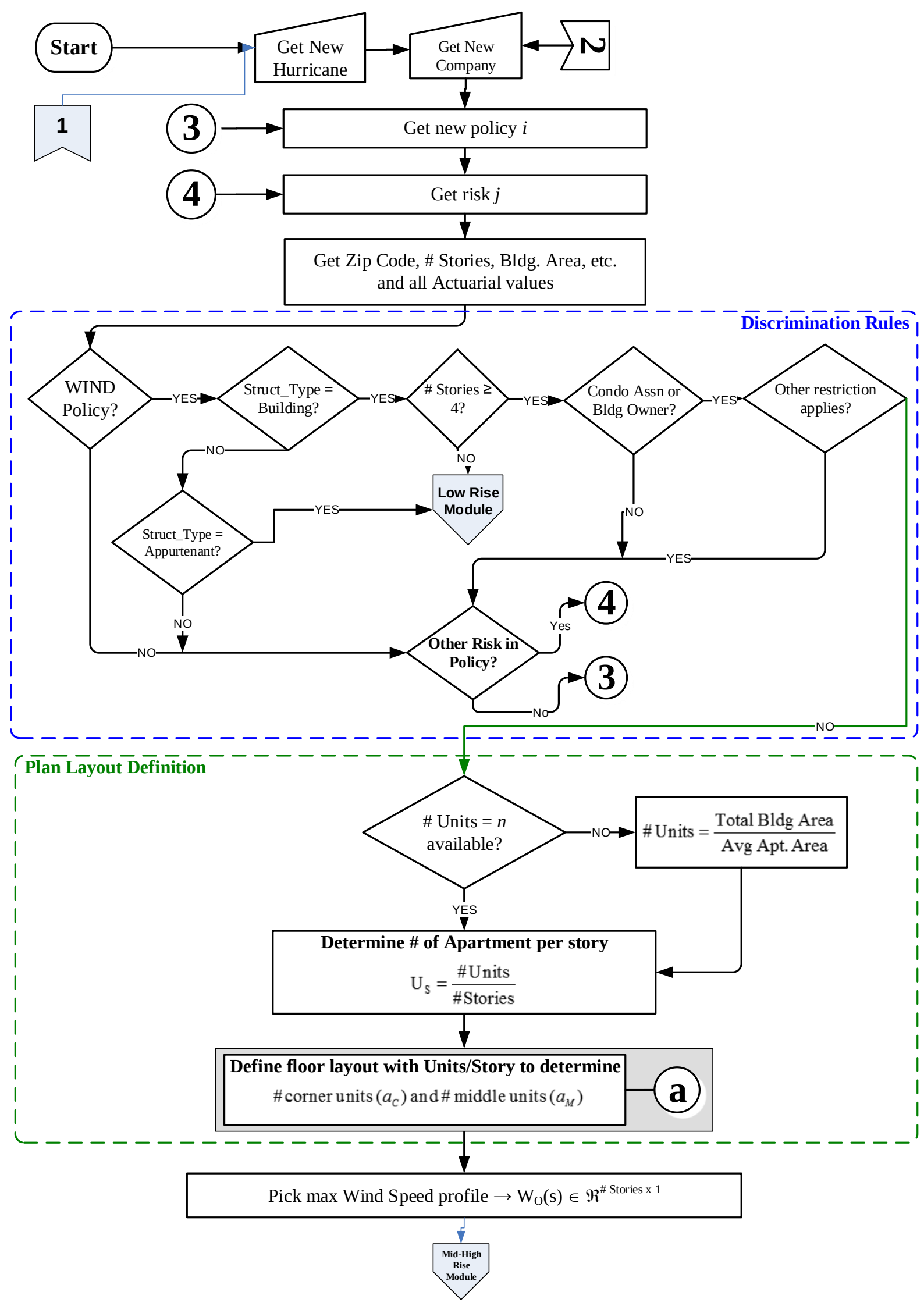
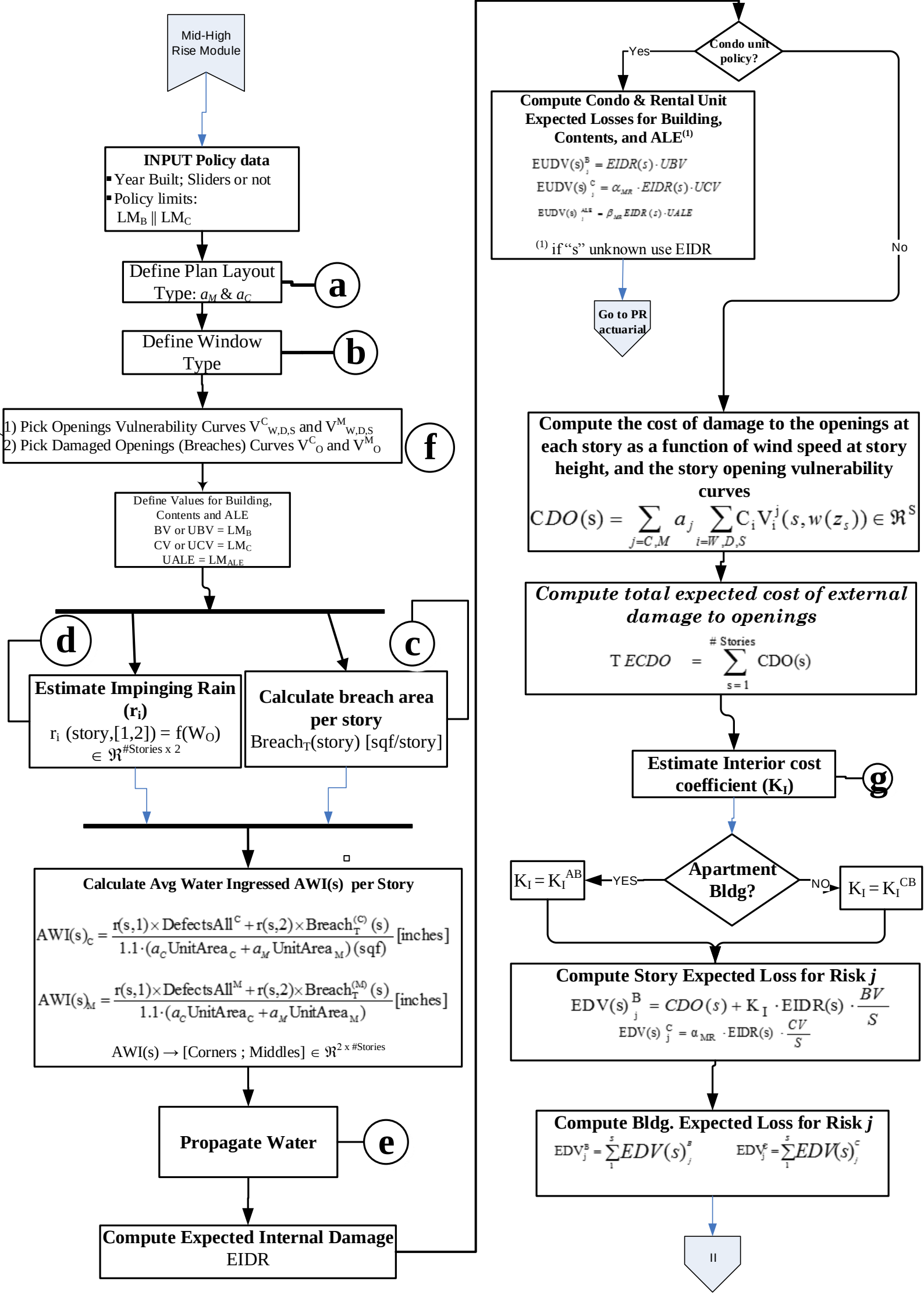
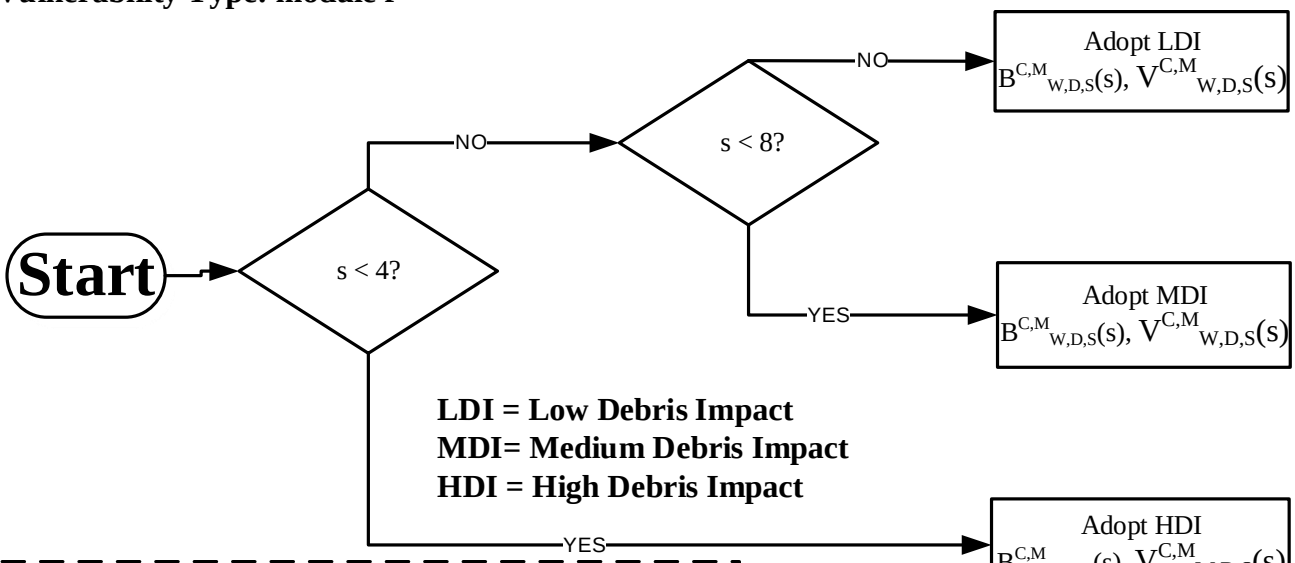

Start
Get New Hurricane
Get New Company
2
1
3
Get new policy i
4
Get risk j
Get Zip Code, # Stories, Bldg. Area, etc. and all Actuarial values
Discrimination Rules
WIND Policy?
YES
Struct_Type = Building?
YES
Stories ≥ 4?
YES
Condo Assn or Bldg Owner?
YES
Other restriction applies?
NO
NO
Low Rise Module
Struct_Type = Appurtenant?
YES
NO
NO
YES
Other Risk in Policy?
Yes
4
No
3
NO
Plan Layout Definition
Units = n available?
NO
Units = Total Bldg Area / Avg Apt. Area
YES
Determine # of Apartment per story
U_S = #Units / #Stories
Define floor layout with Units/Story to determine
corner units (a_C) and # middle units (a_M)
a
Pick max Wind Speed profile → W_O(s) ∈ ℜ^(# Stories x 1)
Mid-High Rise Module


Mid-High Rise Module
INPUT Policy data
Year Built; Sliders or not
Policy limits: LMB || LMC
Define Plan Layout Type: aM & aC
a
Define Window Type
b
1) Pick Openings Vulnerability Curves V^C W,D,S and V^M W,D,S
2) Pick Damaged Openings (Breaches) Curves V^C O and V^M O
f
Define Values for Building, Contents and ALE
BV or UBV = LMB
CV or UCV = LMC
UALE = LMALE
d
c
Estimate Impinging Rain (ri)
ri (story,[1,2]) = f(WO) ∈ ℜ^#Stories x 2
Calculate breach area per story
BreachT(story) [sqf/story]
Calculate Avg Water Ingressed AWI(s) per Story
AWI(s)C = r(s,1) × DefectsAll^C + r(s,2) × Breach_T^(C)(s) / 1.1 · (aC UnitAreaC + aM UnitAreaM) (sqf) [inches]
AWI(s)M = r(s,1) × DefectsAll^M + r(s,2) × Breach_T^(M)(s) / 1.1 · (aC UnitAreaC + aM UnitAreaM) [inches]
AWI(s) → [Corners ; Middles] ∈ ℜ^2 x #Stories
Propagate Water
e
Compute Expected Internal Damage
EIDR
Condo unit policy?
Yes
No
Compute Condo & Rental Unit Expected Losses for Building, Contents, and ALE(1)
EUDV(s)^B_j = EIDR(s) · UBV
EUDV(s)^C_j = αMR · EIDR(s) · UCV
EUDV(s)^ALE_j = βMR EIDR(s) · UALE
(1) if "s" unknown use EIDR
Go to PR actuarial
Compute the cost of damage to the openings at each story as a function of wind speed at story height, and the story opening vulnerability curves
CDO(s) = Σ_{j=C,M} aj Σ_{i=W,D,S} Ci Vi^j(s, w(zs)) ∈ ℜ^S
Compute total expected cost of external damage to openings
TECDO = Σ_{s=1}^{# Stories} CDO(s)
Estimate Interior cost coefficient (KI)
g
Apartment Bldg?
YES
NO
KI = KI^AB
KI = KI^CB
Compute Story Expected Loss for Risk j
EDV(s)^B_j = CDO(s) + KI · EIDR(s) · BV/S
EDV(s)^C_j = αMR · EIDR(s) · CV/S
Compute Bldg. Expected Loss for Risk j
EDV^B_j = Σ_1^5 EDV(s)^B_j
EDV^C_j = Σ_1^5 EDV(s)^C_j
II

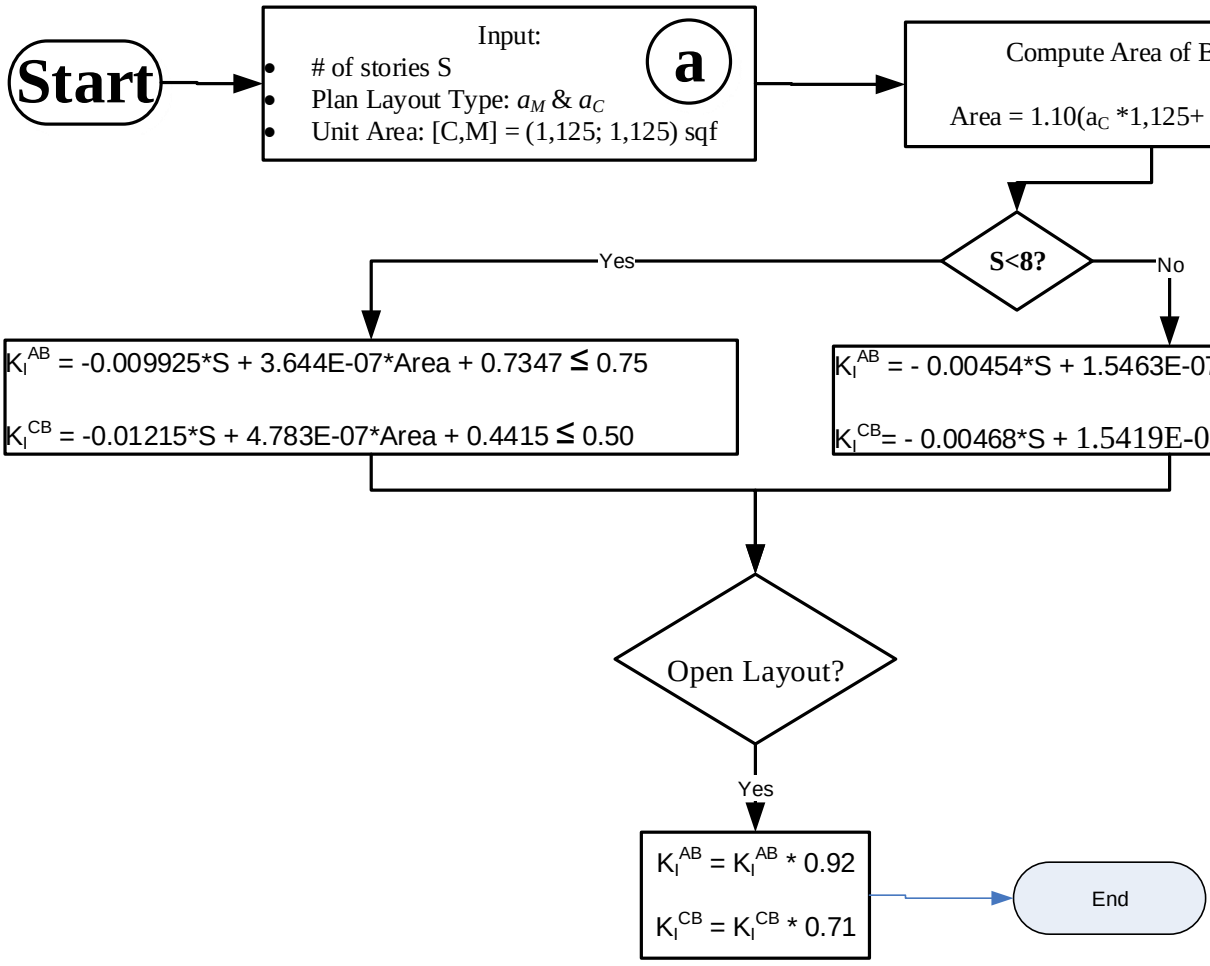
Vulnerability Type: module f



LDI = Low Debris Impact
MDI= Medium Debris Impact
HDI = High Debris Impact

1) Pick Openings Vulnerability Curves $V^{C}_{W,D,S}$ and $V^{M}_{W,D,S} \in \Re^{1x41}$ ($\Re^{S \text{ x Wind intervals}}$)
2) Pick Damaged Openings (Breaches) Curves V^{C}_{O} and $V^{M}_{O} \in \Re^{3x41}$ ($\Re^{S\text{xWind intervals}}$)

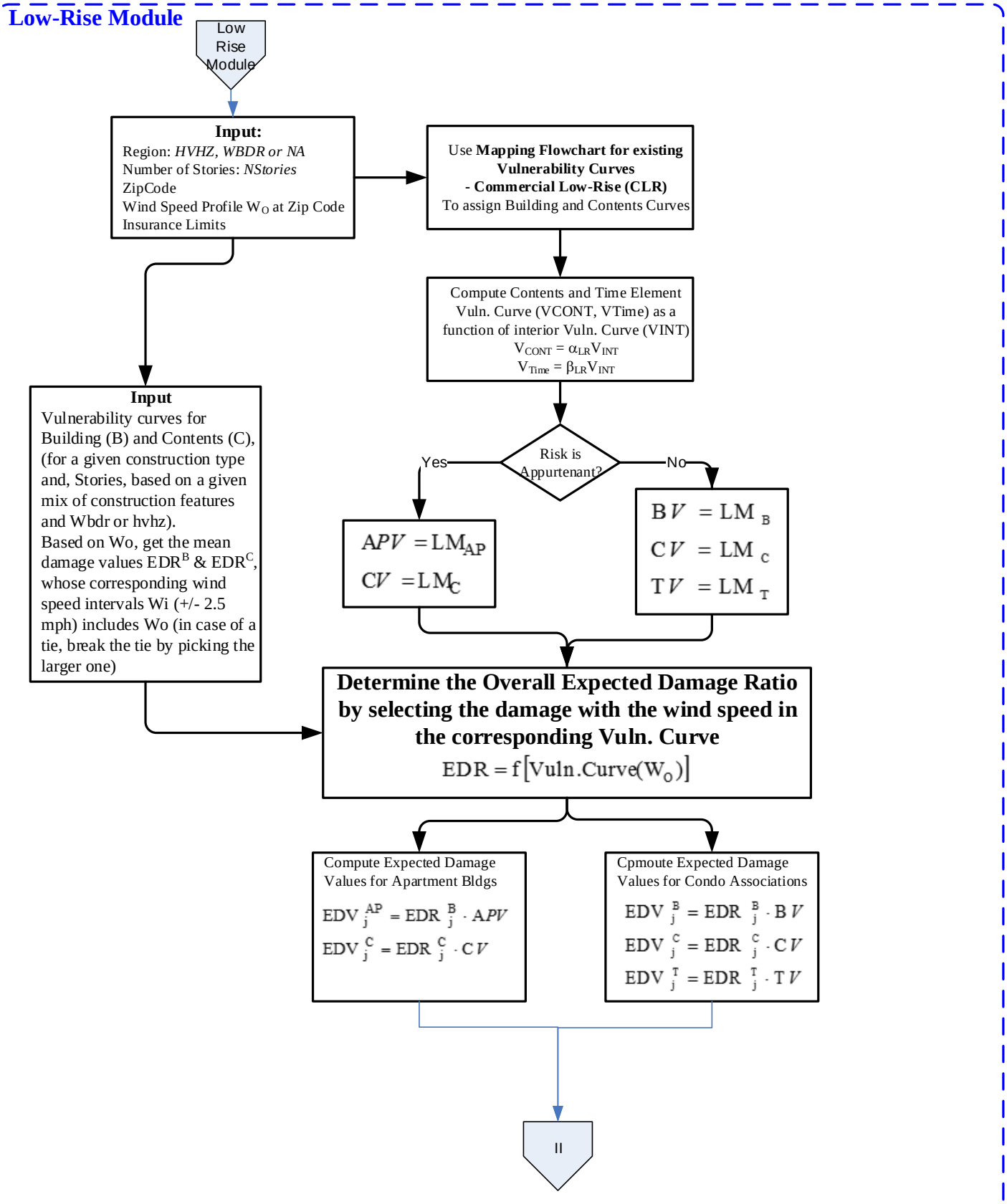
Interior Cost Coefficient: module g



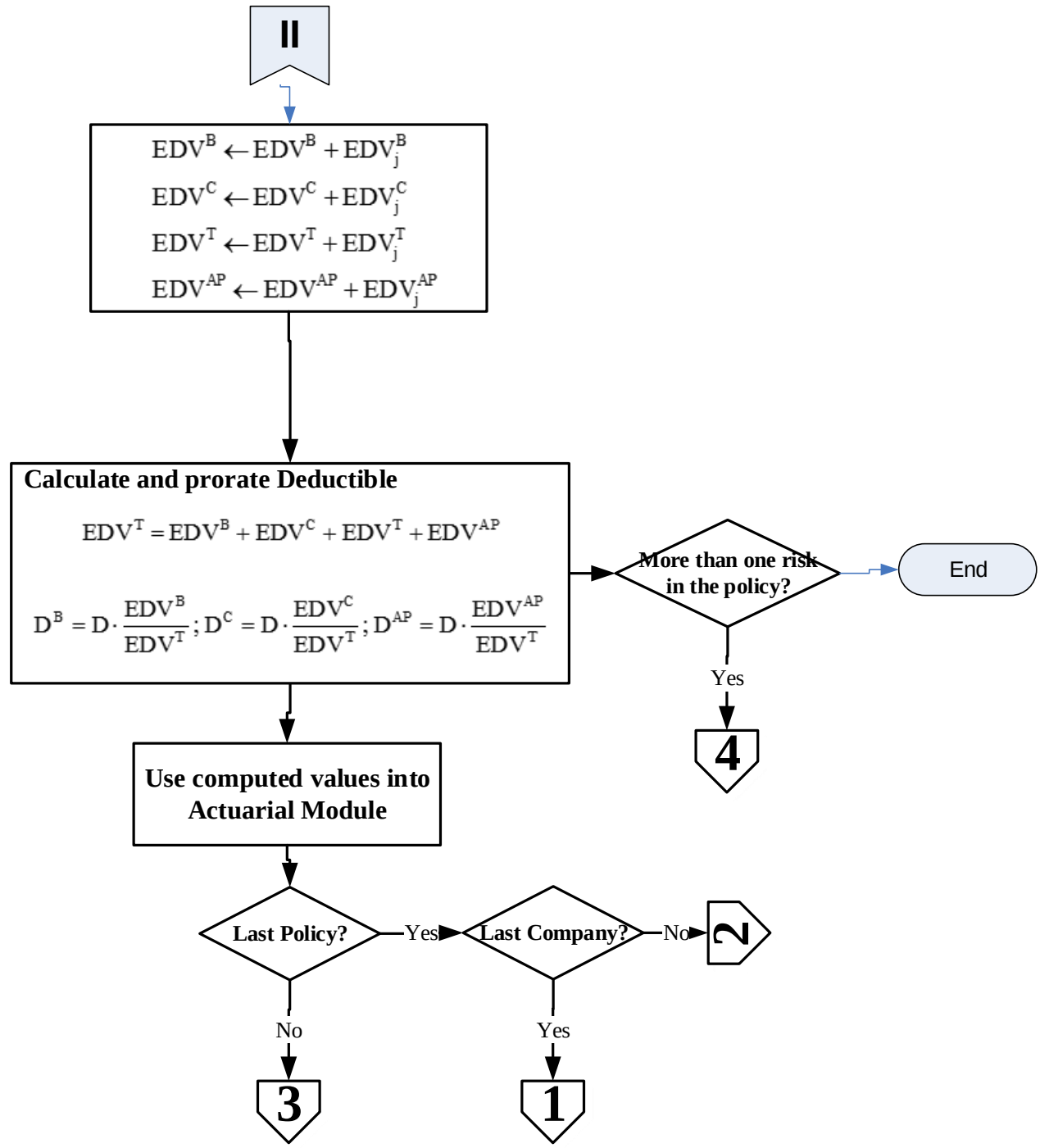
Openings Unit Replacement Costs:

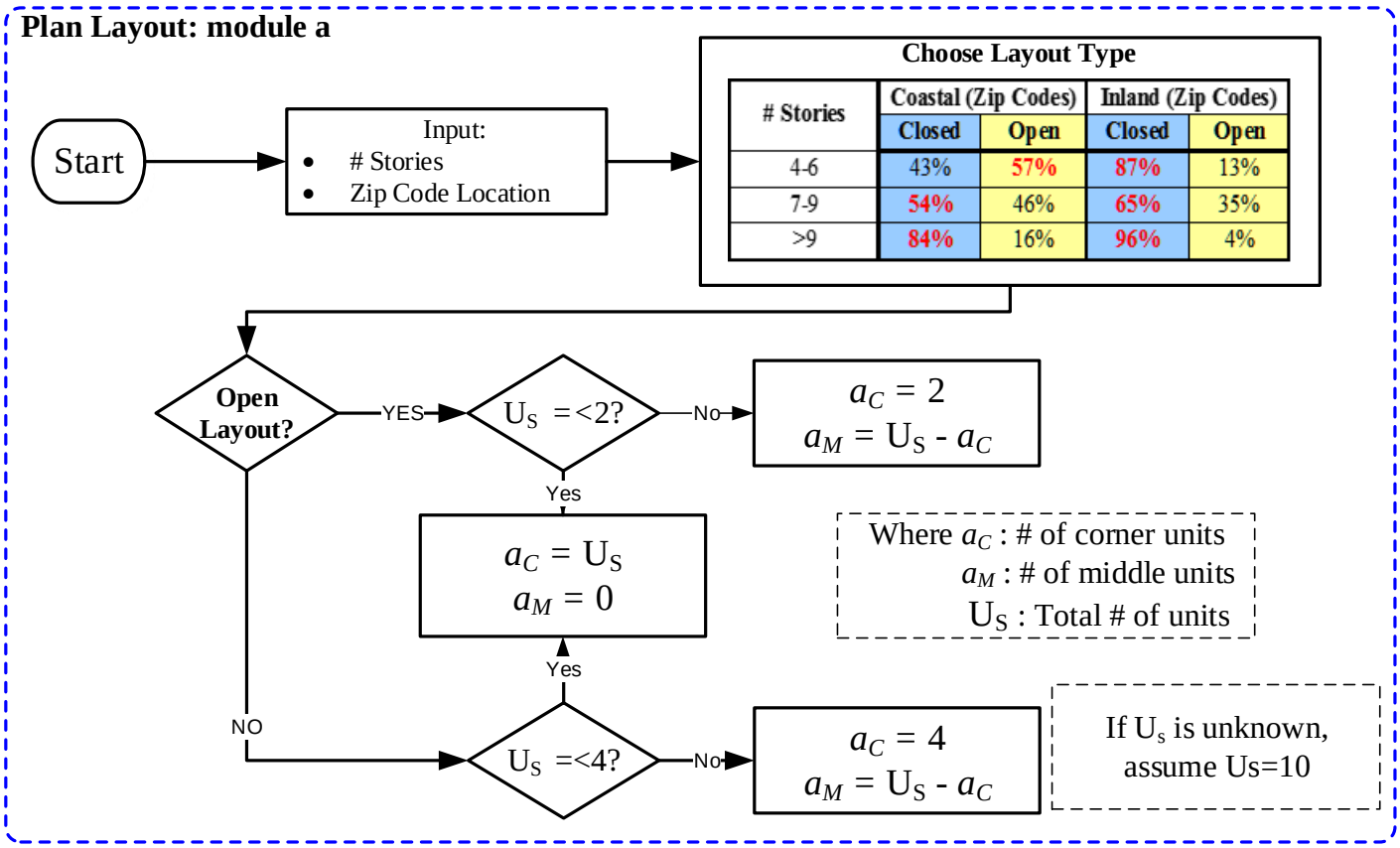
- $C_{W\text{-}IR}$= $780
- $C_{W\text{-}Standard}$= $430
- $C_{W\text{-}StandardShutter}$= $700
- $C_{S\text{-}IR}$= $1530
- $C_{S\text{-}Standard}$=$935
- $C_{S\text{-}StandardShutter}$=$1300
- $C_{D\text{-}IR}$= $1650
- $C_{D\text{-}Standard}$= $900

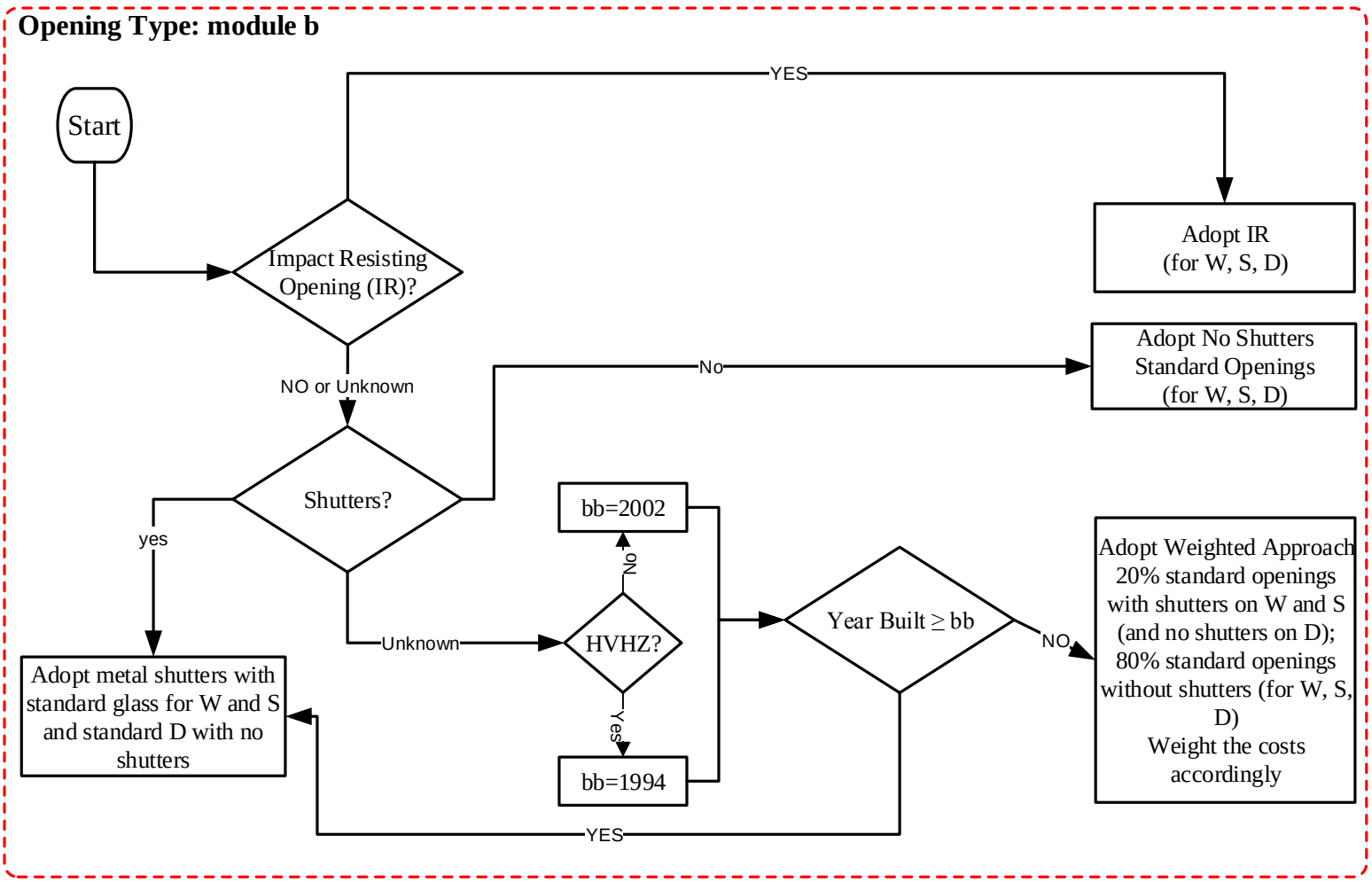
Note: if the openings are weighted, weight the costs accordingly


Low-Rise Module
Low Rise Module
Input:
Region: HVHZ, WBDR or NA
Number of Stories: NStories
ZipCode
Wind Speed Profile W_O 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 (VCONT, VTime) as a function of interior Vuln. Curve (VINT)
$V_{CONT} = \alpha_{LR} V_{INT}$
$V_{Time} = \beta_{LR} V_{INT}$
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 Wo, get the mean damage values EDR^B & EDR^C, whose corresponding wind speed intervals Wi (+/- 2.5 mph) includes Wo (in case of a tie, break the tie by picking the larger one)
Risk is Appurtenant?
Yes
No
$APV = LM_{AP}$
$CV = LM_C$
$BV = LM_B$
$CV = LM_C$
$TV = LM_T$
Determine the Overall Expected Damage Ratio by selecting the damage with the wind speed in the corresponding Vuln. Curve
$EDR = f[\text{Vuln.Curve}(W_o)]$
Compute Expected Damage Values for Apartment Bldgs
$EDV_j^{AP} = EDR_j^B \cdot APV$
$EDV_j^C = EDR_j^C \cdot CV$
Cpmoute Expected Damage Values for Condo Associations
$EDV_j^B = EDR_j^B \cdot BV$
$EDV_j^C = EDR_j^C \cdot CV$
$EDV_j^T = EDR_j^T \cdot TV$
II

Aggregation of Damage Values




Plan Layout: module a
Start
Input:
Stories
Zip Code Location
Choose Layout Type
Stories
Coastal (Zip Codes)
Inland (Zip Codes)
Closed
Open
Closed
Open
4-6
43%
57%
87%
13%
7-9
54%
46%
65%
35%
>9
84%
16%
96%
4%
Open Layout?
YES
U_S =<2?
No
$a_C = 2$
$a_M = U_S - a_C$
Yes
$a_C = U_S$
$a_M = 0$
Where a_C : # of corner units
a_M : # of middle units
U_S : Total # of units
Yes
NO
U_S =<4?
No
$a_C = 4$
$a_M = U_S - a_C$
If U_s is unknown, assume Us=10


Opening Type: module b
Start
YES
Impact Resisting Opening (IR)?
Adopt IR (for W, S, D)
NO or Unknown
No
Adopt No Shutters Standard Openings (for W, S, D)
Shutters?
yes
bb=2002
No
Unknown
HVHZ?
Year Built ≥ bb
NO
Adopt Weighted Approach 20% standard openings with shutters on W and S (and no shutters on D); 80% standard openings without shutters (for W, S, D) Weight the costs accordingly
Yes
bb=1994
Adopt metal shutters with standard glass for W and S and standard D with no shutters
YES

Openings Breach Area: module c

Start

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)

Select corresponding breach curves (all in sqf as a fct of wind speed)

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

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

f

Are there sliders?

No sliders

Set Slider breaches and defects to zero

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

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

w/sliders

Bldg layout?

Bldg Closed

Set Door breaches and defects to zero and Define number of windows

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

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

CC: #Windows^C = 7

MC: #Windows^M = 4

Bldg Open

Define number of windows

CO: #Windows^C = 8

MO: #Windows^M = 5

Bldg layout?

Building Closed

Set Door breaches and defects to zero and Define number of windows

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

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

CC: #Windows^C = 6

MC: #Windows^M = 3

Building Open

Define number of windows

CO: #Windows^C = 7

MO: #Windows^M = 4

Define Breaches Area (sqf) per story and unit type

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

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

Define survival functions for each type of opening

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

Define defects (sqf) per story and unit type

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

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

Compute the total breach from wind pressure and debris impact plus defects as:

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

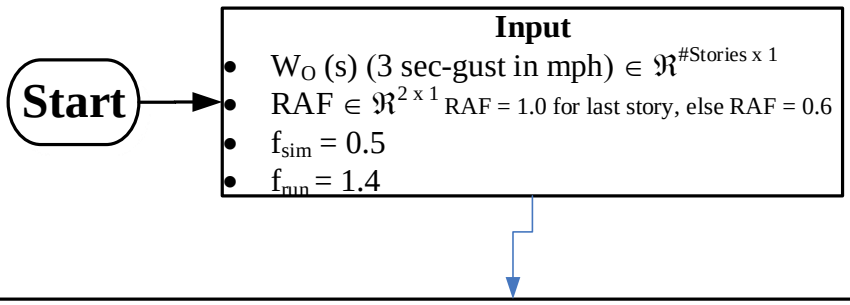
$$\text{Defectsall}^M = \left(\#\text{ Windows}^M \times d_W + d_D + d_S\right) \cdot a_M$$

$$\text{Breach}_T^C(s) = \text{Breach}(s, C) + \text{Defects}(s, C)$$

$$\text{Breach}_T^M(s) = \text{Breach}(s, M) + \text{Defects}(s, M)$$

End

Computation of impinging rain: Module d



Compute Wind Driven Rain Accumulated (inches)

alpha = 1.178E-09*$W_o(s=3)^5$ - 4.094E-07*$W_{o(s=3)}^4$ + 3.693E-05*$W_o(s=3)^3$ + 4.625E-04*$W_o(s=3)^2$ - 1.355E-02*$W_o(s=3)$ + 1.364E-01

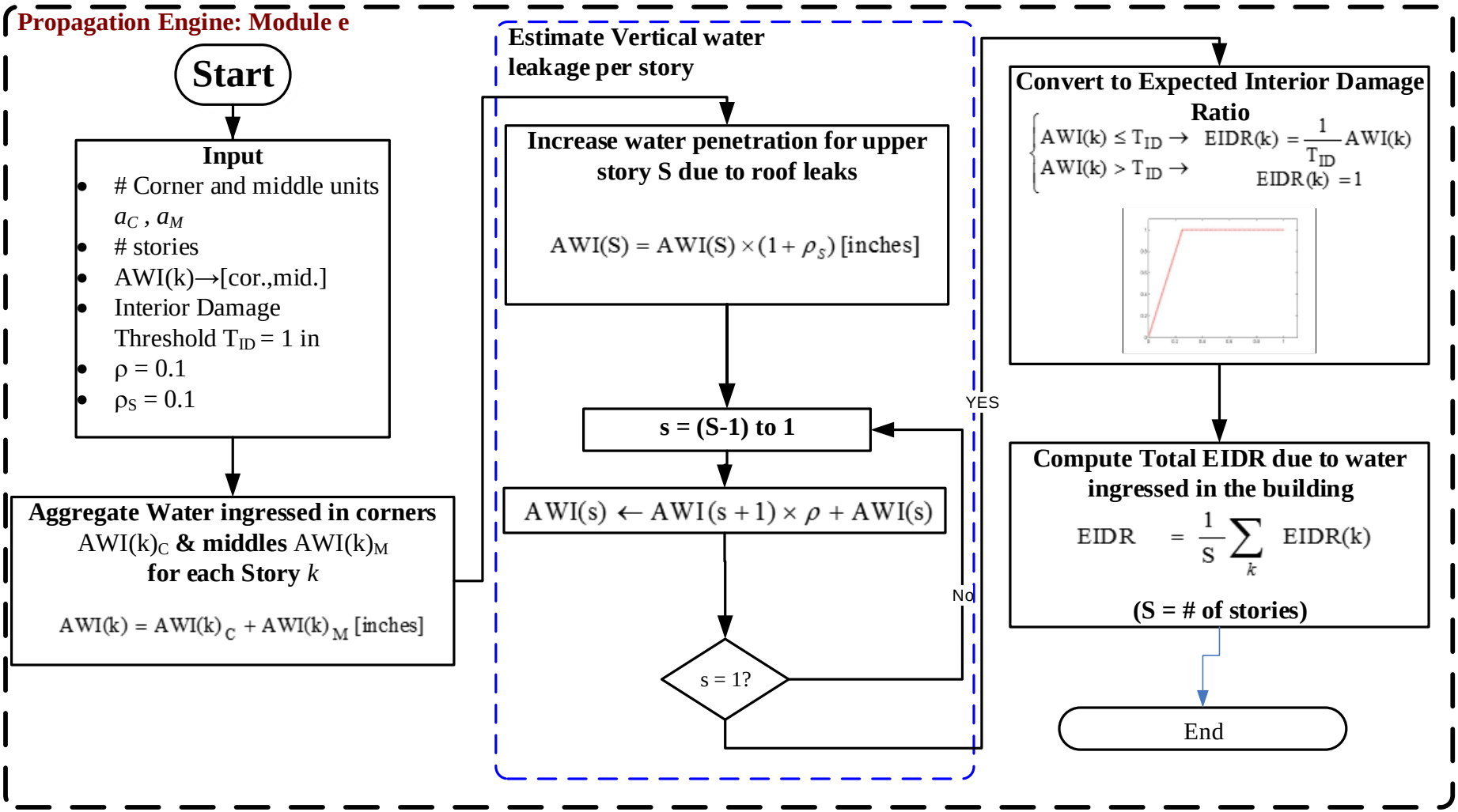
beta = -6.533E-06*$W_o(s=3)^3$ + 1.863E-03*$W_o(s=3)^2$ – 1.706E-02*$W_o(s=3)$

IF $W_o(s=3)$ > 183 mph
alpha = 22.3 inch
beta = 19.23 inch

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

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

End


Propagation Engine: Module e
Start
Input
Corner and middle units a_C , a_M
stories
AWI(k)→[cor.,mid.]
Interior Damage Threshold T_{ID} = 1 in
ρ = 0.1
ρ_S = 0.1
Aggregate Water ingressed in corners AWI(k)C & middles AWI(k)M for each Story k
$AWI(k) = AWI(k)_C + AWI(k)_M$ [inches]
Estimate Vertical water leakage per story
Increase water penetration for upper story S due to roof leaks
$AWI(S) = AWI(S) \times (1 + \rho_S)$ [inches]
s = (S-1) to 1
$AWI(s) \leftarrow AWI(s+1) \times \rho + AWI(s)$
s = 1?
YES
No
Convert to Expected Interior Damage Ratio
$AWI(k) \le T_{ID} \rightarrow EIDR(k) = \frac{1}{T_{ID}} AWI(k)$
$AWI(k) > T_{ID} \rightarrow EIDR(k) = 1$
Compute Total EIDR due to water ingressed in the building
$EIDR = \frac{1}{S} \sum_k EIDR(k)$
(S = # of stories)
End

Glossary

a_C : # of corner units per story

a_M : # of middle units per story

a,b,c,d: linear regression coefficients of impinging rainfall as a function of 3 sec gust at 10m

APV : Appurtenant Value [$]

AWI : Average water ingressed [inches of rain]

A_W, A_D, A_S: Size of individual windows, doors, sliders. (sqf)

α_{MR} : Contents coeff. as proportion of Interior Dam. (Mid-Rise)

α_{LR}, β_{LR}: Contents and time element coverage coeff. as proportion of Interior Dam. (Low-Rise)

β_{MR} : ALE coeff. as proportion of Interior Dam. (Mid-Rise condo unit policy)

bs: Average breach area

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)

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)

BaseArea: total area of story in sqft

Breaches: breaching square footage per story

$Breach_T^C$: total breach size of corner units. (includes defects)

$Breach_T^M$: total breach size of middle units. (includes defects)

BV : Bldg. Value [$]

BV_{AB} : Apt. Bldg. Value [$]

BV_{CB} : Condo Bldg. Value [$]

C_i : unit replacement cost for openings i=W,S, or D (windows-sliders-doors)

CCT : Closed Corridor Type

CV : Contents Value [$]

CDO(s): cost of damage to the openings at story s [$]

D : Deductible

D^{AP} : Appurtenant deductible

D^B : Building deductible

D^C : Contents deductible

DefectsAll: area of all the defects for a given unit

d_W, d_D, d_S: defects area for windows, door and slider (sqf)

EEDR : Expected Exterior Damage Ratio [%]

EDR_S : Exterior Damage Ratio vector per Story [%]

$EDR_j^{B,C,T}$: Expected Dam. Ratio Bldg, Contents, Time resp.

EDV_j^B : Expected Damage Value of Risk j – Building [$]

EDV_j^C : Expected Damage Value of Risk j – Contents [$]

EDV_j^{AP} : Expected Damage Value of Risk j – Appurtenant [$]

EDV^B : Overall Expected Damage Value – Building [$]

EDV^C : Overall Expected Damage Value – Contents [$]

EDV^T : Overall Expected Damage Value – Time Element [$]

EDV^{AP} : Overall Expected Damage Value – Appurtenant [$]

EDV^T : Total Expected Damage Value [$]

EIDR(s) : Expected Interior Damage Ratio per story s [%]

$EDV_j^B(s)$: Expected Story Damage Value of Risk j –Building [$]

$EDV_j^C(s)$: 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 [%]

f_{sim}: Simultaneity factor that accounts for the walls that actually have rain intrusion due to wind angle.

f_{run}: Runoff factor that accounts for the runoff water on the facades

i : Policy Counter / Other counter

IDR(k) : Interior Damage Ratio vector [%]

IDR_C^U : Interior Damage Ratio of a corner unit [%]

IDR_M^U : Interior Damage Ratio of a middle unit [%]

IDR_{VERT} : Interior Damage Ratio due to vert. propagation [%]

IDR_U : Interior Damage Ratio [%]

IR : Impinging rain on bldg façade [in/hr]

IRW: Impact Resistant Window

j : Risk counter

k: story index

k_E^{AB}, k_E^{CB} : Ratio of Exterior Value to total Value for Apt bldgs and Condo Bldgs.

k_I^{AB}, k_I^{CB} : Ratio of Interior Value to total Value for Apt bldgs and Condo Bldgs.

LIF : average Local intensity factor

LM_B : Building policy limit.

LM_C : Contents policy limit.

LM_T : Time element coverage policy limit.

LM_{AP} : Appurtenant policy limit.

OCT : Open Corridor Type

r(story,i) : impinging accumulated rainfall [in] per story for i = 1 time $t_{initial}$ to t_{breach} ; i=2 t_{breach} to t_{end}

ρ = percolation factor

ρ_S = roof leak factor

s = story number

S = total number of stories

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.

T_{ID}= threshold water (inches) to complete interior damage.

TECDO: Total expected cost of external damage to openings [$]

TV [$]: Time element coverage value

U_S : Units per Story

UBV = Condo unit value (structure)

UCV = Condo unit value (contents)

UALE = Condo unit value (additional living expenses)

UW: Unprotected Window

V_{CONT}: Vuln. Curve Contents

V_{TIME}: Vuln. Curve Time Element Coverage

V_i^C : Vulnerability curve for openings of corner units; i= W,D,or S (window, door, or slider). Give the number or fraction of opening damaged as a function of wind speed.

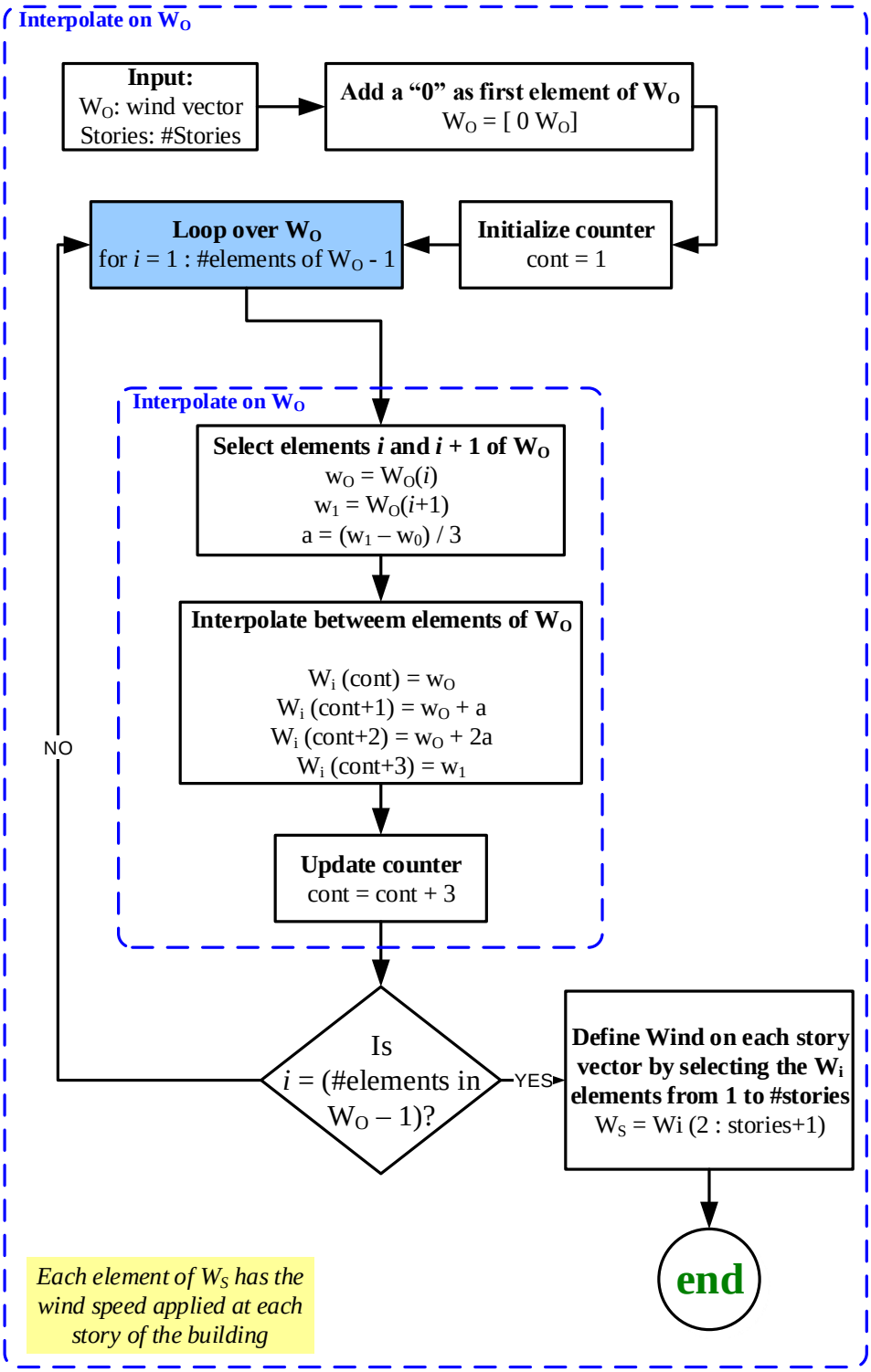
V_i^M : Vulnerability curve for openings of middle units; i= W,D,or S (window, door, or slider).

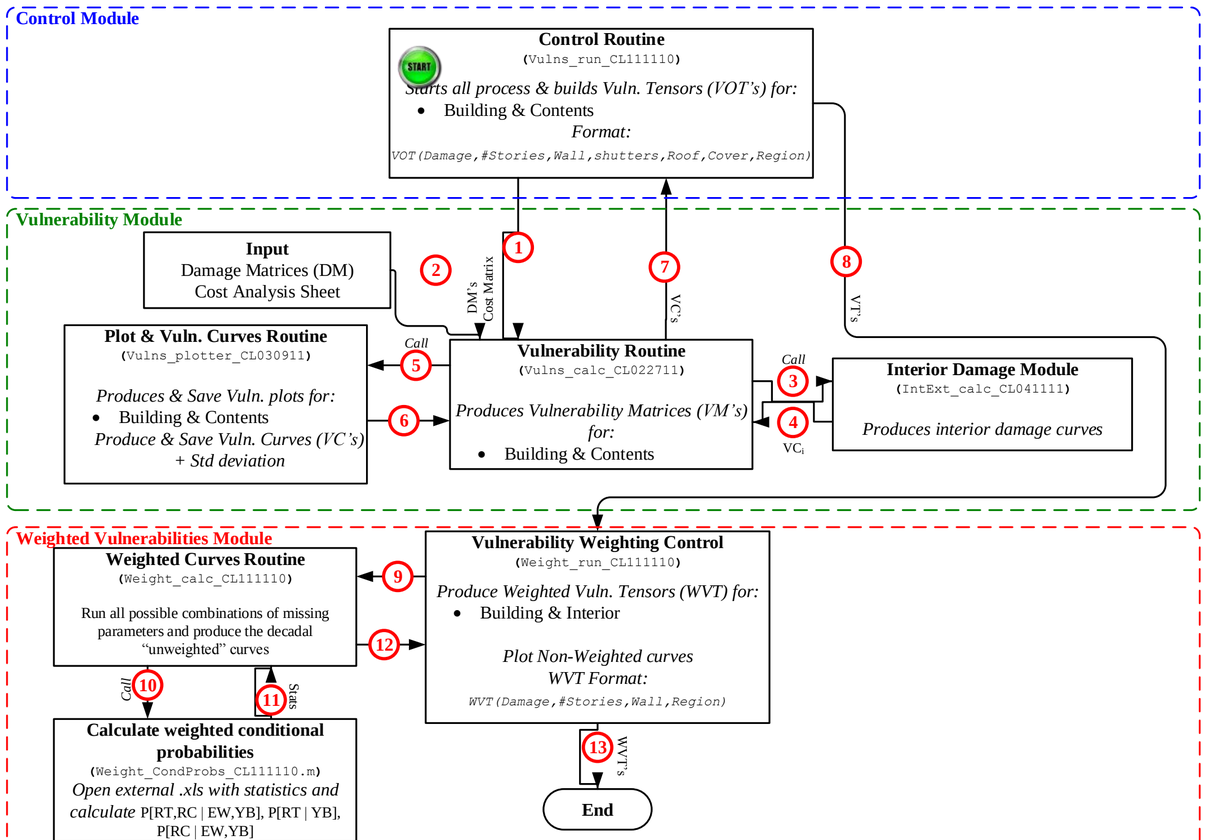
V_I : Adopted Unit's Interior Vulnerability Curve

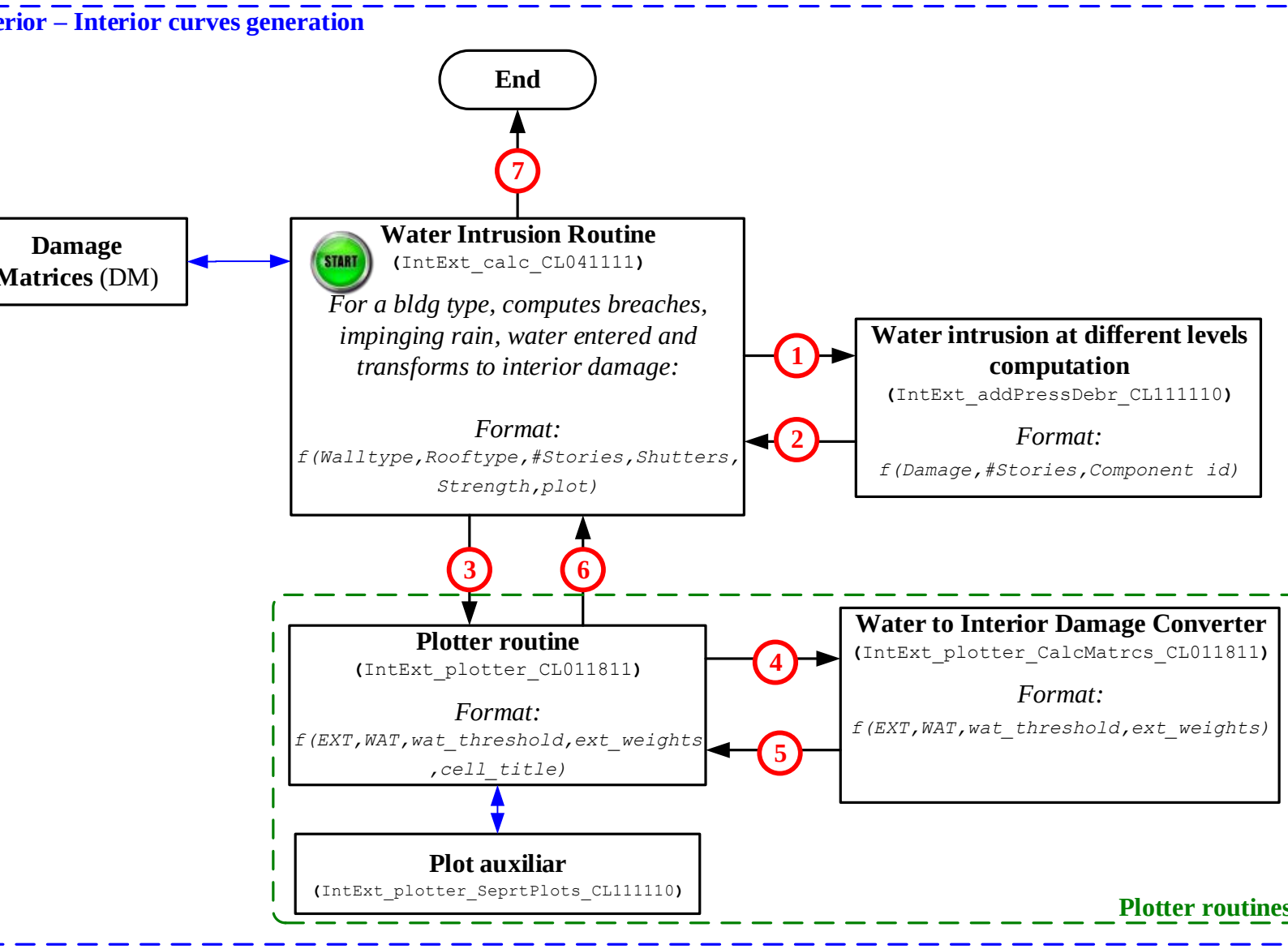
V_{INT}: Vuln. Curve Interior

$W_O(s)$: Wind speed profile per story s

z_s = mean height of story s. For s=3, z_s is assumed to be 10 m.


Interpolate on W_O
Input:
W_O: wind vector
Stories: #Stories
Add a "0" as first element of W_O
W_O = [0 W_O]
Initialize counter
cont = 1
Loop over W_O
for i = 1 : #elements of W_O - 1
Interpolate on W_O
Select elements i and i + 1 of W_O
$w_O = W_O(i)$
$w_1 = W_O(i+1)$
$a = (w_1 - w_0) / 3$
Interpolate betweem elements of W_O
W_i (cont) = w_O
W_i (cont+1) = w_O + a
W_i (cont+2) = w_O + 2a
W_i (cont+3) = w_1
Update counter
cont = cont + 3
Is
i = (#elements in W_O − 1)?
NO
YES
Define Wind on each story vector by selecting the W_i elements from 1 to #stories
W_S = Wi (2 : stories+1)
end
Each element of W_S has the wind speed applied at each story of the building


Control Module
Control Routine
(Vulns_run_CL111110)
Starts all process & builds Vuln. Tensors (VOT's) for:
Building & Contents
Format:
VOT(Damage,#Stories,Wall,shutters,Roof,Cover,Region)
Vulnerability Module
Input
Damage Matrices (DM)
Cost Analysis Sheet
1
2
DM's Cost Matrix
7
VC's
8
VT's
Plot & Vuln. Curves Routine
(Vulns_plotter_CL030911)
Produces & Save Vuln. plots for:
Building & Contents
Produce & Save Vuln. Curves (VC's) + Std deviation
Call
5
6
Vulnerability Routine
(Vulns_calc_CL022711)
Produces Vulnerability Matrices (VM's) for:
Building & Contents
Call
3
4
VCi
Interior Damage Module
(IntExt_calc_CL041111)
Produces interior damage curves
Weighted Vulnerabilities Module
Weighted Curves Routine
(Weight_calc_CL111110)
Run all possible combinations of missing parameters and produce the decadal "unweighted" curves
9
12
Vulnerability Weighting Control
(Weight_run_CL111110)
Produce Weighted Vuln. Tensors (WVT) for:
Building & Interior
Plot Non-Weighted curves
WVT Format:
WVT(Damage,#Stories,Wall,Region)
Call
10
11
Stats
Calculate weighted conditional probabilities
(Weight_CondProbs_CL111110.m)
Open external .xls with statistics and calculate P[RT,RC | EW,YB], P[RT | YB], P[RC | EW,YB]
13
WVT's
End


erior – Interior curves generation
End
7
Damage Matrices (DM)
Water Intrusion Routine
(IntExt_calc_CL041111)
START
For a bldg type, computes breaches, impinging rain, water entered and transforms to interior damage:
Format:
f(Walltype,Rooftype,#Stories,Shutters, Strength,plot)
1
2
Water intrusion at different levels computation
(IntExt_addPressDebr_CL111110)
Format:
f(Damage,#Stories,Component id)
3
6
Plotter routine
(IntExt_plotter_CL011811)
Format:
f(EXT,WAT,wat_threshold,ext_weights ,cell_title)
4
5
Water to Interior Damage Converter
(IntExt_plotter_CalcMatrcs_CL011811)
Format:
f(EXT,WAT,wat_threshold,ext_weights)
Plot auxiliar
(IntExt_plotter_SeprtPlots_CL111110)
Plotter routines