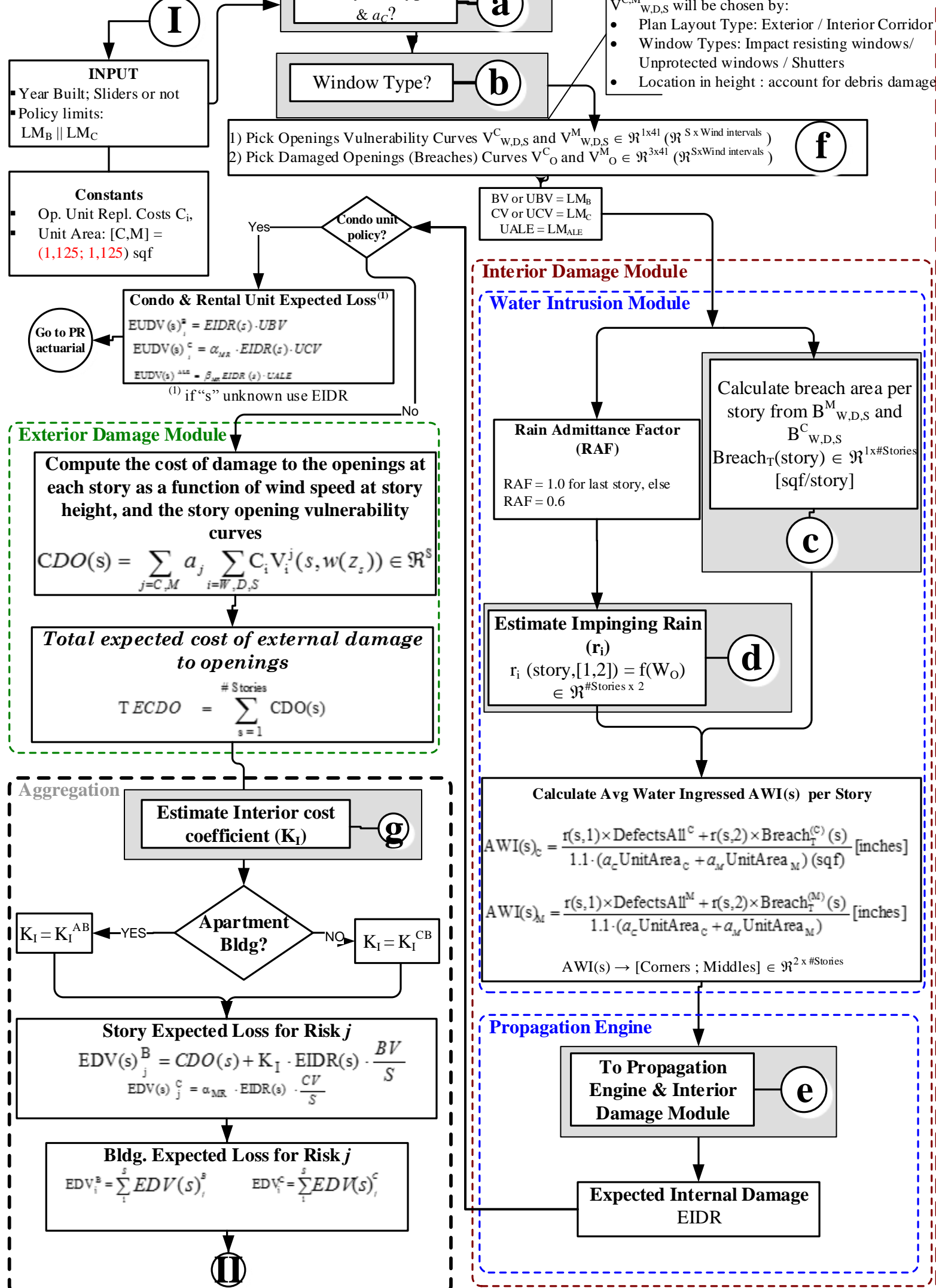
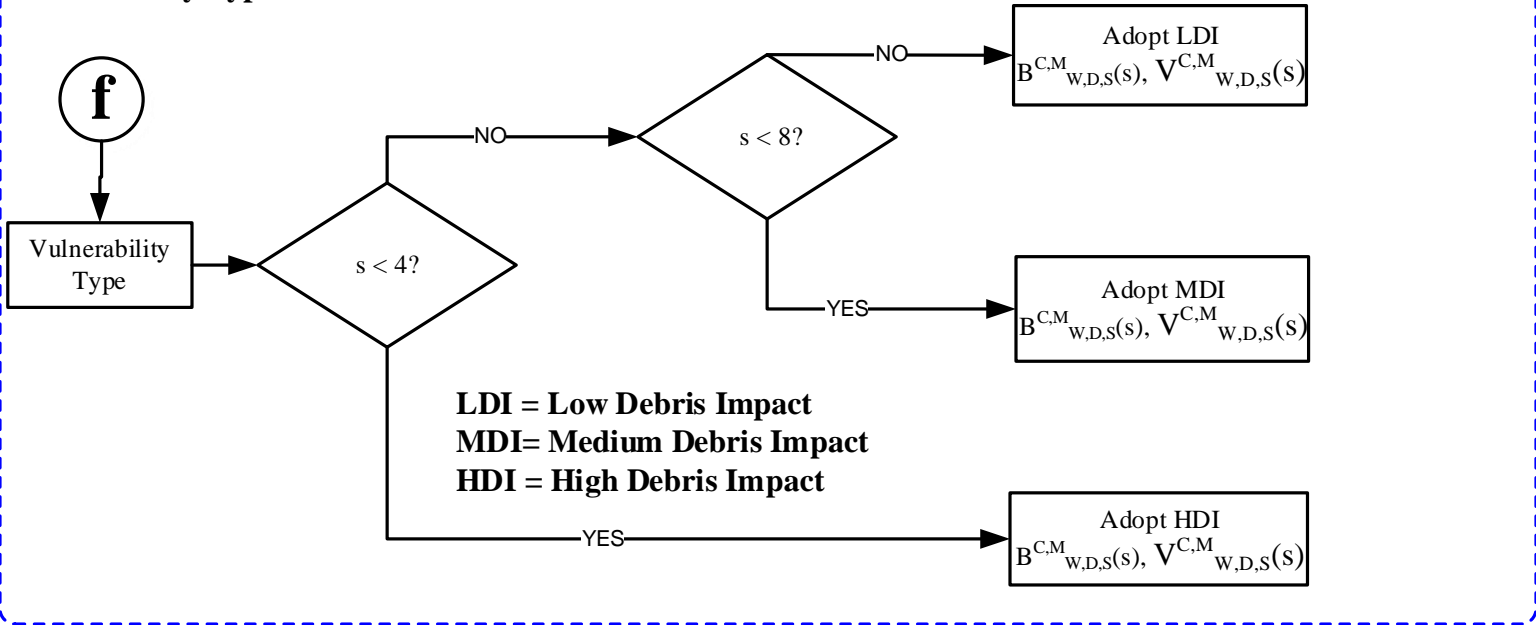


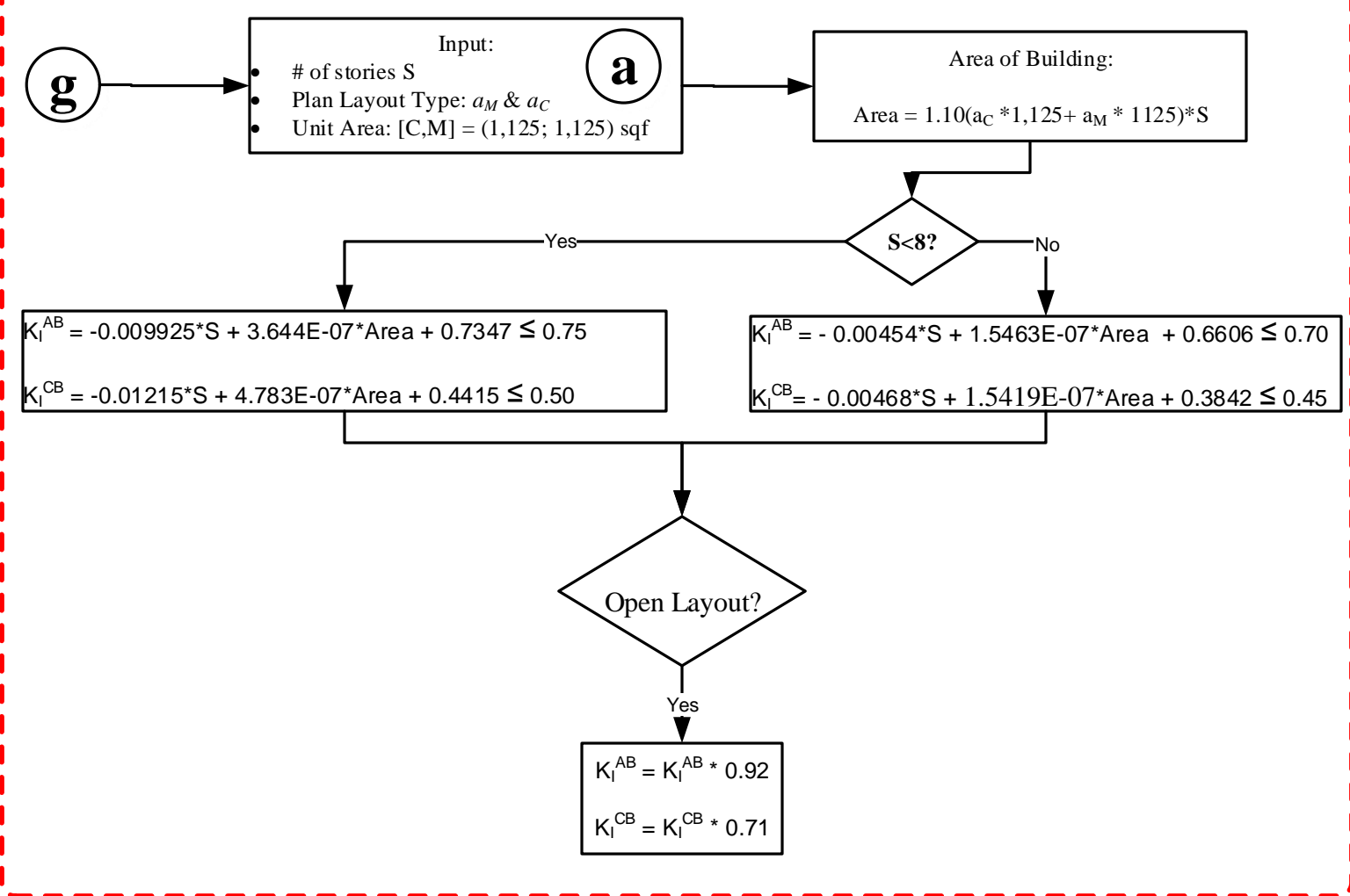
Mid-High Rise Module



Vulnerability Type



Interior Cost Coefficient



Openings Unit Replacement Costs:

- $C_{W-IR} = \$780$
- $C_{W-Standard} = \$430$
- $C_{W-StandardShutter} = \700
- $C_{S-IR} = \$1530$
- $C_{S-Standard} = \$935$
- $C_{S-StandardShutter} = \1300
- $C_{D-IR} = \$1650$
- $C_{D-Standard} = \$900$

Note: if the openings are weighted, weight the costs accordingly

Low-Rise Module

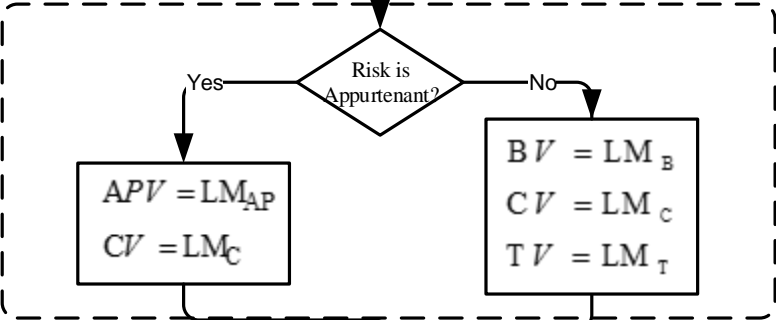
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Input:
 Region: *HVHZ, WBDR or NA*
 Number of Stories: *NStories*
 ZipCode
 Wind Speed Profile W_0 at Zip Code
 Insurance Limits

Use **Mapping Flowchart for existing Vulnerability Curves - Commercial Low-Rise (CLR)**
 To assign Building and Contents Curves

Compute Contents and Time Element Vuln. Curve (V_{CONT} , V_{Time}) as a function of interior Vuln. Curve (V_{INT})
 $V_{CONT} = \alpha_{LR} V_{INT}$
 $V_{Time} = \beta_{LR} V_{INT}$

Input
 Vulnerability curves for Building (B) and Contents (C), (for a given construction type and, Stories, based on a given mix of construction features and Wbdr or hvhz).
 Based on W_0 , get the mean damage values EDR^B & EDR^C , whose corresponding wind speed intervals W_i (+/- 2.5 mph) includes W_0 (in case of a tie, break the tie by picking the larger one)



$APV = LM_{AP}$
 $CV = LM_C$

$BV = LM_B$
 $CV = LM_C$
 $TV = LM_T$

Determine the Overall Expected Damage Ratio by selecting the damage with the wind speed in the corresponding Vuln. Curve
 $EDR = f[Vuln. Curve(W_0)]$

$EDV_j^{AP} = EDR_j^B \cdot APV$
 $EDV_j^C = EDR_j^C \cdot CV$

$EDV_j^B = EDR_j^B \cdot BV$
 $EDV_j^C = EDR_j^C \cdot CV$
 $EDV_j^T = EDR_j^T \cdot TV$

II

Aggregation of Damage Values

$$\begin{aligned} EDV^B &\leftarrow EDV^B + EDV_j^B \\ EDV^C &\leftarrow EDV^C + EDV_j^C \\ EDV^T &\leftarrow EDV^T + EDV_j^T \\ EDV^{AP} &\leftarrow EDV^{AP} + EDV_j^{AP} \end{aligned}$$

Calculate and prorate Deductible

$$EDV^T = EDV^B + EDV^C + EDV^T + EDV^{AP}$$
$$D^B = D \cdot \frac{EDV^B}{EDV^T}; D^C = D \cdot \frac{EDV^C}{EDV^T}; D^{AP} = D \cdot \frac{EDV^{AP}}{EDV^T}$$

More than one risk in the policy?

Yes
4

II

Go to Actuarial Module

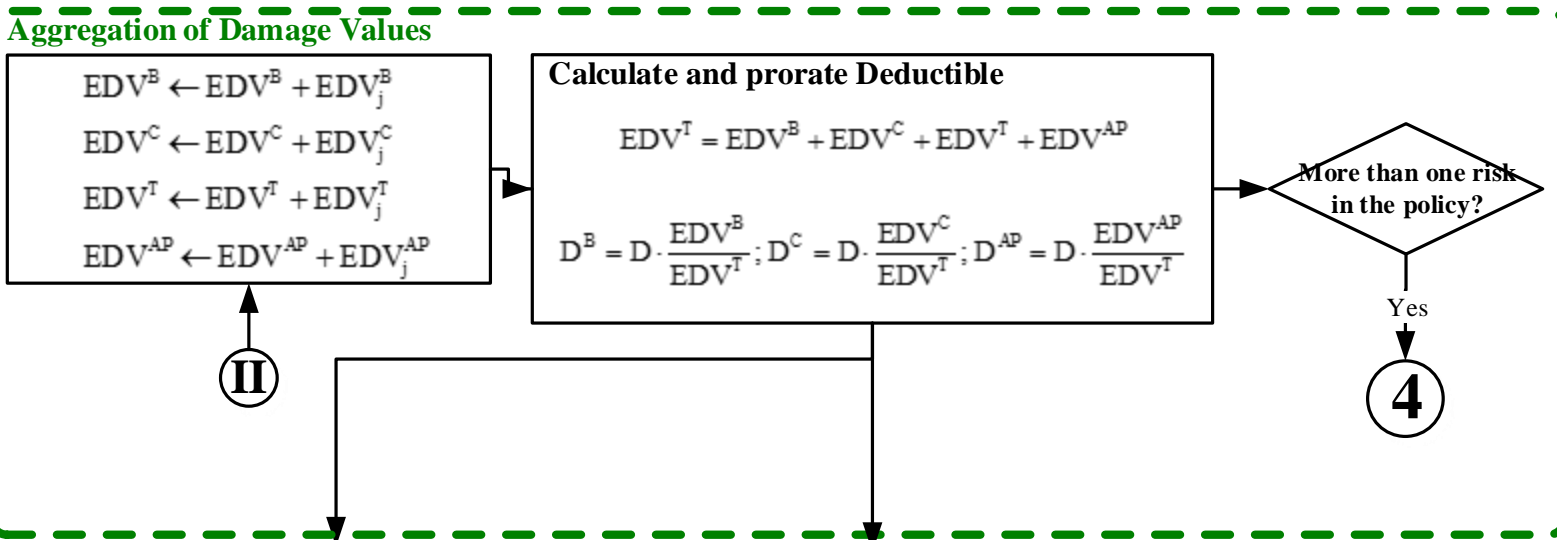
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Last Policy?

Last Company?

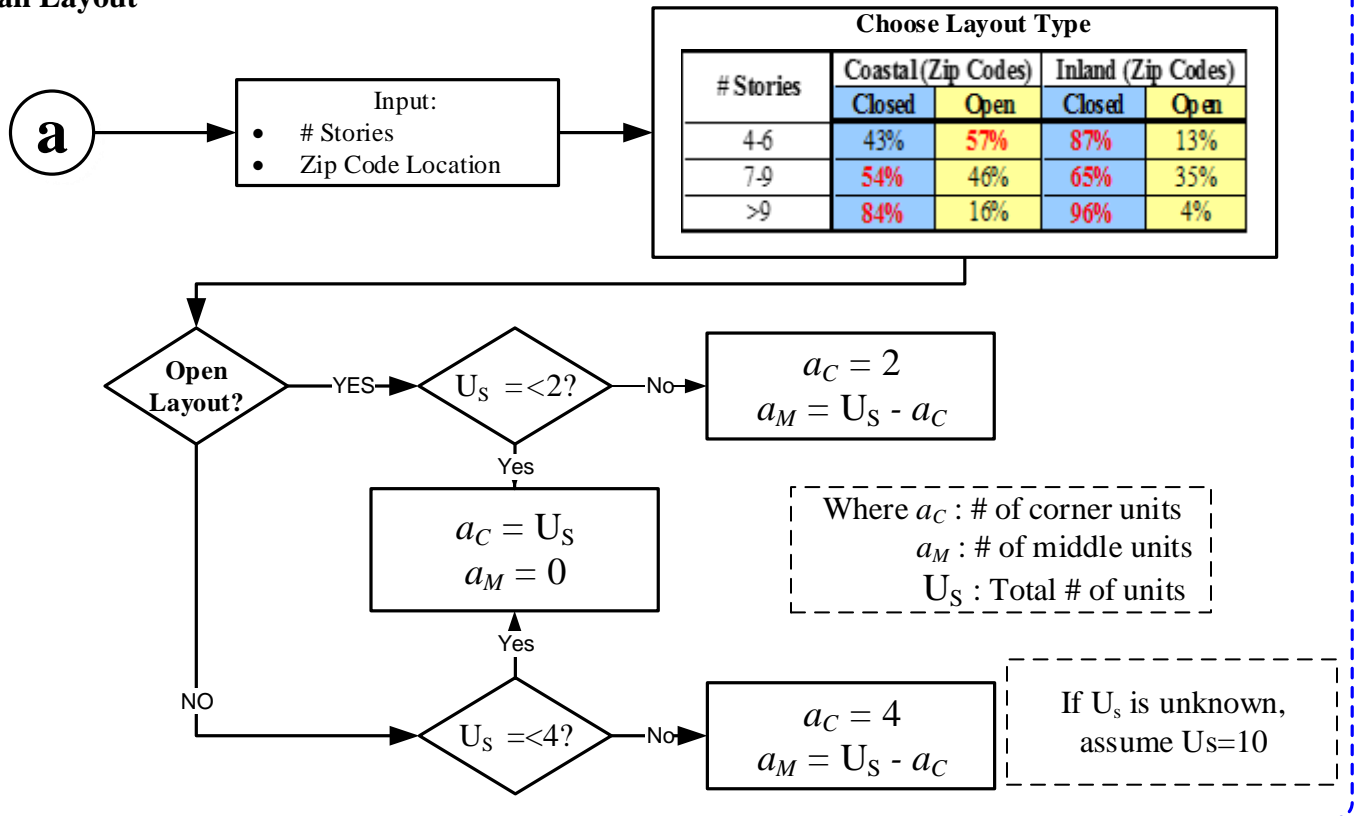
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1

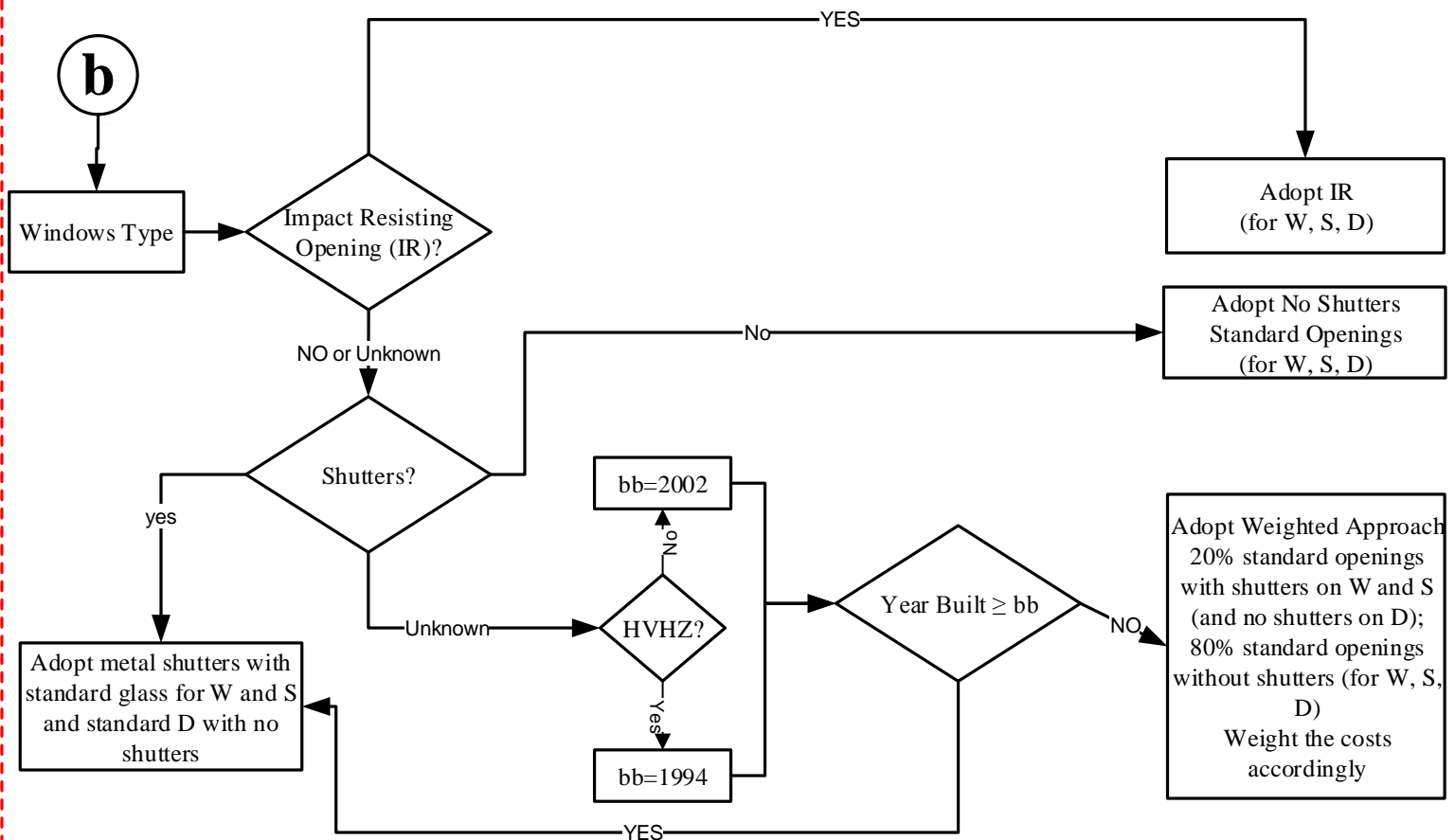


Glossary	
a_C : # of corner units per story	f_{sim} : Simultaneity factor that accounts for the walls that actually have rain intrusion due to wind angle.
a_M : # of middle units per story	f_{run} : Runoff factor that accounts for the runoff water on the facades
a,b,c,d: linear regression coefficients of impinging rainfall as a function of 3 sec gust at 10m	i : Policy Counter / Other counter
APV : Appurtenant Value [\$]	IDR(k) : Interior Damage Ratio vector [%]
AWI : Average water ingressed [inches of rain]	IDR _C ^U : Interior Damage Ratio of a corner unit [%]
A_W, A_D, A_S : Size of individual windows, doors, sliders. (sqft)	IDR _M ^U : Interior Damage Ratio of a middle unit [%]
α_{MR} : Contents coeff. as proportion of Interior Dam. (Mid-Rise)	IDR _{VERT} : Interior Damage Ratio due to vert. propagation [%]
α_{LR}, β_{LR} : Contents and time element coverage coeff. as proportion of Interior Dam. (Low-Rise)	IDR _U : Interior Damage Ratio [%]
β_{MR} : ALE coeff. as proportion of Interior Dam. (Mid-Rise condo unit policy)	IR : Impinging rain on bldg façade [in/hr]
bs: Average breach area	IRW: Impact Resistant Window
B_i^C : Breach curve for openings i=W,S, or D (windows-sliders-doors) - corner units (ft ² as a fct of wind speed)	j : Risk counter
B_i^M : Breach curve for openings i=W,S, or D (windows-sliders-doors) - middle units (ft ² as a fct of wind speed)	k : story index
BaseArea: total area of story in sqft	k_E^{AB}, k_E^{CB} : Ratio of Exterior Value to total Value for Apt bldgs and Condo Bldgs.
Breaches: breaching square footage per story	k_I^{AB}, k_I^{CB} : Ratio of Interior Value to total Value for Apt bldgs and Condo Bldgs.
Breach _T ^C : total breach size of corner units. (includes defects)	LIF : average Local intensity factor
Breach _T ^M : total breach size of middle units. (includes defects)	LM _B : Building policy limit.
BV : Bldg. Value [\$]	LM _C : Contents policy limit.
BV _{AB} : Apt. Bldg. Value [\$]	LM _T : Time element coverage policy limit.
BV _{CB} : Condo Bldg. Value [\$]	LM _{AP} : Appurtenant policy limit.
C_i : unit replacement cost for openings i=W,S, or D (windows-sliders-doors)	OCT : Open Corridor Type
CCT : Closed Corridor Type	$r(\text{story}, i)$: impinging accumulated rainfall [in] per story for $i = 1$ time $t_{initial}$ to t_{breach} ; $i=2$ t_{breach} to t_{end}
CV : Contents Value [\$]	ρ = percolation factor
CDO(s): cost of damage to the openings at story s [\$]	ρ_s = roof leak factor
D : Deductible	s = story number
D^{AP} : Appurtenant deductible	S = total number of stories
D^B : Building deductible	S_W, S_D, S_S : Complement of the vulnerability function for MHRB, i.e. 1 – Vuln Function, for computing water intrusion due to defects.
D^C : Contents deductible	T_{ID} = threshold water (inches) to complete interior damage.
DefectsAll: area of all the defects for a given unit	TECDO: Total expected cost of external damage to openings [\$]
d_w, d_D, d_S : defects area for windows, door and slider (sqft)	TV [\$]: Time element coverage value
EEDR : Expected Exterior Damage Ratio [%]	U_S : Units per Story
EDR _S : Exterior Damage Ratio vector per Story [%]	UBV = Condo unit value (structure)
EDR _j ^{B,C,T} : Expected Dam. Ratio Bldg, Contents, Time resp.	UCV = Condo unit value (contents)
EDV _j ^B : Expected Damage Value of Risk j – Building [\$]	UALE = Condo unit value (additional living expenses)
EDV _j ^C : Expected Damage Value of Risk j – Contents [\$]	UW: Unprotected Window
EDV _j ^{AP} : Expected Damage Value of Risk j – Appurtenant [\$]	V_{CONT} : Vuln. Curve Contents
EDV ^B : Overall Expected Damage Value – Building [\$]	V_{TIME} : Vuln. Curve Time Element Coverage
EDV ^C : Overall Expected Damage Value – Contents [\$]	V_i^C : Vulnerability curve for openings of corner units; $i=W, D, \text{ or } S$ (window, door, or slider). Give the number or fraction of opening damaged as a function of wind speed.
EDV ^T : Overall Expected Damage Value – Time Element [\$]	V_i^M : Vulnerability curve for openings of middle units; $i=W, D, \text{ or } S$ (window, door, or slider).
EDV ^{AP} : Overall Expected Damage Value – Appurtenant [\$]	V_I : Adopted Unit's Interior Vulnerability Curve
EDV ^T : Total Expected Damage Value [\$]	V_{INT} : Vuln. Curve Interior
EIDR(s) : Expected Interior Damage Ratio per story s [%]	$W_O(s)$: Wind speed profile per story s
EDV _j ^B (s): Expected Story Damage Value of Risk j –Building [\$]	z_s = mean height of story s. For $s=3$, z_s is assumed to be 10 m.
EDV _j ^C (s): Expected Story Damage Value of Risk j–Contents [\$]	
EUDV _j ^B (s): Expected Condo Unit Damage Value , at story s – Building [\$]	
EUDV _j ^{C/ALE} (s): Expected Condo Unit Story Damage Value, at story s – Contents [\$] or ALE [\$]	
EIDR : Expected Interior Damage Ratio for entire building [%]	

Plan Layout



Opening Type



Openings Breach Area

Component Breaches Curves (all in sqf as a fct of wind speed)

$$B_{W,D,S}^{C,M} \rightarrow [\text{Windows, Sliders, Entry Doors}] \in \mathfrak{R}^{\text{Wind interv.} \times 3}$$

(c)

INPUT

- Shutters or IRG/No Shutters or No-IRG
- Sliders/No sliders
- Height position (1-3 / 4-7 / 8+)
- $d_W = 0.0026$; $d_D = 0.0258$; $d_S = 0.0237$ (sqf each)
- $A_W = 20$ sqf; $A_D = 20.1$; $A_S = 33.5$; (sqf)

Load corresponding

$$B_{W,D,S}^C \text{ and } B_{W,D,S}^M$$

(f)

$$B_S^C(W_O) = d_S = 0$$

$$B_S^M(W_O) = d_S = 0$$

No sliders

IF

Building = Closed

$$B_D^C(W_O) = d_D = 0$$

$$B_D^M(W_O) = d_D = 0$$

$$CC: \#Windows^C = 7$$

$$MC: \#Windows^M = 4$$

Building = Open

$$CO: \#Windows^C = 8$$

$$MO: \#Windows^M = 5$$

IF

Building = Closed

$$B_D^C(W_O) = d_D = 0$$

$$B_D^M(W_O) = d_D = 0$$

$$CC: \#Windows^C = 6$$

$$MC: \#Windows^M = 3$$

Building Closed

w/sliders

IF

Building Open

Building = Open

$$CO: \#Windows^C = 7$$

$$MO: \#Windows^M = 4$$

Breaches Area (sqf) per story and unit type

$$\text{Breach}(s, C) = f \left[B_W^C(W_O) + B_S^C(W_O) + B_D^C(W_O), W_O(s) \right] \cdot a_C$$

$$\text{Breach}(s, M) = f \left[B_W^M(W_O) + B_S^M(W_O) + B_D^M(W_O), W_O(s) \right] \cdot a_M$$

$$S_W^{C,M} = \left(\# \text{ Windows} - \frac{B_W^{C,M}}{A_W} \right) \quad S_D^{C,M} = \left(1 - \frac{B_D^{C,M}}{A_D} \right) \quad S_S^{C,M} = \left(1 - \frac{B_S^{C,M}}{A_S} \right)$$

$$\text{Defects}(s, C) = f \left[d_W \times S_W^C(W_O) + d_S \times S_S^C(W_O) + d_D \times S_D^C(W_O), W_O(z_s) \right] \cdot a_C$$

$$\text{Defects}(s, M) = f \left[d_W \times S_W^M(W_O) + d_S \times S_S^M(W_O) + d_D \times S_D^M(W_O), W_O(z_s) \right] \cdot a_M$$

So the total breach for wind pressure and debris plus defects is

$$\text{Defects all }^C = \left(\# \text{ Windows }^C \times d_W + d_D + d_S \right) \cdot a_C$$

$$\text{Defects all }^M = \left(\# \text{ Windows }^M \times d_W + d_D + d_S \right) \cdot a_M$$

$$\text{Breach } \frac{C}{T}(s) = \text{Breach}(s, C) + \text{Defects}(s, C)$$

$$\text{Breach } \frac{M}{T}(s) = \text{Breach}(s, M) + \text{Defects}(s, M)$$

d

Input

- $W_o(s)$ (3 sec-gust in mph) $\in \mathfrak{R}^{\#\text{Stories} \times 1}$
- $RAF \in \mathfrak{R}^{2 \times 1}$
- $f_{sim} = 0.5$
- $f_{run} = 1.4$

Wind Driven Rain Accumulated (inches)

$$\alpha = 1.178E-09 \cdot W_o(s=3)^5 - 4.094E-07 \cdot W_o(s=3)^4 + 3.693E-05 \cdot W_o(s=3)^3 + 4.625E-04 \cdot W_o(s=3)^2 - 1.355E-02 \cdot W_o(s=3) + 1.364E-01$$

$$\beta = -6.533E-06 \cdot W_o(s=3)^3 + 1.863E-03 \cdot W_o(s=3)^2 - 1.706E-02 \cdot W_o(s=3)$$

IF $W_o(s=3) > 183$ mph

alpha = 22.3 inch

beta = 19.23 inch

$$r(s,1) = f_{run} \cdot f_{sim} \cdot RAF \cdot \alpha \cdot \frac{W_o(s)}{W_o(s=3)}$$

$$r(s,2) = f_{run} \cdot f_{sim} \cdot RAF \cdot \beta \cdot \frac{W_o(s)}{W_o(s=3)}$$

Propagation Engine

e

Input

- # Corner and middle units
 a_C, a_M
- # stories
- $AWI(k) \rightarrow [\text{cor.}, \text{mid.}]$
- Interior Damage Threshold $T_{ID} = 1$ in
- $\rho = 0.1$
- $\rho_S = 0.1$

Aggregate Water ingressed in corners $AWI(k)_C$ & middles $AWI(k)_M$ for each Story k

$$AWI(k) = AWI(k)_C + AWI(k)_M \text{ [inches]}$$

Estimate Vertical water leakage per story

Increase water penetration for upper story S due to roof leaks

$$AWI(S) = AWI(S) \times (1 + \rho_S) \text{ [inches]}$$

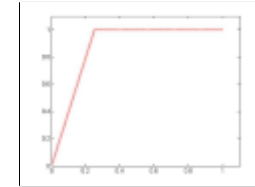
$s = (S-1)$ to 1

$$AWI(s) \leftarrow AWI(s+1) \times \rho + AWI(s)$$

$s = 1?$

Convert to Expected Interior Damage Ratio

$$\begin{cases} AWI(k) \leq T_{ID} \rightarrow EIDR(k) = \frac{1}{T_{ID}} AWI(k) \\ AWI(k) > T_{ID} \rightarrow EIDR(k) = 1 \end{cases}$$



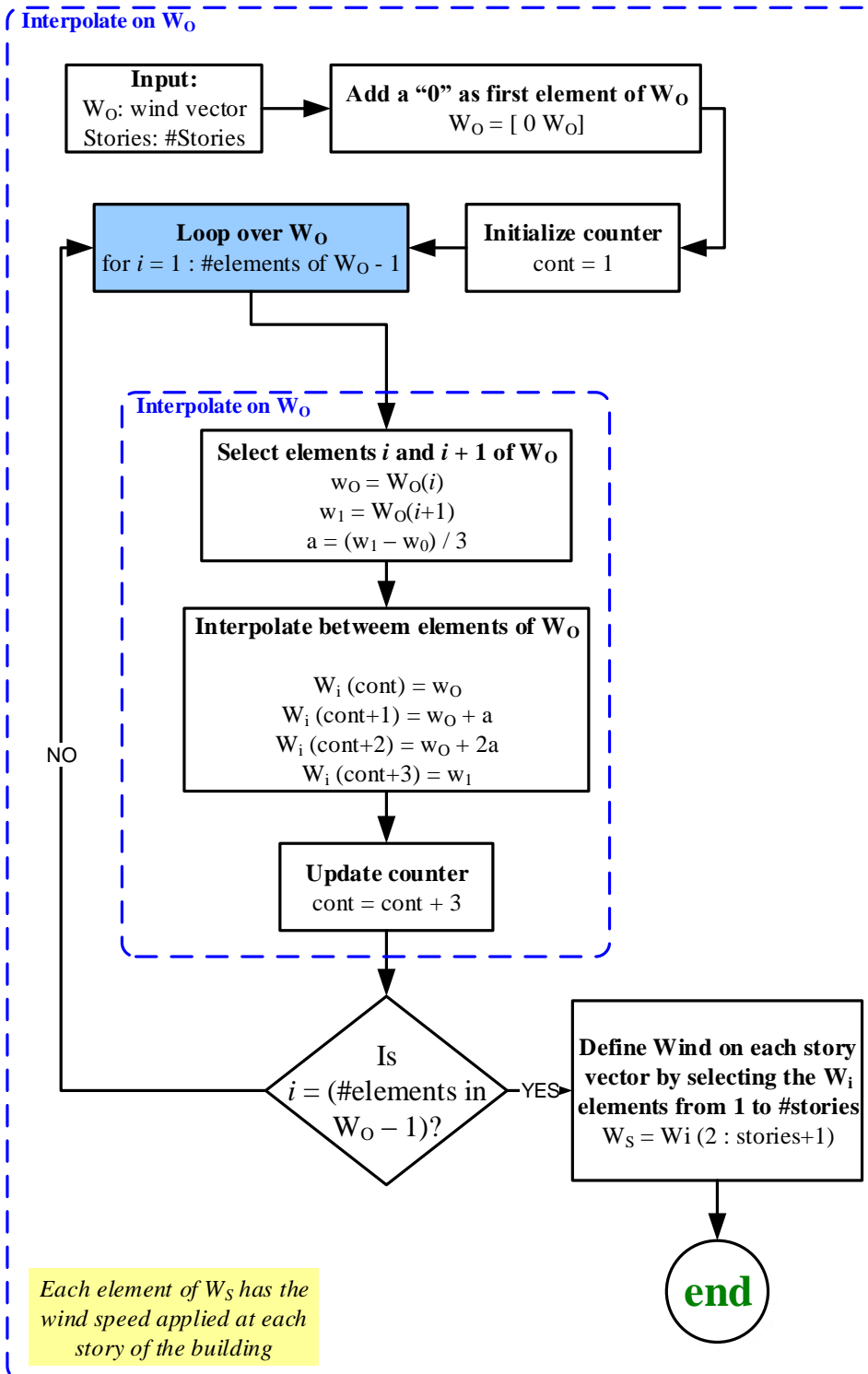
Compute Total EIDR due to water ingressed in the building

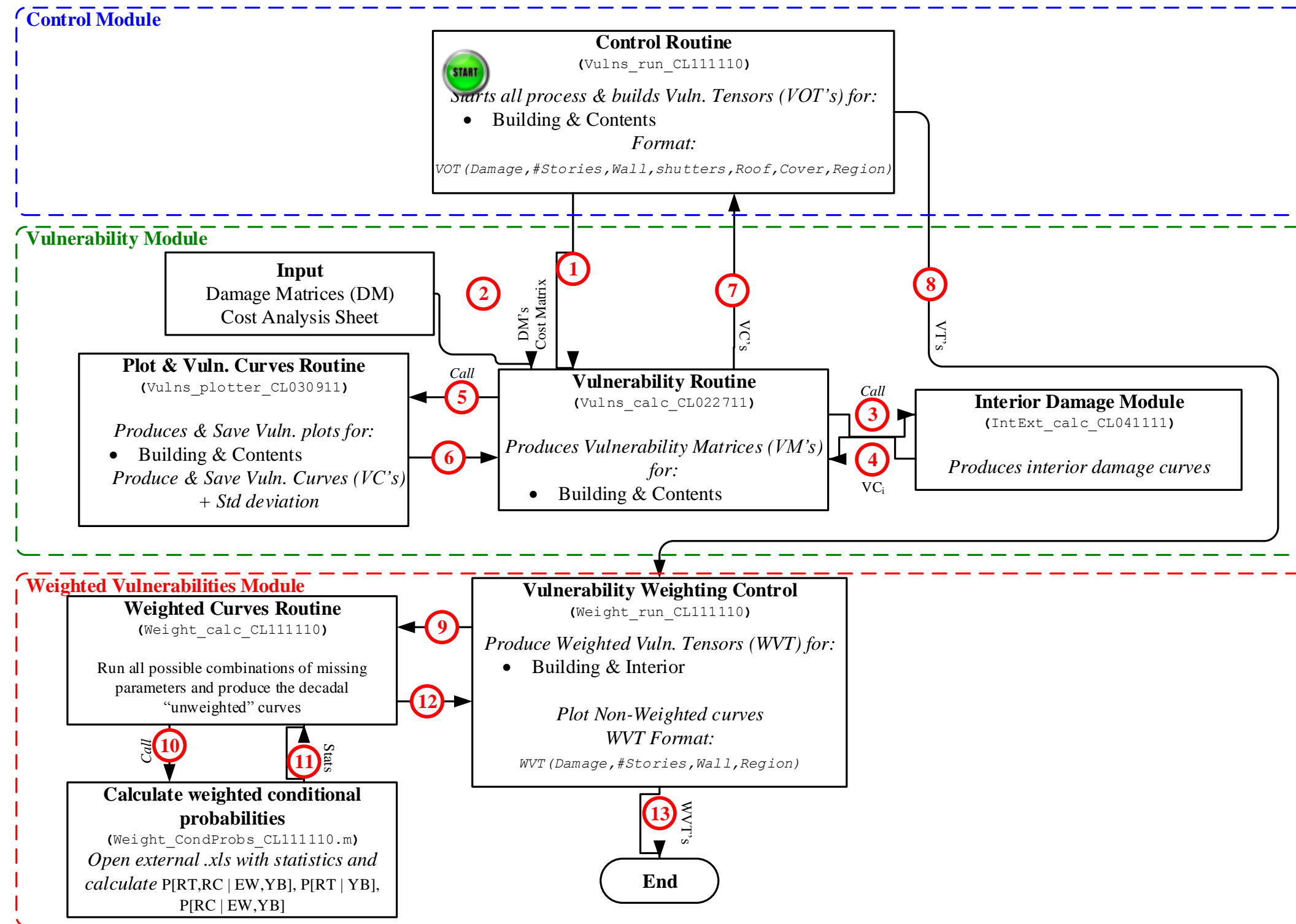
$$EIDR = \frac{1}{S} \sum_k EIDR(k)$$

$S = \#$ of stories

YES

No





Interior – Interior curves generation

