the regional level,

(3) The application of the tools may provide a rational means of evaluating insurance risks,

(4) The application of the tools may also provide a decision making tool to aid the insurance industry in selecting more profitable markets, and

(5) In combination with techniques from economic analysis, the tools may provide appropriate government agencies and insurance companies a means by which to establish rational and equitable premiums.

5.0 REFERENCES

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Table 1: Estimated (1995) Population and Economic Activity in the Caribbean Region

Country	Population	GDP	GDP/CAP	Debt
Anguilla	7,099	49,000,000	7,000	N/A
Antigua & Barbuda	65,176	400,000,000	6,000	250,000,00
Aruba	65,974	1,100,000,000	17,000	81,000,000
The Bahamas	256,616	4,400,000,000	15,000	455,000,000
Barbados	256,395	2,4000,000,000	9,200	652,000,000
Belize	214,061	575,000,000	2,750	158,000,000
British Virgin's Islands	13,027	133,000,000	10,600	4,500,000
Cayman Islands	33,192	700,000,000	23,000	15,000,000
Cuba	10,937,635	14,000,000,000	1,260	10,000,000,000
Dominica	82,608	200,000,000	2,260	92,800,000
Dominican Republic	7,511,263	24,000,000,000	3,070	4,300,000,000
Guyana	723,774	1,400,000,000	1,950	2,200,000,000
Haiti	6,539,983	5,600,000,000	870	871,000,000
Honduras	5,459,743	9,700,000,000	1,820	4,000,000,000
Jamaica	2,574,291	7,800,000,000	3,050	3,600,000,000
Martinique	394,787	3,900,000,000	10,000	N/A
Montserrat	12,730	55,600,000	4,380	2,050,000
Netherlands Antilles	203,505	1,850,000,000	10,000	672,000,000
Puerto Rico	3,812,569	26,800,000,000	7,050	N/A
Saint Kitts and Vis	40,992	210,000,000	5,300	43,300,000
Saint Lucia	150,050	610,000,000	4,200	96,400,000
Saint Vincent and Grenadines	117,344	235,000,000	2,000	74,900,00
Trinidad and Tobago	1,271,159	15,000,000,000	11,280	2,000,000,000
Turks and Caicos Islands	13,941	80,800,000	6,000	N/A
U.S. Virgin Island	97,229	1,200,000,000	11,000	N/A
TOTAL	40,855,143	122,398,400,000		30,367,950,000

Source: Central Intelligence Agency, The World Factbook, NTIS, Washington D.C., 1995

Table 2: Possible Sources of Information for Input to Loss Models

Needed Input	Metero. Records	Post Dis. Studies	Codes	Insp. Dur. Constr.	Insp. of Ex. Bldg.	Insurance Payout	Local Design Professionals
Hurricane Risk	•		•				
Hurricane Magnitude	•	•					•
Hurricane Trajectory	•	•				•	•
Hurricane Profile	•	•				•	•
Building Exposure		•	•	•	•		•
Building Vulnerability		•	•	•	•	•	•
Nonstructural Exposure		•	•	•	•	•	•
Nonstructural Vulnerability		•		•	•	•	•
Contents Exposure		•	•	•	•	•	
Contents Vulnerability		•			•	•	•

Table 3: Estimated Wind Speeds and The Annual Probability of Exceedance for Certain Locations*

	Wind Speeds (V_o) [mph sustained]			
	Annual Probability of Exceedance			
Location	0.02	0.01	0.005	0.002
Guyana	57	66	74	84
Trinidad (N)	61	71	79	90
Trinidad (S)	75	87	97	109
Tobago	79	90	100	112
Grenada	89	100	110	122
Barbados	95	106	116	128
St. Vincent	97	108	117	129
St. Lucia	98	109	119	130
Dominica	104	115	125	137
Montserrat	104	116	126	139
Antigua	103	115	125	137
St. Kitts	104	116	126	139
Jamaica	101	112	121	133
Puerto-Rico	104	116	125	137
US. Virgin	101	112	121	133
Belize (N)	101	112	122	134
Belize (S)	85	93	102	112

*Developed from data presented in Table A201.1, Caribbean Uniform Building Code (1989)

Table 4: Example of Assignment of Hurricane Hazard Modifiers

Factor	Typical Adjustment Factors			
	Barrier Island	Coastal County	30 Miles Inland	45 Miles Inland
Attenuation (distance from Coast)	1.00	0.97	0.92	0.82
Hurricane Profile	1.00	0.99	1.00	0.95
Terrain Exposure	1.20	0.89	0.89	1.00
Shelthering Effect	1.00	0.80	0.80	0.80
Mininimum Factor Value	1.00	0.80	0.80	0.80

Table 5: Component Resistances for Typical Structure

Building Component	Resistance Thresholds* (mph, One-Minute Sustained)		
	Low		High
Roof Covering	55	-	110
Roof Decking	80	-	120
Roof Framing	80	-	120
Roof-Wall Anchorage Damage Via Suction	90	-	120
Roof-Wall Anchorage Damage Via Suct. & Int Pressure	80	-	100
Lateral Bracing System	90	-	125
Openings	60	-	110
Cladding Damage	80	-	120
Frame-Foundation Connection Damage	90	-	135
Foundation Damage	115	-	150

Table 6: Hurricane Loss Calculation Results for Masonry Building on Barrier Island

Damage Type	Damage Magnitude (Percent)				
	Saffir-Simpson Hurricane Category (Mean Speed mph one-minute sustained)				
	I (85)	II (103)	III (120)	IV (140)	V (160)
Structural Damage Ratio:	2.8	10.1	24.0	41.8	59.5
Content Damage Ratio:	0.2	4.1	14.6	35.5	58.1
Single Event Damage Loss:	2.9	12.5	32.8	63.1	94.4
Annual Event Damage Loss:	0.2	0.2	0.2	0.1	*

Annual Mean Damage Ratio for all Hurricane Categories: 0.7 percent
*Negligible

Table 7: Hurricane Loss Calculation Results for Masonry Building Away from Coastal Zone

Damage Type	Damage Magnitude (Percent)				
	Saffir-Simpson Hurricane Category (Mean Speed, mph)				
	I (68)	II (82)	III (96)	IV (112)	V (128)
Structural Damage Ratio:	0.2	2.1	6.4	16.9	31.1
Content Damage Ratio:	0.0	0.0	2.0	8.4	21.8
Single Event Damage Loss:	0.2	2.1	7.6	22.0	44.2
Annual Event Damage Loss:	*	*	*	*	*

Annual Mean Damage Ratio for all Hurricane Categories: 0.1 percent
*Negligible

Table 8: Typical Summary of Results for Loss Calculation for a Major Region with Several Zones

(1) Zone No.	(2) Str.[1] D.R.	(3) Con.[2] D.R.	(4) Value[3] D.R.	(5) Value* Str.	(6) Value* Con.	(7) Value* Val.	(8) Tot.* Ins.	(9) Zone D.R.	(10) Fract. of Tot. Value	(11) Region Damage Ratio	(12) Expected Loss
1	0.004	0.042	0.024	54.9	32.8	26.3	114.0	0.020	0.277	0.005	2.228
2	0.004	0.042	0.024	58.2	34.2	11.3	103.8	0.019	0.252	0.005	1.940
3	0.001	0.086	0.042	25.3	16.7	9.0	50.9	0.036	0.124	0.004	1.839
4	0.002	0.042	0.024	22.9	19.3	8.3	50.5	0.021	0.123	0.003	1.056
5	0.043	0.158	0.062	17.2	10.1	2.5	29.7	0.084	0.073	0.006	2.490
6	0.000	0.086	0.042	11.9	7.4	4.2	23.5	0.035	0.057	0.002	0.813
7	0.990	0.990	0.500	12.0	7.3	3.6	22.9	0.878	0.056	0.037	20.107
8	0.990	0.990	0.500	6.1	3.5	1.5	11.1	0.924	0.027	0.018	10.254
9	0.000	0.086	0.042	2.9	1.7	0.2	4.8	0.032	0.012	0.000	0.155

*All values are in millions of dollars   Total Value Insured = $411.2   Total Expected Losses = $40.882

[1]Structure Damage Ratio (D.R.) in Fractions

[2]Contents Damage Ratio in Fractions

[3]Valuables Damage Ratio in Fractions

Note. The damage ratio for the structure, the contents of the structure, and other valuables are computed using the algorithms discussed above and are listed in Columns 2-4. The total insured values for the structure, contents, and valuables, which are provided by the insurance company, are listed in Columns 5-7. The total value insured is listed in Column 8. Combining the results in Columns 2-4 and Columns 5-7, the expected loss in the last column (Column 12) can be computed. Combining the total insured value in Column 8 with the expected losses in Column 12, the damage ratios for the Zone in Column 9 are obtained by dividing the values in Column 12 by the values in Column 8. Column 10, the fraction of the value exposed in a specific zone relative to the value of the region, is obtained by dividing the value in Column 8 by the total value insured. Finally, the region damage ratio in Column 11 is obtained by dividing the value in Column 12 by the total value insured. Clearly from these results, a disproportionate amount of damage occurs in Zone 7 and Zone 8.

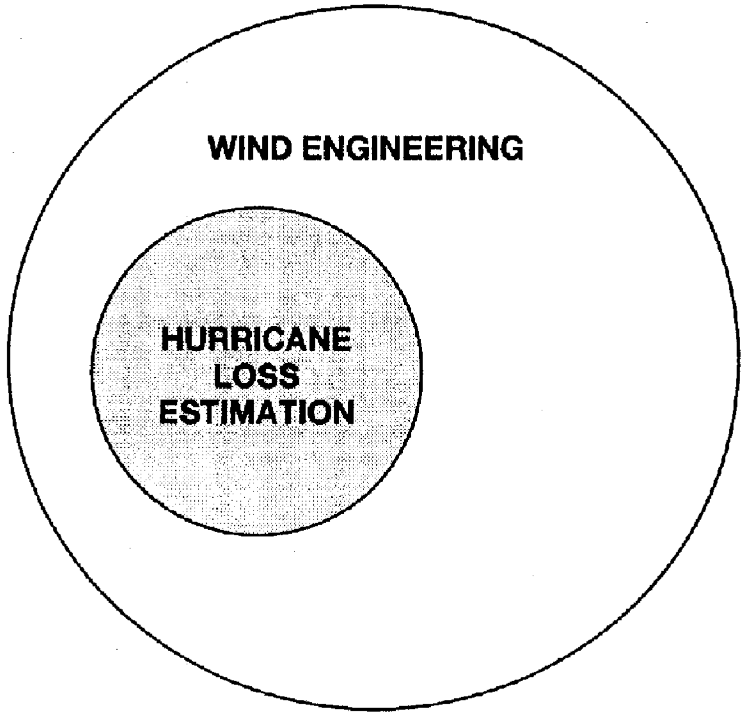

Figure 1 (a) An Inaccurate Conception of Hurricane Loss Estimation

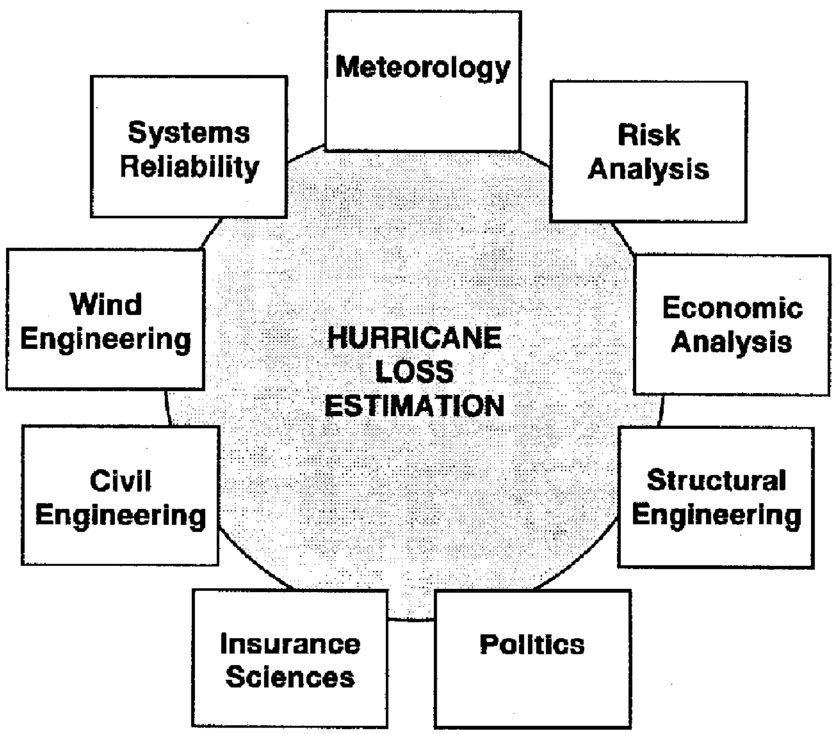

Figure 1 (b) A Better Representation of Hurricane Loss Estimation

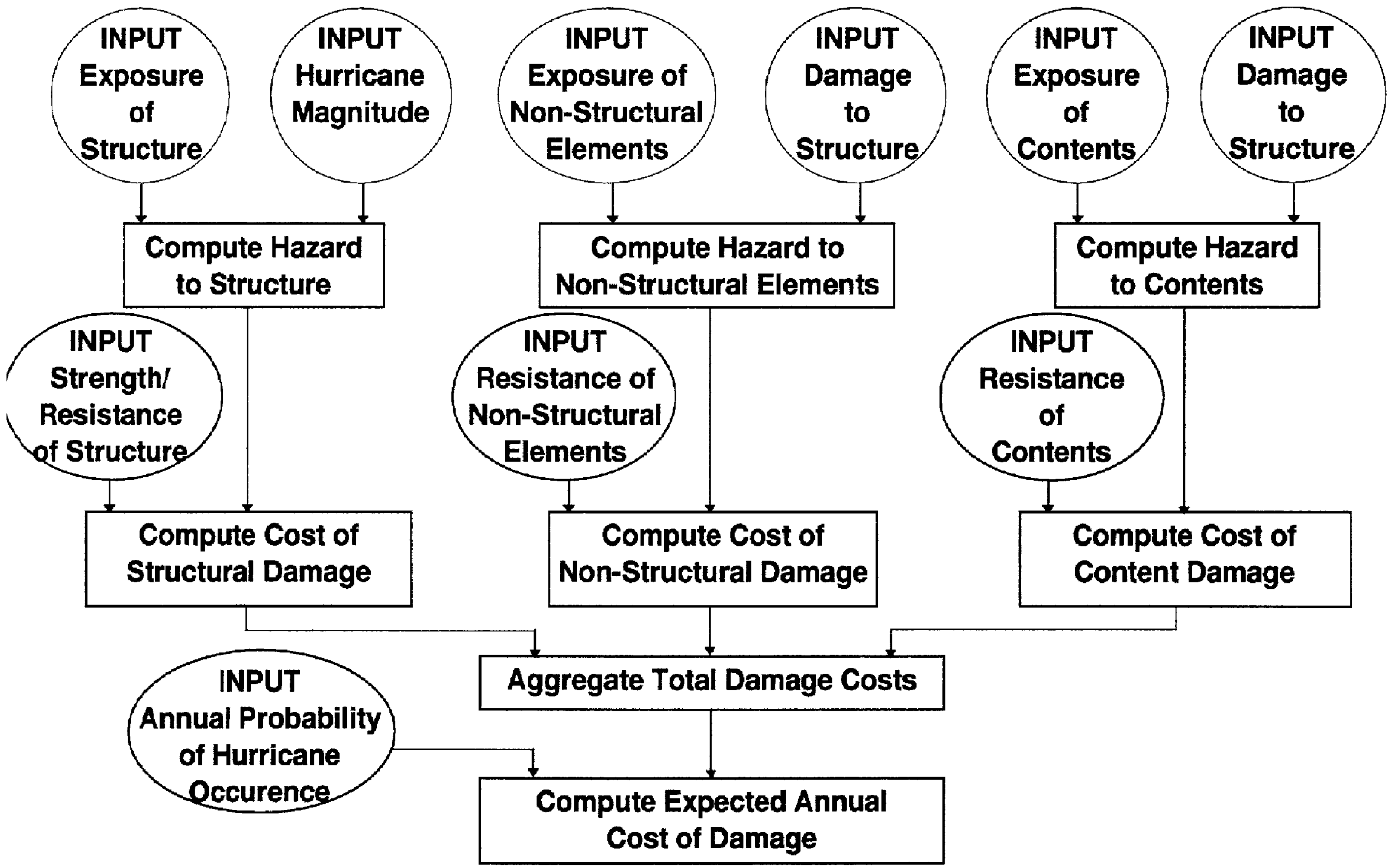

Figure 2. General Scheme for Hurricane Loss Estimation

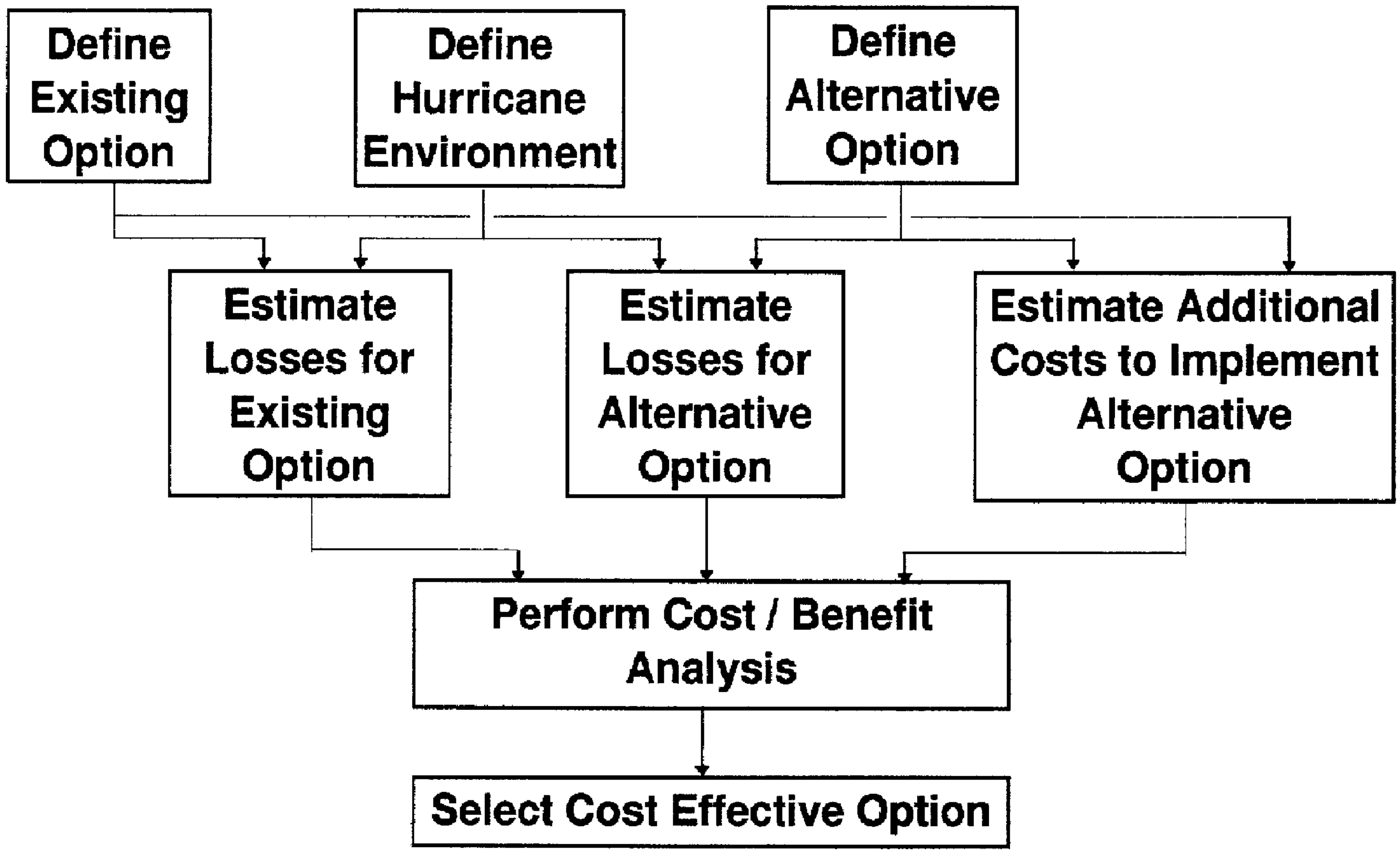

Figure 3 Generalized Scheme for Cost-Effectiveness Evaluation of Mitigation Strategies

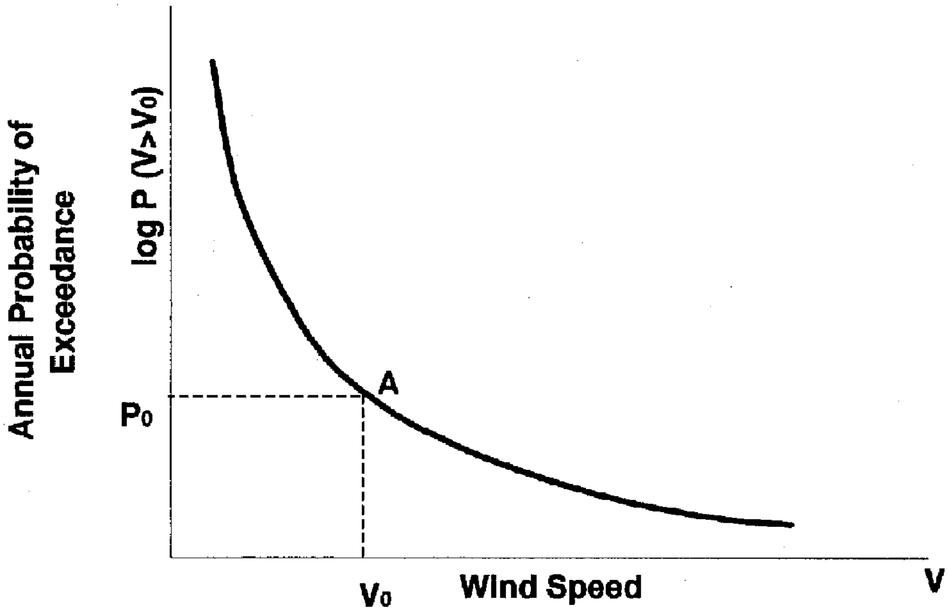

Figure 4(a). Typical Extreme Wind Risk Curve for a Specific Location

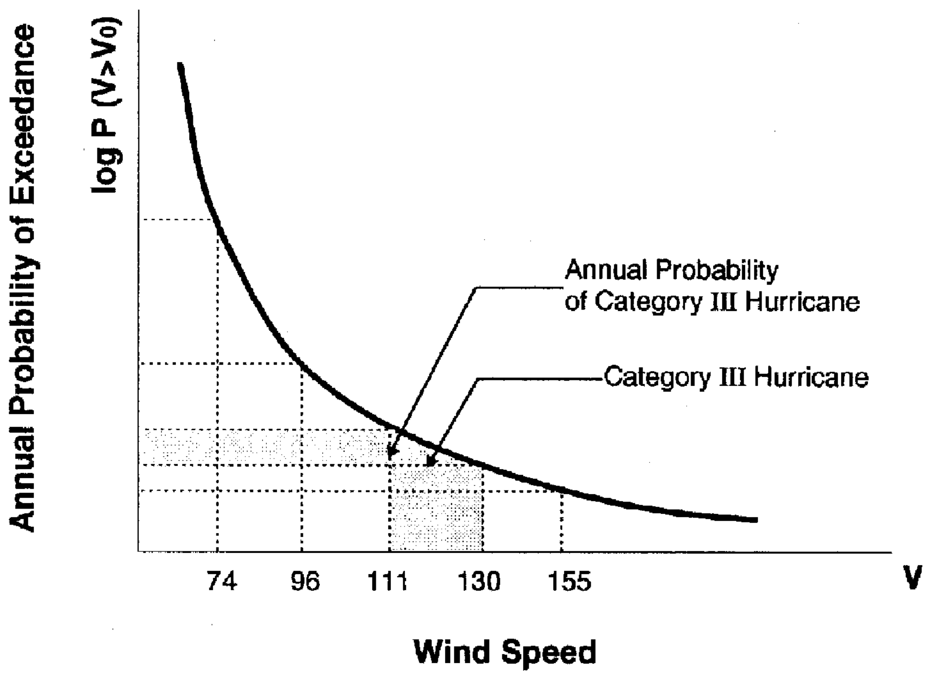

Figure 4(b). Probability of Occurrence for a Hurricane of a Given Magnitude

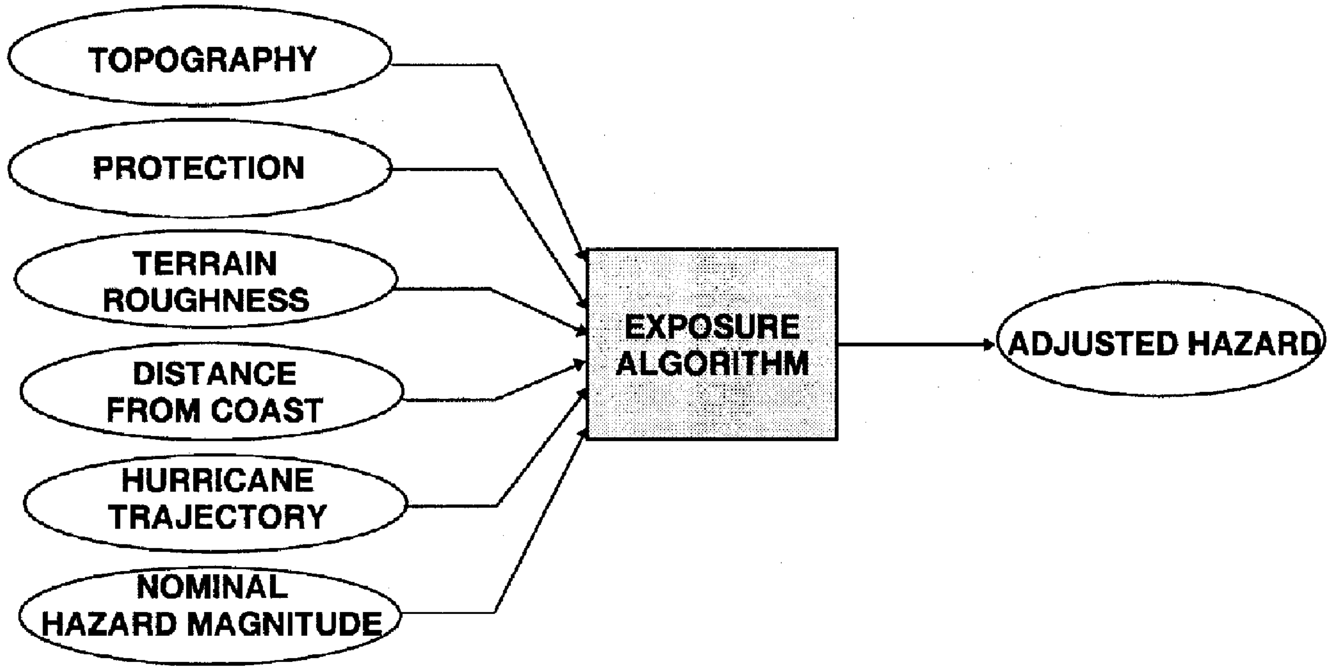

Figure 5 (a). Schematic of Hazard Modification Algorithm

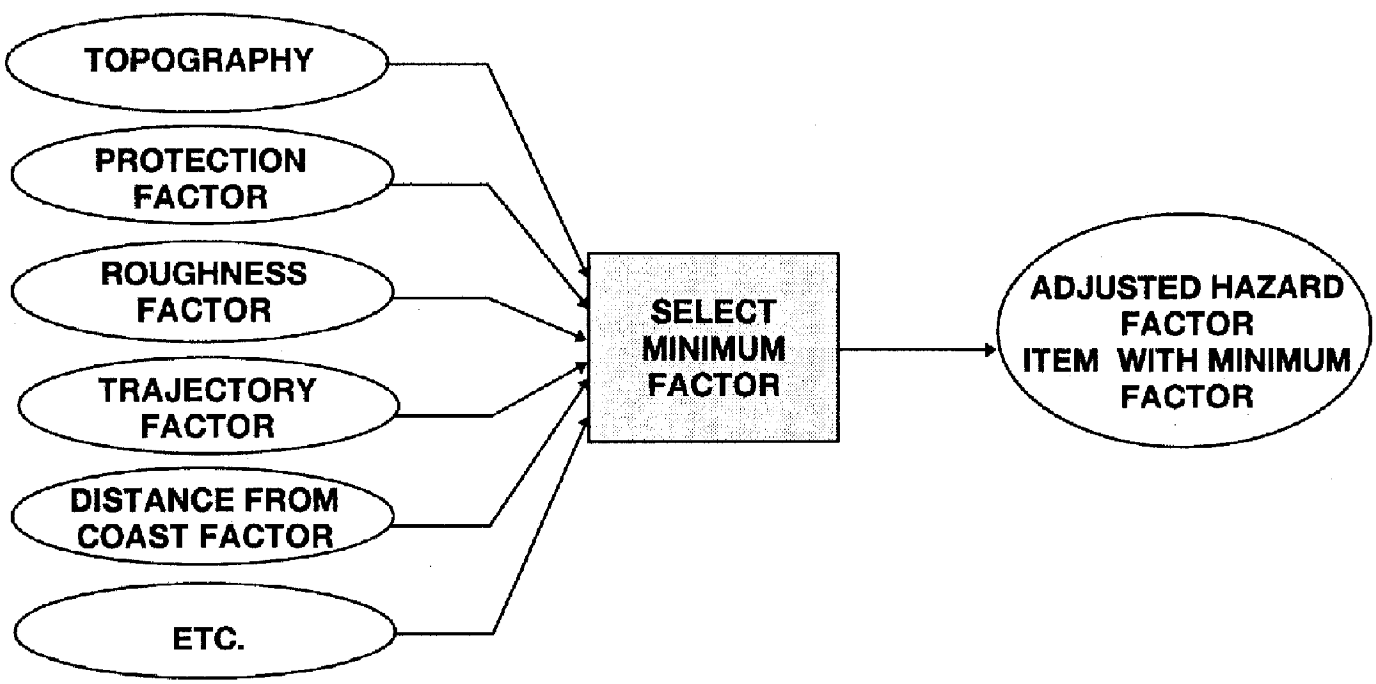

Figure 5 (b). Schematic Describing One Way to Select a Factor to Adjust the Hazard

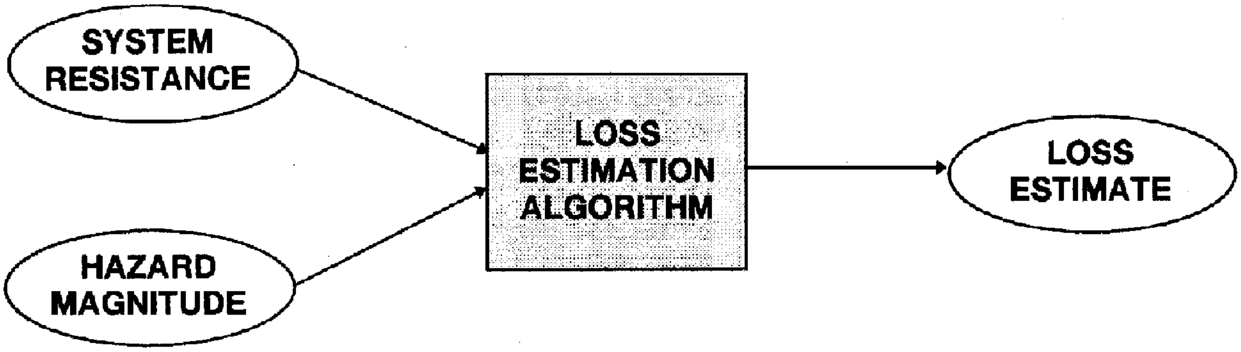

Figure 6 (a). General Form of Loss Estimation Calculation Procedure

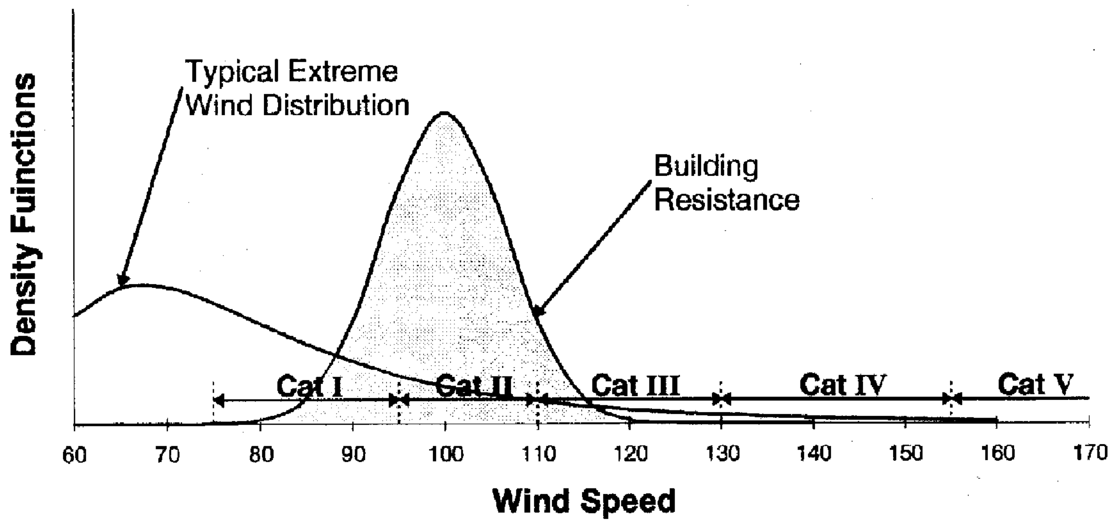

Figure 6 (b). Distribution of Hurricane Compared to Distribution of Resistance of System

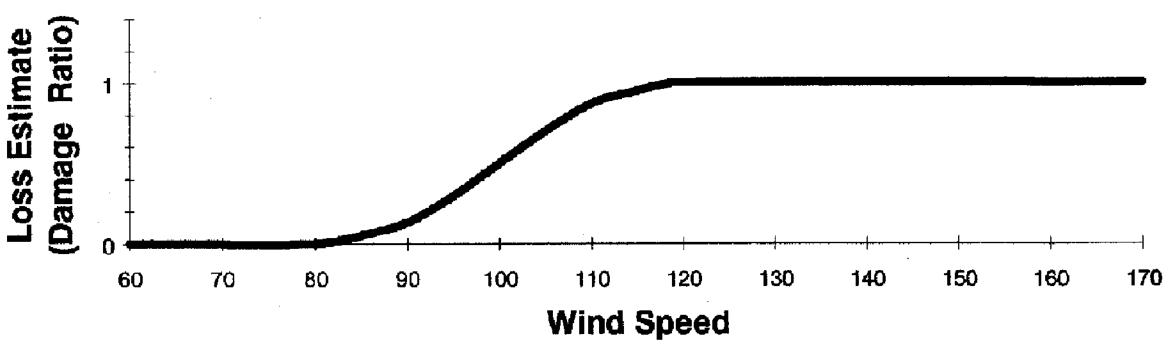

Figure 6 (c). Loss Estimates as a Function of Wind Speed

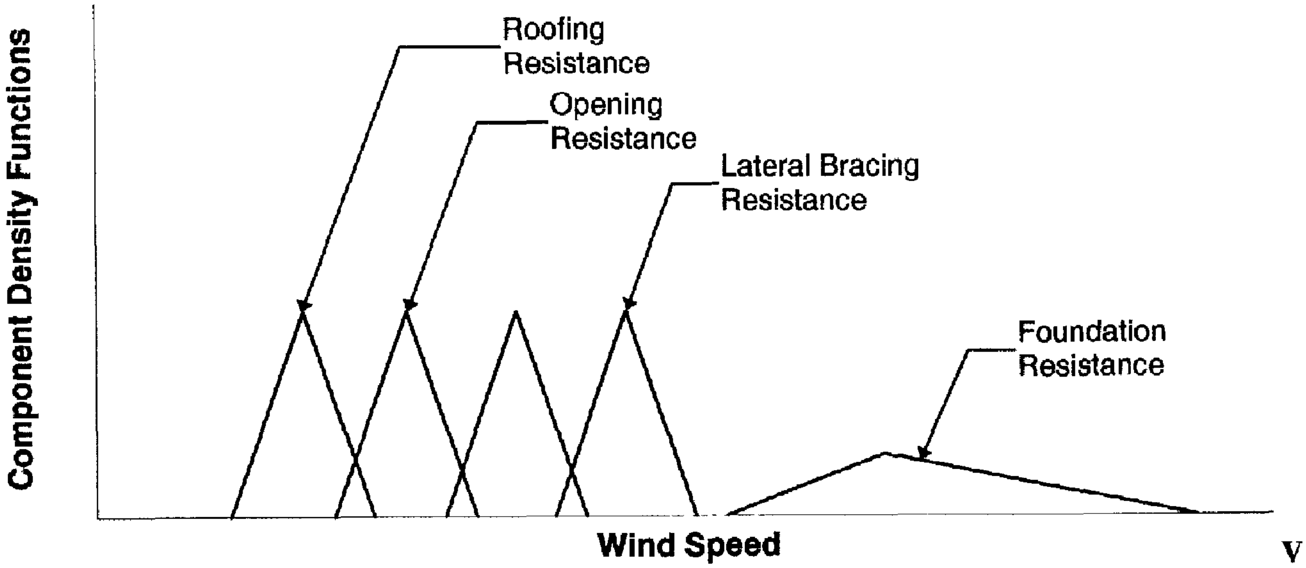

Figure 7(a). Relative Resistance of Building Components

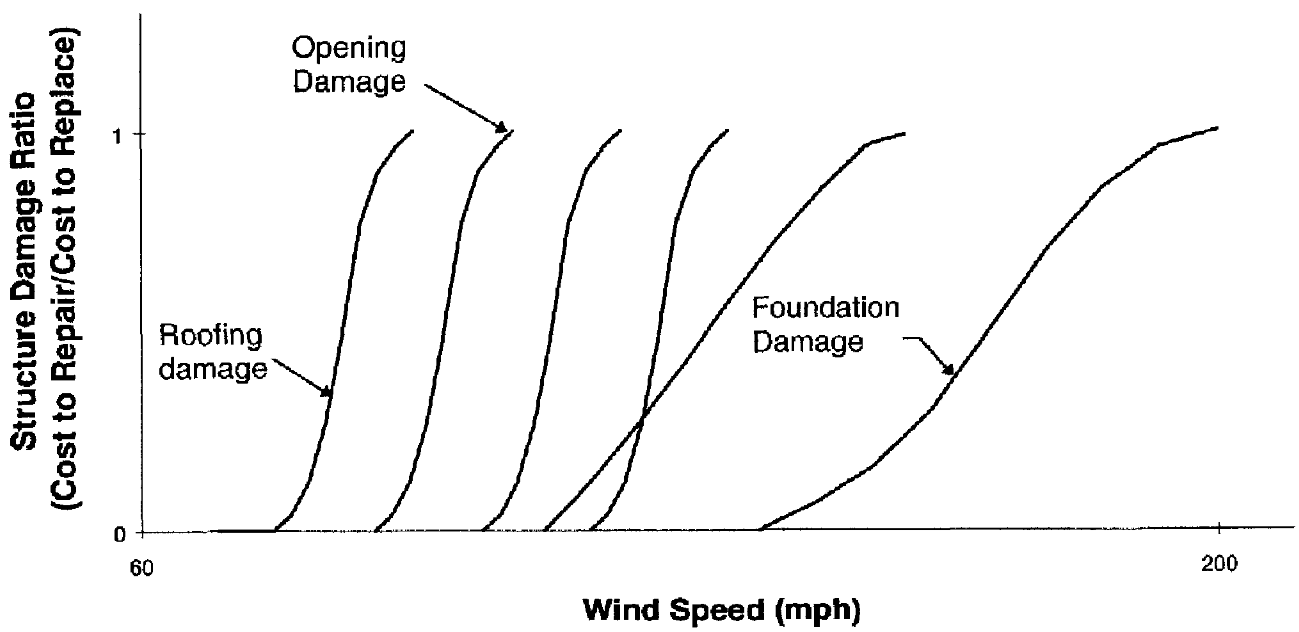

Figure 7(b). Relative Building Component Damagability

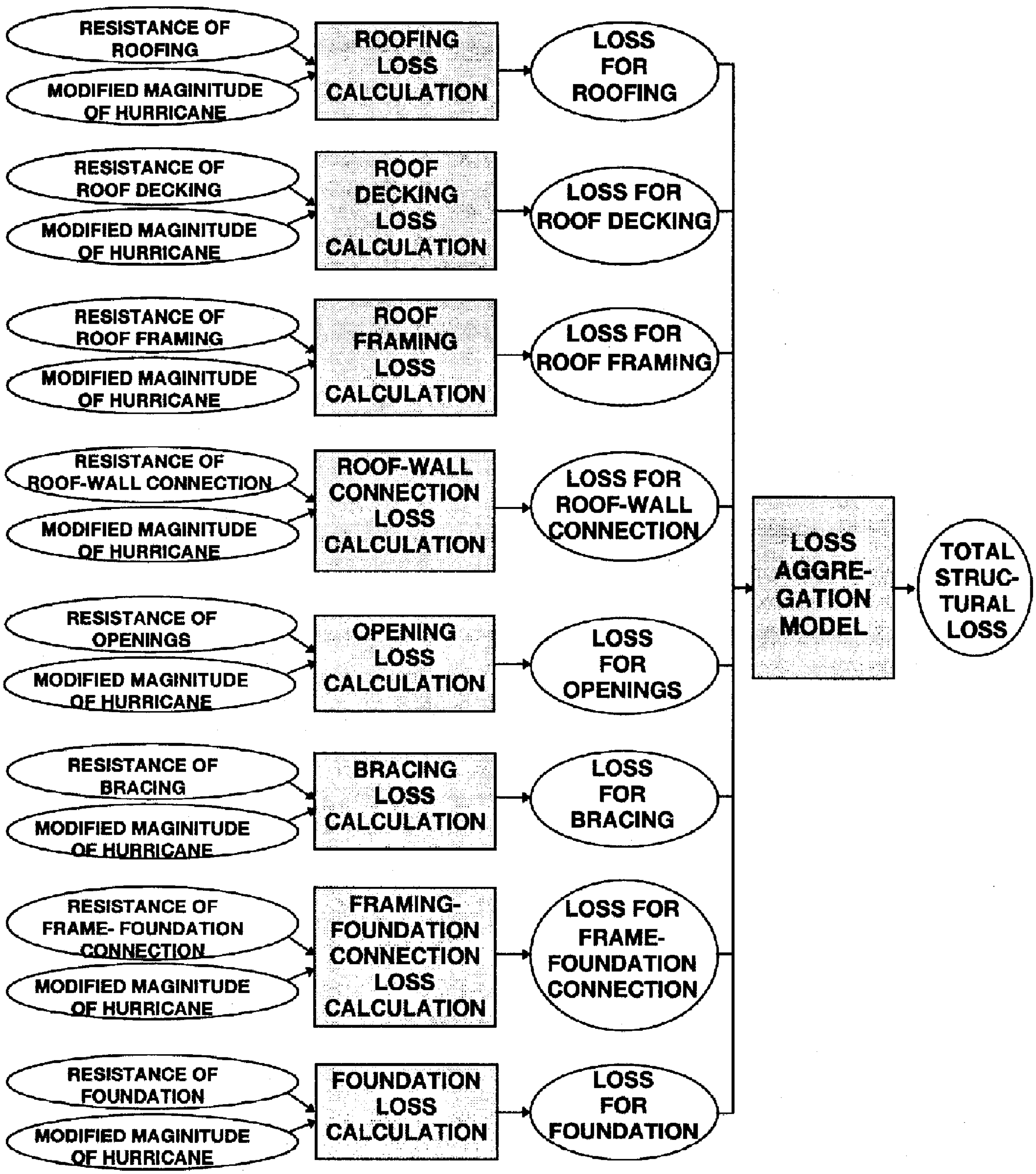

Figure 8. Deterministic Structural Loss Estimation for a Specific Hurricane

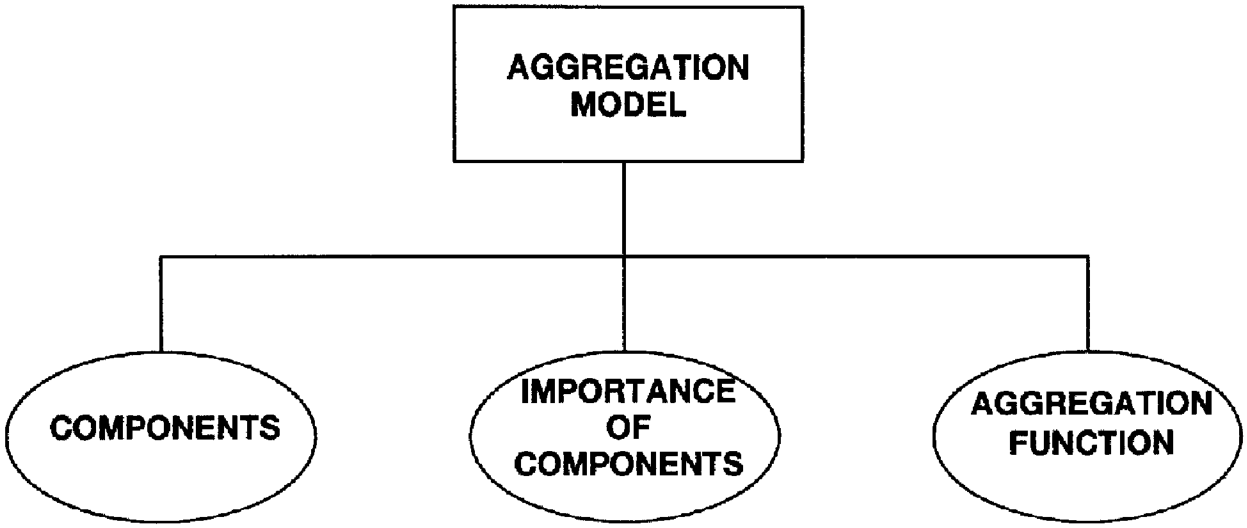

Figure 9. Elements of Aggregation Model

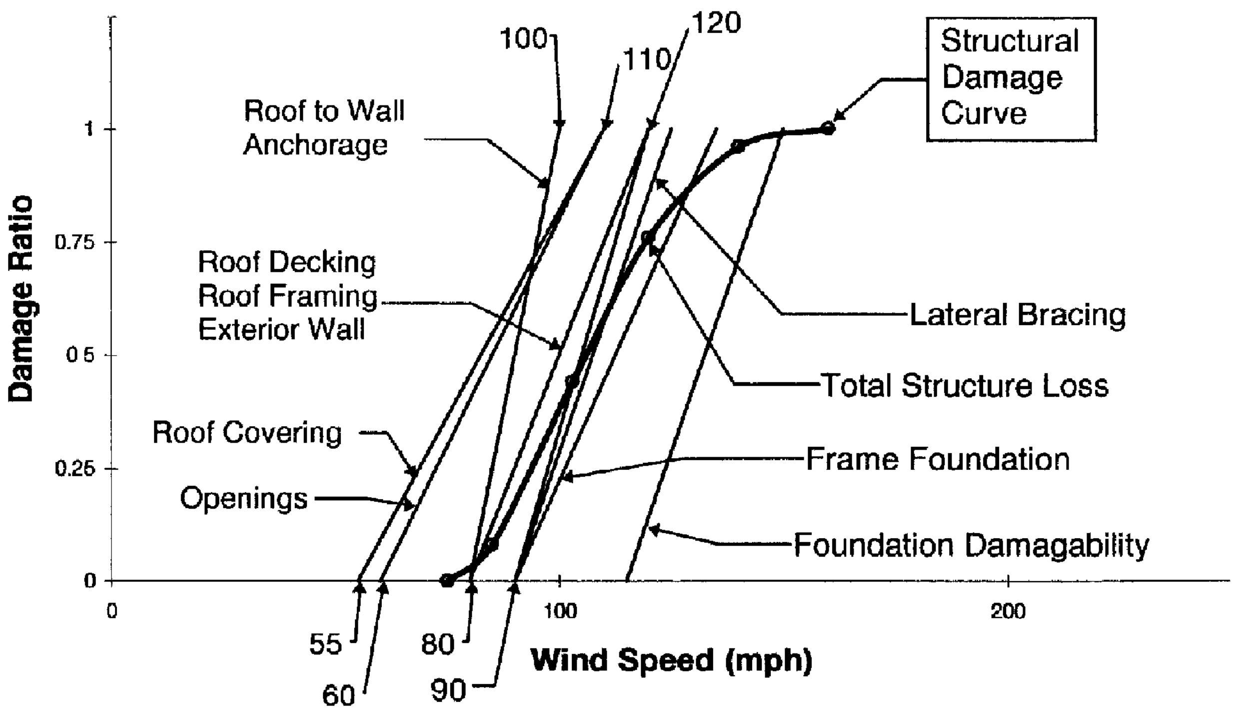

Figure 10. Relative Structural Damage Ratios for Components of a Structure and the Structure as a Function of Wind Speed

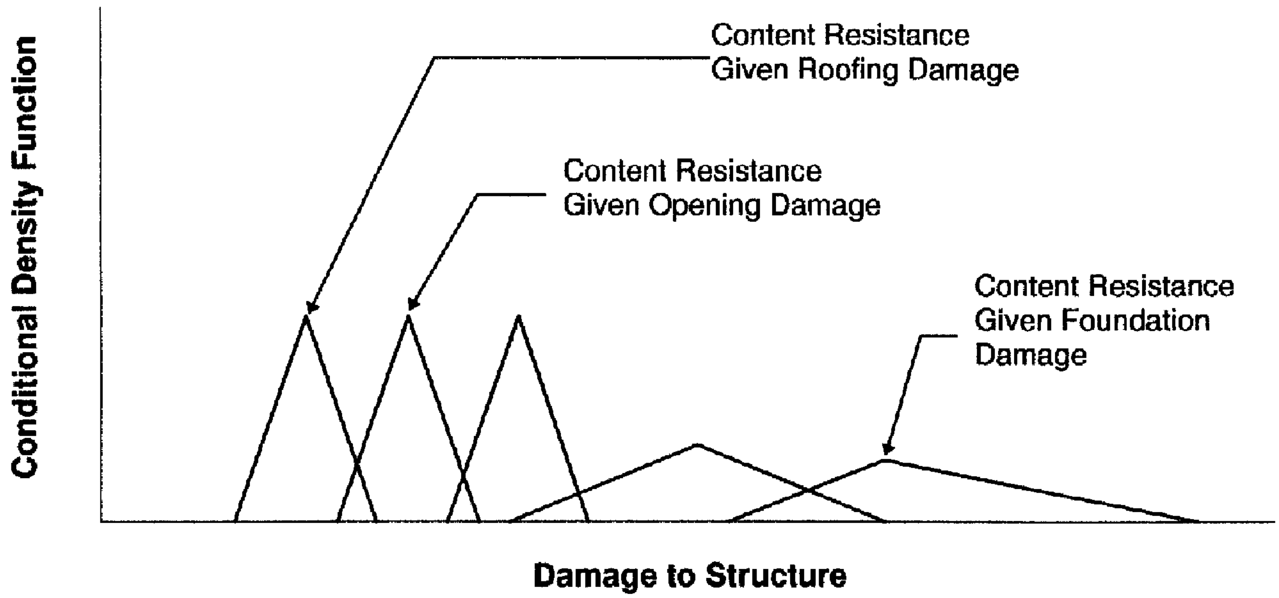

Figure 11(a). Conditional Distributions for Resistance of Contents Relative to Specific Damage Modes

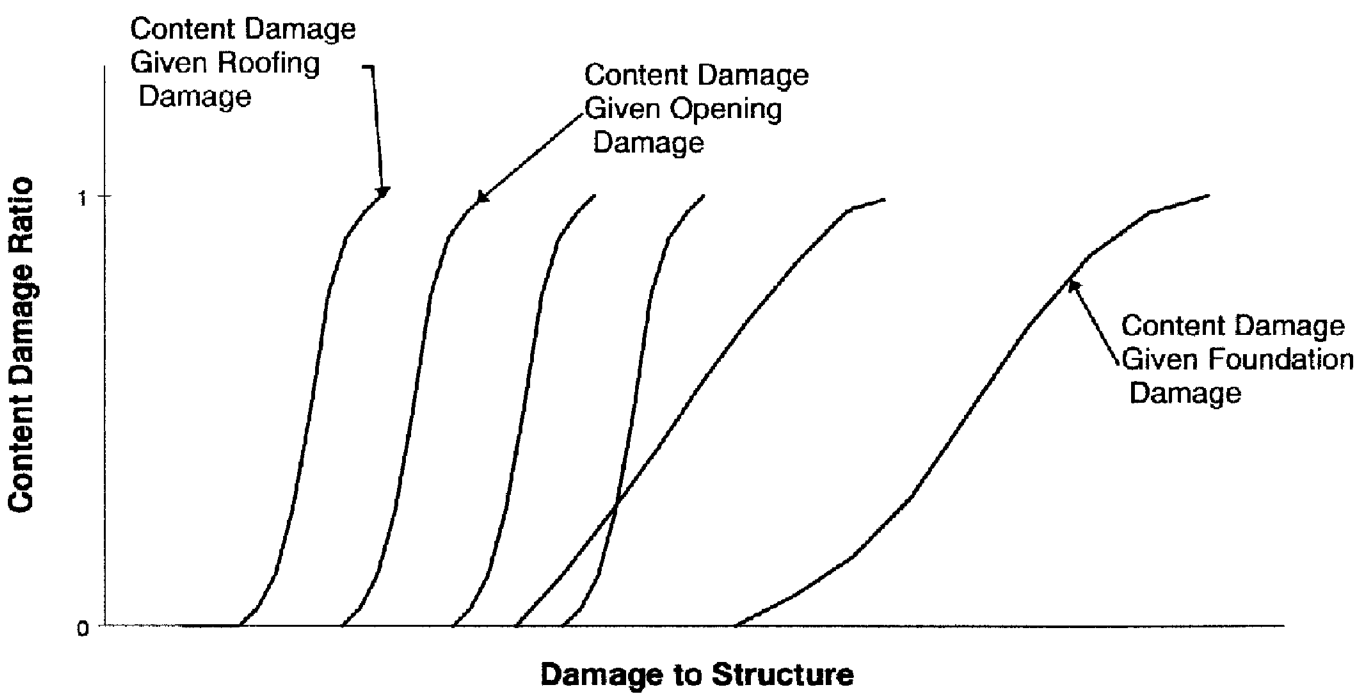

Figure 11(b). Relative Content Damagability for Various Damage Modes

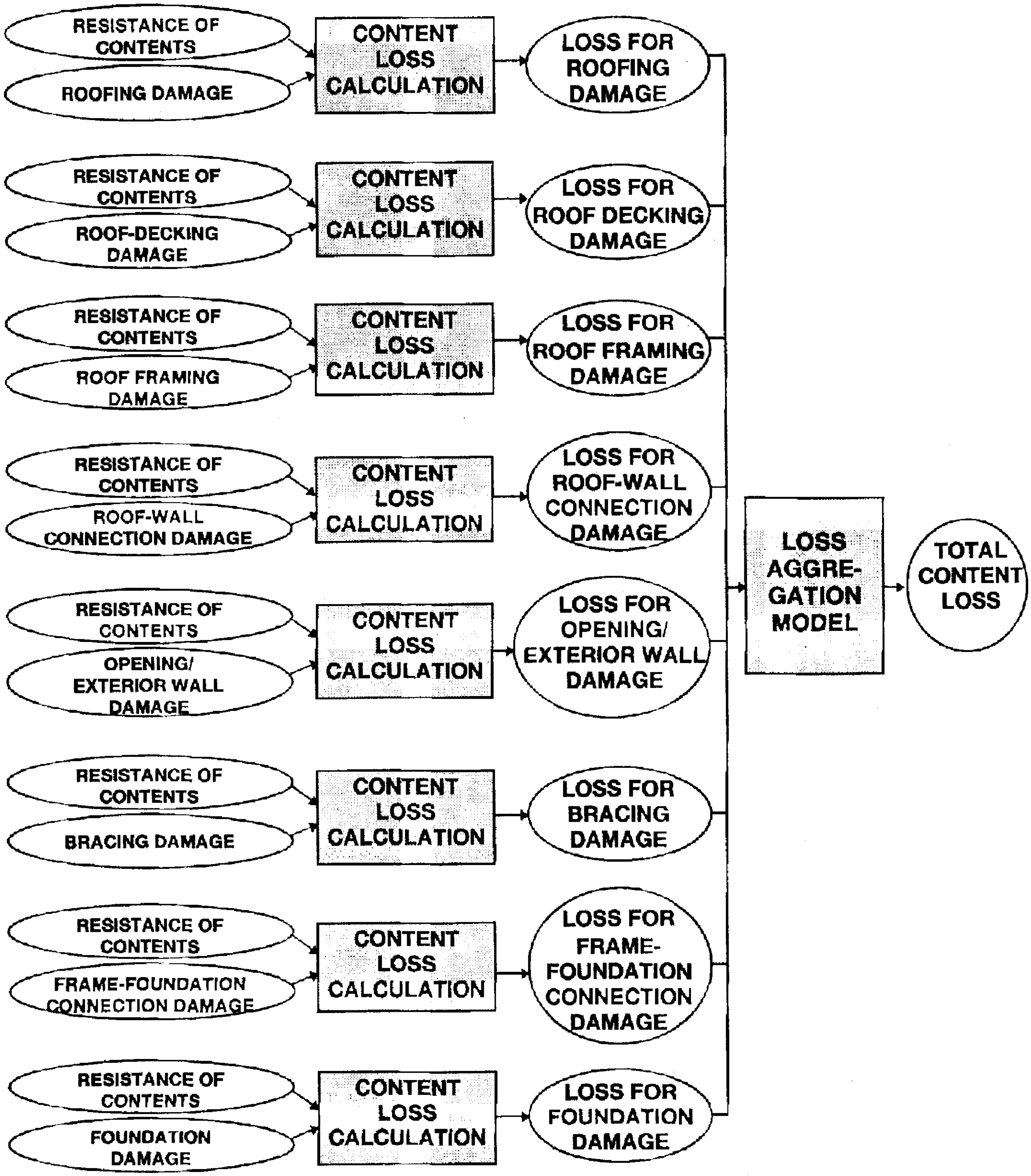

Figure 12. Deterministic Content Loss Estimation for a Specific Hurricane

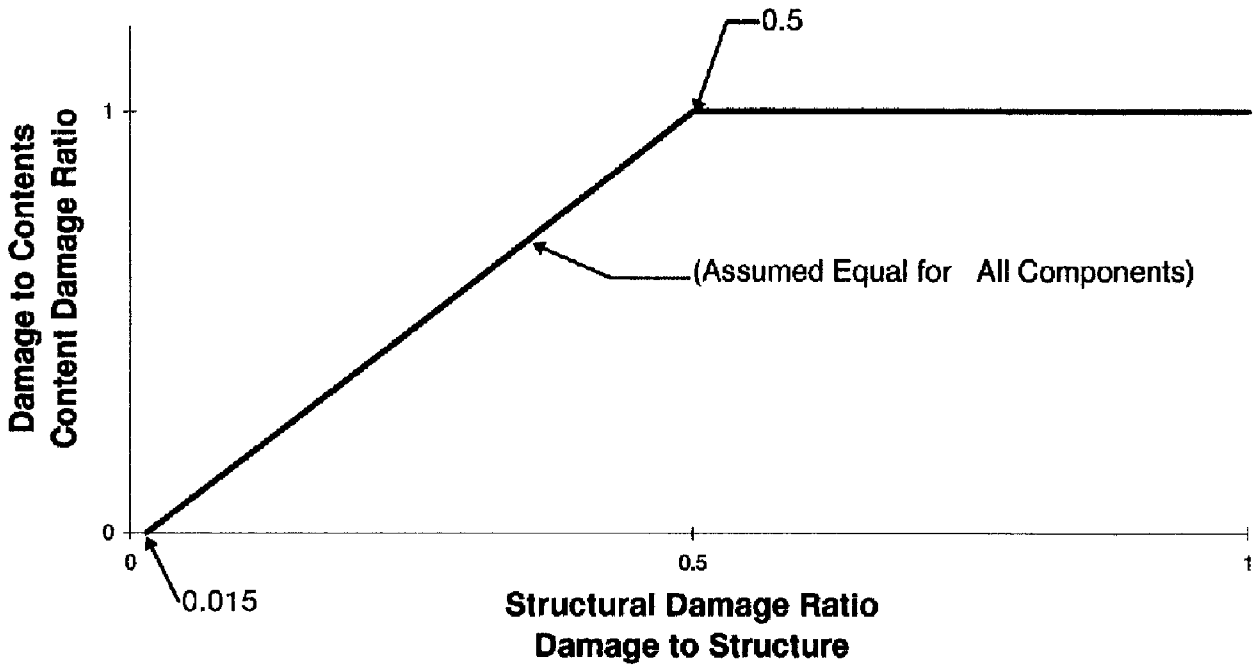

Figure 13(a). Assumed Relationship between Structural Damage and Content Damage

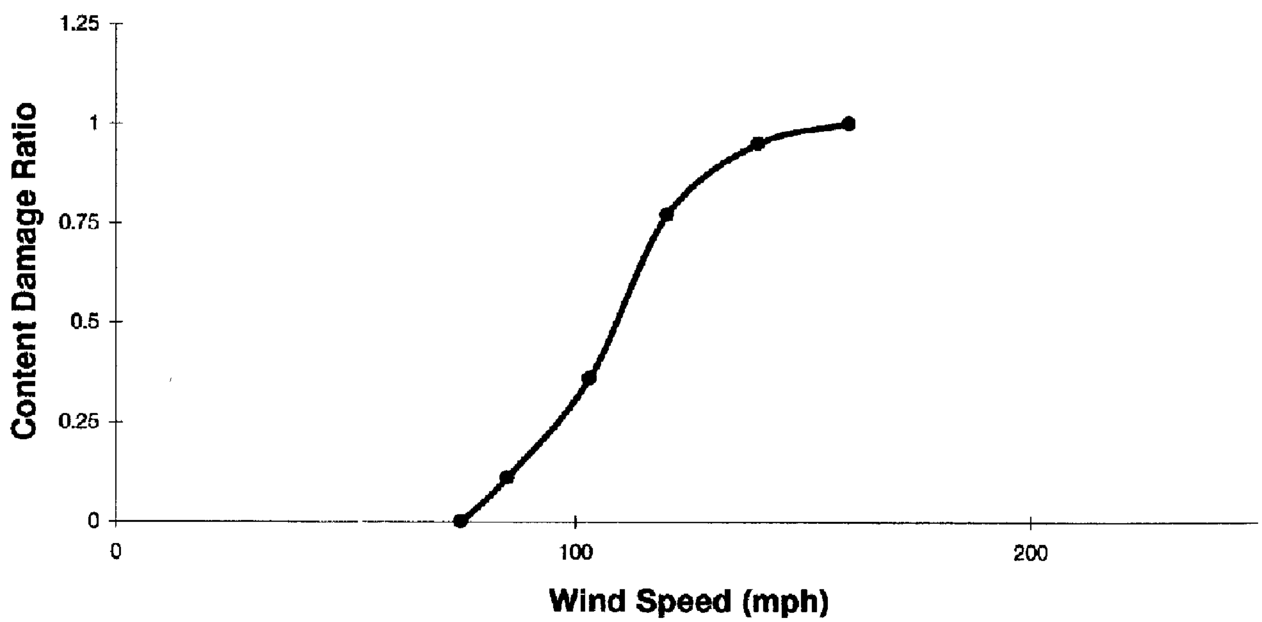

Figure 13(b). Resulting Relationship between Wind Speed and Content Damage

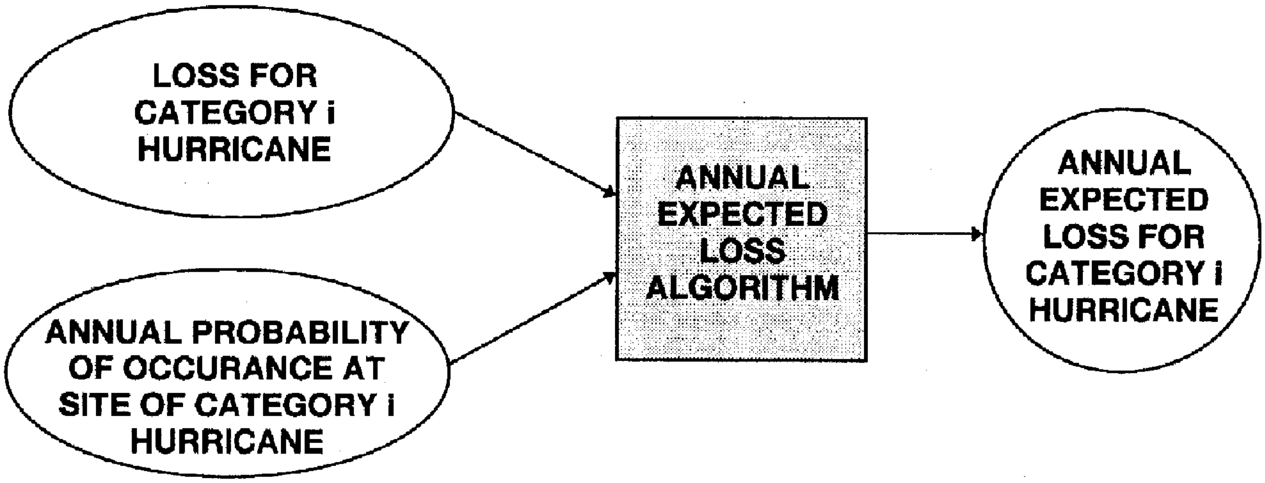

Figure 14 (a). Probabilistic Loss Estimation for a Specific Hurricane and Site

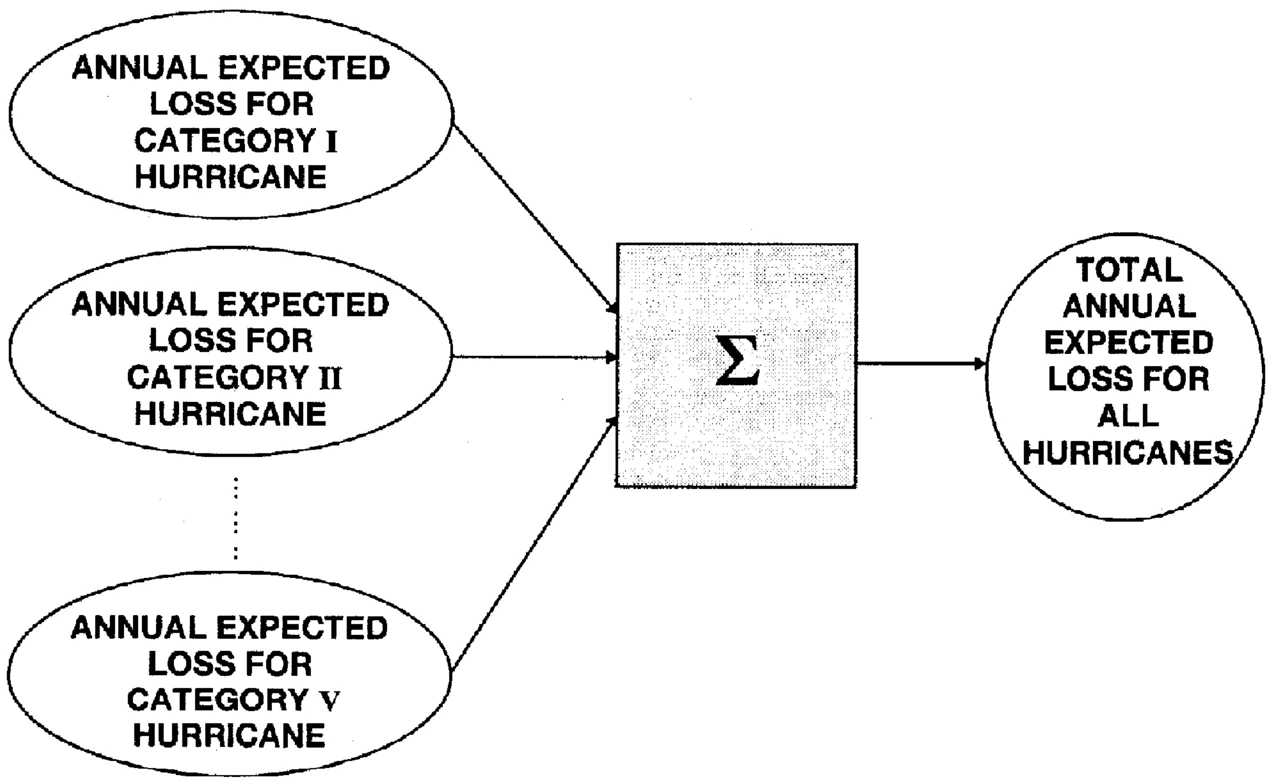

Figure 14 (b). Probabilistic Loss Estimation for All Future Hurricanes

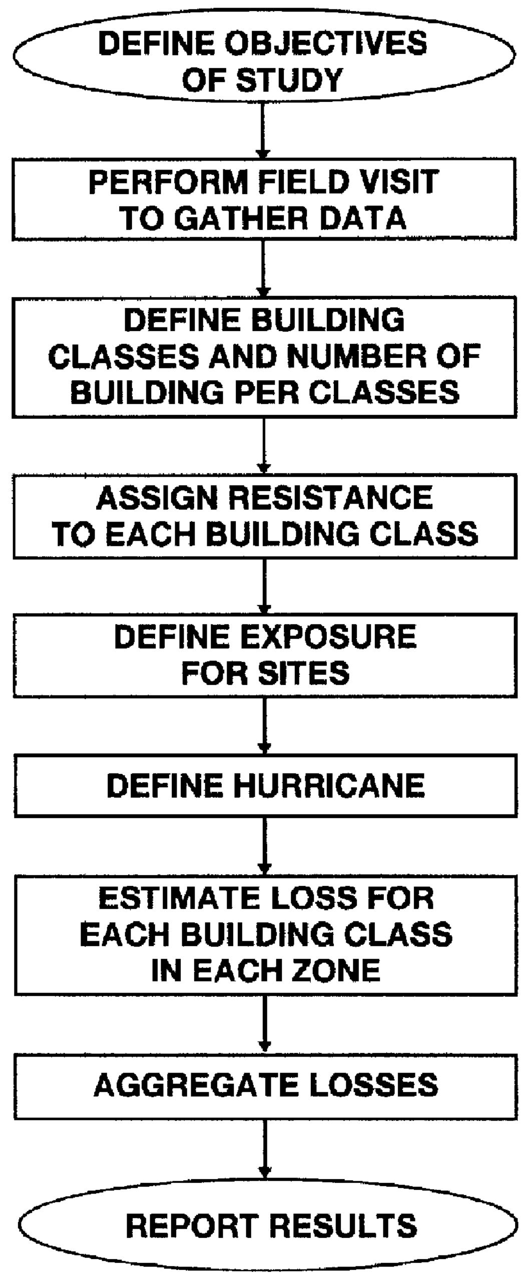

Figure 15. Logic for Computing Losses for Zones or Portfolios

CARIBBEAN DISASTER MITIGATION PROJECT

The Caribbean Disaster Mitigation Project (CDMP) is a coordinated effort to promote the adoption of natural disaster mitigation and preparedness practices by both the public and private sectors in the Caribbean region through a series of activities carried out over a five-year period. The CDMP is funded by the **USAID Office of Foreign Disaster Assistance (OFDA)** and implemented by the **Organization of American States/Unit of Sustainable Development and Environment (OAS/USDE)** for the **USAID Regional Housing & Urban Development Office in the Caribbean (RHUDO/CAR)**.

The CDMP provides a framework for collaboration with the Caribbean region to establish sustainable public and private sector mechanisms for natural disaster mitigation that will measurably lessen loss of life, reduce the potential for physical and economic damage, and shorten the disaster recovery period over the long term. Project activities vary according to location, contents and implementation strategy, but all contribute to attainment of the overall CDMP goal: a more disaster-resistant environment for the people who live, work and invest in this hazard-prone region.

Project activities include: 1) natural hazard risk audits for electrical utilities and other infrastructure systems and key lifeline facilities; 2) hazard mapping to support improved planning and location of physical development; 3) assisting the insurance industry in improving risk management for insured property; 4) assisting countries to adopt improved building standards and practices and training of builders, architects and artisans in their use; 5) stimulating community-based disaster preparedness and mitigation efforts with support of the private sector, and, 6) post disaster mitigation planning and program design.

The Project is being implemented in Caribbean countries where USAID has active assistance programs, i.e. the Dominican Republic, the Eastern Caribbean countries which are served by the Caribbean Office of Regional Assistance (CORA) of USAID, Haiti, Belize, and Jamaica. The entire region is to benefit from the project through an active dissemination of project information and methods.

The CDMP will build on past and ongoing regional initiatives in disaster preparedness and mitigation, and will promote technology transfer and institutional capacity building through direct involvement of professional associations, bankers, builders, insurance companies and reinsurers, NGO's, PVO's, community groups and government organizations in project activities.

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depending upon which entity (insurance or government) commissions the loss study. Ideally a loss estimation study should be based on relevant documented data and, if possible, observations resulting from actual field visits. On the basis of the analysis of the data, building classes for the study should reflect local building practices and the history of the region. The assignment of resistances to each building class, definition of the exposure for the various zones, modification of the hurricane hazard, and estimation of the structural damage ratio and the content damage ratio should proceed as discussed above. From a knowledge of the percentage of each building class in a zone, the content and structural damage for the zone, and the total value insured in that zone, the expected losses for structural damage and content damage can be estimated for the zone. In a similar manner, the losses for the individual zones may be aggregated to yield the losses for the region.

The following summary example provides an idea of the kind of information that a loss calculation can yield for a zone or a larger region consisting of several zones. Occasionally, devastating hurricanes like Gilbert in 1989 that impacted Jamaica and the Yucatan Peninsula or Andrew in 1992 that impacted the Bahamas, Florida, and Louisiana become candidates for scenario hurricanes. Given the devastation incurred by such events, government and insurance officials may want to know the impact of such storms on their jurisdiction or territory. Recently the writer was assigned the problem of estimating the impact of an "Andrew-like" storm striking certain key properties in the New Orleans area. More specifically the insurer wanted answers to such questions as:

(1) What is the relative impact of such a storm on the building?

(2) What is the protection offered by any foliage in the area?

(3) What is the impact of the age of the construction on the distribution of the damage? and

(4) How does the predicted damage in the selected zip codes compare with that observed in Florida?

In solving the problem, the logical sequence presented in Figure 15 was followed here. For the sake of brevity, only the final results, which are summarized in Table 8, will be discussed below.

Eight building classes were selected for this study. The categories were determine by the main four periods of construction in the area (Pre-1940, 1940-1960, 1960-1980, and Post-1980) and the number of building stories (i.e., single story or greater than one story). Note that only residential construction was considered in this exercise.

The protection from wind was considered to be a function of the density and height of the foliage, relative to the houses, and the density of the buildings. For example, tall and dense trees provided relatively "excellent" protection from wind; while, short and dispersed trees provided relatively "poor" wind protection. These terms are discussed further and quantified in Appendix I of this report.

Each of the nine zones in Table 8 was identified by a combination of the predominant building classes in the zone and the wind protection offered by the surrounding foliage and building density. For example, Zone 1 was characterized by the massive, multi-story, pre-1940 *(ante bellum)* construction and tall, dense, tree covering; while, Zones 7 and 8 were characterized by smaller single-story, 1960-1980, residential construction. From Table 8, the structural damage ratio ranged from less than 0.1 percent (in Zones 3,6, and 9) to 99 percent (in Zones 7 and 8). The content damage ratio followed the same trend as the structural damage ratio but was usually higher in magnitude. The damage ratio for the valuables (another type of content) followed the same trend as the content damage ratio. Note that magnitudes of the valuables damage ratio are somewhat less than the values reported for the content damage ratio. This result follows from the fact that residents would make an extra effort to protect valuables in the event of a hurricane. The total insured value for each zone is given in Column 8. The insured value varies from $114 million in Zone 1 to $4.8 million in Zone 9. The expected losses for each zone are listed in Column 12 and range from a high value of $20.107 million for Zone 7 to a low value of $0.155 million for Zone 9. Note that the numbers listed in Column 10 represent the fraction of the value insured in a given zone (e.g., $114 million in Zone 1) relative to the value insured for the entire region (i.e., $411.2 million).

Even though the results presented in Table 8 were prepared for insurance officials who are interested in making sound business judgments, the same type of information is relevant to government officials who are interested in managing the hurricane event. For the scenario under consideration here, the result that the major damage to buildings will occur in Zones 7 and 8 and that the damage in these zones will be very severe may lead government officials to adjust their hurricane management strategy for the two zones in several ways. First, as a pre-disaster mitigation strategy, government officials may consider ways and means by which the affected classes of construction may be strengthened. Second, as a pre-disaster preparedness strategy, on recognizing that the threat to property and life in Zones 7 and 8 is acute, government officials should ensure that evacuation plans and warning systems are in place and understood by the residents in these zones. Third, as a disaster response strategy, knowing in advance where the greatest damage will occur, government officials can (1) make better decisions regarding the location and characteristics of shelters, and (2) optimize the staging and deployment of resources needed directly after the event. Finally, as a post-disaster recovery strategy, government's officials may either ban specific types of construction in Zones 7 and 8, or out-rightly disallow construction in those zones.

From the insurance officials' perspective, the results presented in Table 8 may also provide information for making sound business judgments. Note that while only approximately 9 percent of the insured value reside in Zones 7 and 8 (See Column 10), those zones account for approximately 75 percent of the expected losses. Note that Zones

1 and 2 account for approximately 10 percent of the losses but 53 percent of the insured value. At this stage, the wise insurance official might be advised either to cancel all insurances in Zones 7 and 8 or to readjust the premium and deductibles in the zone to reflect the expected losses and the constraint that the company must make some kind of profit.

3.8 On Accuracy and Uncertainties in Loss Estimation Models

The tools described above are intended to produce loss estimates resulting from scenario hurricanes or to estimate losses at a given location on an annual basis. In the first case, a hurricane with a known wind speed field is imposed on a region and the appropriate losses computed. In the second case, the probabilities associated with the hurricane occurrences are integrated into the loss estimate. No matter which approach is utilized, the uncertainties (i.e., the lack of knowledge or ignorance) in the loss estimates should always be noted (e.g., a range of possible values may be given). Uncertainties in hurricane loss estimation stem from many sources. First, there is uncertainty in the values reported for the nominal hurricane magnitude. Second, there is uncertainty associated with modifying the wind speed to reflect conditions at the site. Third, there are uncertainties associated with the various loss estimation algorithms as well as the assignment of resistances to structures and their contents. Finally, there is even uncertainty in the process of inventorying and classifying the buildings. As more data become available, these uncertainties will shrink but they can never be fully eliminated.

3.9 Some Considerations for the Evaluation of Commercial Hurricane Loss Estimation

Recently, several organizations have produced commercial software packages for hurricane loss estimation. Since these products have been developed outside of the Caribbean and target buildings located primarily along the Gulf and Atlantic Coasts of the United States, potential Caribbean users of such technologies need to evaluate such packages carefully before selecting any one product. Certainly, one can develop a formal evaluation methodology for such products. At a minimum, such a methodology should contain the following seven considerations: (1) the methodology should accommodate building classes to be found in the Caribbean Region, (2) the methodology should contain a complete description of the hurricane hazard in the Caribbean region, (3) how the hazard is modified to address a specific site should be clearly stated, (4) details of the resistance model for structures and their contents should be stated along with all assumptions used to generate the models, (5) allowances should be made to exploit sources of information such as local meteorological records, post-disaster studies in the Caribbean, local building codes, field inspections, local insurance records, and the expert opinions on local design and construction, (6) an indication of the uncertainty associated with the methodology should be presented, and (7) validation examples of the methodology should be provided.

3.10 Effort, Time, and Cost Needed to Implement Loss Estimation Studies

The end product of a loss estimation study depends heavily upon the user requirements. Products may range from reports such as the one presented in Table 8 to studies of the probable damage sustained in a hurricane by critical facilities such as hospitals, police stations, harbours, and airports. The effort that goes into a loss estimation study could be divided into the development of the building class, the collection of the vulnerability data, the generation of the hazard data, the computation of the loss data, and the generation of the report. Involved in this total effort are meteorologists, actuaries, structural engineers, wind engineers, computer programmers, and damageability experts.

The availability, or non-availability, of a working software package to the government agency or insurance company and the appropriate vulnerability data are the major factors that will determine the time a government agency or an insurance company will need in order to implement a major loss estimation study. A government agency or an insurance company may find itself in one of four extreme cases:

Case I - No loss estimation software and no vulnerability data,
Case II - No loss estimation software but vulnerability data,
Case III - Loss estimation software but no vulnerability data, and
Case IV - Loss estimation software and vulnerability data.

In the writer's opinion: if Case IV controls, loss studies can be completed in weeks; if Case II or Case III controls, studies can be implemented and completed in one to three months; and if Case I controls, two to six months may be needed to implement studies.

The major factors that determine the cost of a loss estimation study are (1) the amount of information that is to be embedded into the vulnerability curves (e.g., level of classification, age of construction, quality of construction, special building characteristics, etc.), (2) the amount of hazard information for a particular site (i.e. topography, terrain roughness, protection, etc..), and (3) the cost of the loss estimation software. Depending upon the source of the software program, item 3 above may vary tremendously.

To provide the reader with a realistic estimate of what is involved in a loss estimation study, the approximate numbers for the study in Table 8 are listed below:

Field visit - 4 man days
Determination of building classification - 1 man day
Development of hazard data - 1 man day
Development of vulnerability data - 2 man days
Loss estimation - 2 man days
Report preparation - 2 man days

Thus a total of 13 man days were used to complete the study. Assuming a rate structure of $1000.00 per man day, the cost for the referenced study is $13,000. Note this number assumes that software was in place and the study was performed by professionals familiar with the methodologies. Since eight building classes were used in the study, a ball-park estimate of the cost of a loss estimation study is \$13,000/8 = \$1,685 per building class. Certainly, this number will move up or down depending upon local conditions.