Freeboard Life-cycle Benefit-cost Analysis of a Rental Single- family Residence

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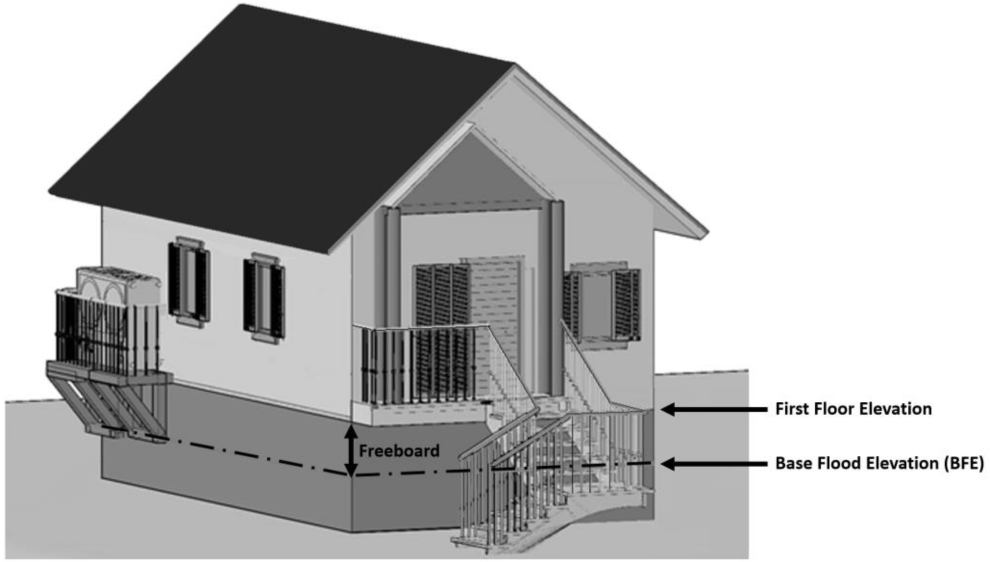
Freeboard

An additional amount of height above the Base Flood Elevation (BFE) to determine the elevation of the lowest floor. (Freeboard | FEMA.gov)



https://www.mass.gov/service-details/using-freeboard-to-elevate-structures-above-predicted-floodwaters

Life-cycle BCA for landlord, tenant, and insurer

Background:

- Single-family home rental represents an increasing share of the housing industry in U.S. (Charles, 2020)

- 14.9 million renter-occupied single-family homes as of 2017 (Rosen, 2018)

- FEMA has acknowledged that flood policies neglect rental housing and focus only on owner-occupied housing (Hamideh et al., 2018)

Purpose

- Provide a methodology to evaluate the benefit of freeboard through a micro-scale life-cycle BCA for landlord, tenant, and insurer

By: Getty Images

Methodology

Flood losses are divided into two categories

- Direct physical loss: The expected loss to building and contents
- Loss of function: The loss that is incurred when the building is damaged by flood (FEMA, 2019). It consists of
  - Loss of rental income
  - Displacement cost
  - Moving cost
- **Landlord losses**
  - Building loss
  - Loss of rental income
- **Tenant losses**
  - Content loss
  - Displacement cost
  - Moving cost

The methodology consists of the following steps

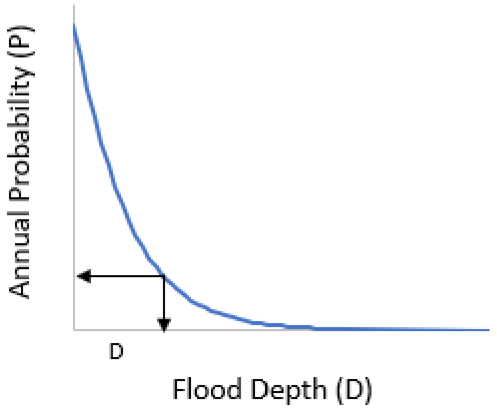
- Determine the annualized costs for each freeboard versus at BFE costs for landlord and tenant
- Conducting the life-cycle BCA

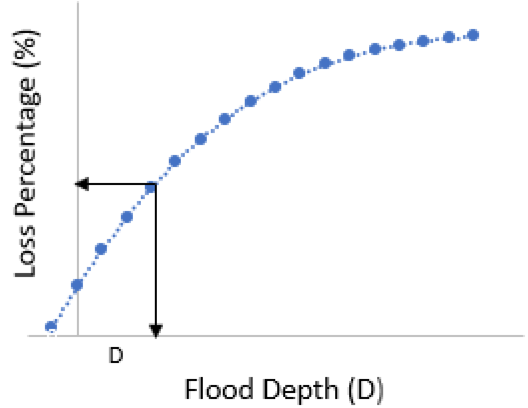
Landlord Loss

Landlord annual loss L_l is the sum of building AAL_B, freeboard cost F_c, building annual flood insurance premium P_B, and annual rental loss R_l, or

$$L_l = AAL_B + F_c + P_B + R_l$$

- Building annual flood insurance premium P_B calculated based on NFIP manual





Building AAL

$AAL_{B\%}$ is the summation of all building losses divided by total Monte Carlo simulations *N*, or

$$\mathrm{AAL}_{\mathrm{B\%}} = \frac{1}{N}\sum_{i=1}^{N} F^{-1}[Rand(i)]L_b(E_i)$$

where *i* is the simulated event between *N* simulations, $Rand(i)$ is a random probability, $F^{-1}[(i)]$ is Gumbel's inverse CDF, and $L(E_i)$ is the loss function corresponding to elevation (E_i)

To calculate AAL_B in absolute currency, $AAL_{B\$}$ is the product of $\mathrm{AAL}_{\mathrm{B\%}}$ and building value (BV), or

$$AAL_{B\$} = \mathrm{AAL}_{\mathrm{B\%}} \cdot BV$$

Landlord Loss (continued)

Upfront Freeboard Cost

Upfront cost $F_{i_{C_U}}$ is the freeboard percentage increase in cost $F_{i_{PI}}$ (FEMA, 2008) multiplied by building value at BFE (BV_{BFE}), or

$$F_{i_{C_U}} = F_{i_{PI}} \times BV_{BFE}$$

Freeboard (ft)	A-Zone	Coastal A-Zone	V-Zone
BFE + 1	2.3	3.9	1.8
BFE + 2	4.5	4.8	3.6
BFE + 3	6.8	6.1	5.4
BFE + 4	9.1	8.1	7.2

Loan Freeboard Cost

Standard amortization formula is used to calculate the freeboard's monthly/annual amounts $F_{i_{C_{AM}}}$, such that

$$F_{i_{C_{AM}}} = \frac{F_{i_{C_U}}\left(\frac{r}{n}\right)}{1 - \left(1 + \frac{r}{n}\right)^{-nt}}$$

where r is the interest rate, n is the number of payments per year, and t is the loan term

Landlord Loss (continued)

Loss of Rental Income

- Rental loss is a time-based loss, where loss is dependent on the restoration time (S_t). The restoration time is based on FEMA (2013) depth-restoration time function

Depth (ft)	Physical Restoration (Months)	Clean-up (Months)	Inspection Permits Approval (Months)	Contractor Availability (Months)	Total Restoration Time (Months)
0	3	1	2	3	9
4	6	1	2	3	12
8	9	1	2	3	15
8+	18	1	2	3	24

*Although restoration time is evaluated in 4 ft. depths, these data are interpolated to estimate restoration time at any point within the data interval

- Rental cost-per-square-foot per month R_m is multiplied by the building's square footage B_q to estimate the monthly rental loss, which is applied to the restoration time to estimate the rental loss R_{l_i}
- The average of the resulting rental loss of all simulated flooding events is the rental loss R_l, such that

$$R_l = \frac{1}{N}\sum_{i=1}^{N}(S_{t_i}) \cdot (R_m \cdot B_q)$$

where *i* is the simulated event of *N* simulations

Tenant Loss

Tenant annual loss T_l is the sum of content AAL_C, content flood insurance premium (P_C), displacement cost (D_c), and moving cost (M_c), or

$$T_l = AAL_C + P_C + D_c + M_c$$

- Only losses above FFE are considered for the tenant
- Content AAL_C calculated similarly like building AAL_B
- Content insurance premium (P_C) calculated based on NFIP manual

Displacement Cost

- Displacement cost of $140 per day rate for lodging (U.S. General Service Administration, 2021)
- Displacement cost per day (D_{d_i}) is converted to a monthly one-time displacement cost. The average of all simulated events is the displacement cost (D_c), such that

$$D_c = \frac{1}{N}\sum_{i=1}^{N}(D_{d_i} \cdot 30)$$

Tenant Loss (continued)

- **Moving Cost**
  - Moving cost is estimated based on the residence square footage, which indicates the size of the household items
  - Moving cost of $1.20 per-square-foot is used (Arkin, 2021)
  - Moving cost-per-square-foot (M_{cq_i}) is multiplied by the building's square footage (B_q) to estimate the moving cost for the event. The average of all simulated events is the moving cost (M_c), or

$$M_c = \frac{1}{N}\sum_{i=1}^{N}(M_{cq_i} \cdot B_q)$$

Life-cycle BCA (Landlord)

Landlord Loss PV

Discounted present value cost C_{DPV} returns annualized costs C_t over a time horizon *t* using the discount rate *RD*, or

$$C_{DPV} = \sum_{t=1}^{t} \frac{C_t}{(1+R_D)^t}$$

BFE PV

The PV at BFE (BFE_{PV}) is the sum of life-cycle cumulative of the building premium P_{DPV}, building AAL_{DPV_B}, and annual rental loss R_{DPV} such that

$$BFE_{PV} = \left(\sum_{t=1}^{t} P_{DPV}\right)_{BFE} + \left(\sum_{t=1}^{t} AAL_{DPV_B}\right)_{BFE} + \left(\sum_{t=1}^{t} R_{DPV}\right)_{BFE}$$

Freeboard PV

The PV of freeboard (F_{PV}) is the sum of life-cycle cumulative of the building premium P_{DPV}, loan annual payment *DPV* $F_{C_{Y_{DPV}}}$, building AAL_{DPV_B}, and annual rental loss R_{DPV} such that

$$F_{PV} = \left(\sum_{t=1}^{t} P_{DPV}\right)_{\mathrm{F}} + \left(\sum_{t=1}^{t} F_{C_{Y_{DPV}}}\right)_{F} + \left(\sum_{t=1}^{t} AAL_{DPV_B}\right)_{\mathrm{F}} + \left(\sum_{t=1}^{t} R_{DPV}\right)_{\mathrm{F}}$$

Life-cycle BCA (Tenant)

Tenant Loss PV

Discounted present value cost C_{DPV} returns annualized costs C_t over a time horizon *t* using the discount rate *RD*, or

$$C_{DPV} = \sum_{t=1}^{t} \frac{C_t}{(1+R_D)^t}$$

BFE PV

The PV at BFE BFE_{PV} is the sum of life-cycle cumulative of the content premium P_{DPV}, content AAL_{DPV_C}, displacement cost D_{DPV}, and moving cost M_{DPV} such that

$$BFE_{PV} = \left(\sum_{t=1}^{t} P_{DPV}\right)_{BFE} + \left(\sum_{t=1}^{t} AAL_{DPV_C}\right)_{BFE} + \left(\sum_{t=1}^{t} D_{DPV}\right)_{BFE} + \left(\sum_{t=1}^{t} M_{DPV}\right)_{BFE}$$

Freeboard PV

The PV of freeboard F_{PV} is the sum of life-cycle cumulative of the content premium P_{DPV}, content AAL_{DPV_C}, displacement cost D_{DPV}, and moving cost M_{DPV} such that

$$F_{PV} = \left(\sum_{t=1}^{t} P_{DPV}\right)_{\mathrm{F}} + \left(\sum_{t=1}^{t} AAL_{DPV_C}\right)_{\mathrm{F}} + \left(\sum_{t=1}^{t} D_{DPV}\right)_{\mathrm{F}} + \left(\sum_{t=1}^{t} M_{DPV}\right)_{\mathrm{F}}$$

Life-cycle BCA

Net Benefit (NB)

Freeboard NB_{F_i} is determined by subtracting the accumulated costs (at the PV) for the freeboard scenario $F_{i_{PV}}$ from at BFE scenario BFE_{PV}

$$NB_{F_i} = BFE_{PV} - F_{i_{PV}}$$

where i is the numerator for different freeboard increments

Net Benefit-Cost Ratio (NBCR)

NB_{F_i} is divided by the cost of the freeboard F_{i_C} to obtain $NBCR_{F_i}$ for adding the freeboard, or

$$NBCR_{F_i} = \frac{BFE_{PV} - F_{i_{PV}}}{F_{i_C}}$$

Case Study

- One-story, single-family home located in zone AE –4 ft in Metairie, Louisiana
- 2,500 ft^2 of living area and construction cost of $231,175
- Ground elevation is –7.0 ft (NAVD88), obtained from digital elevation model (DEM)
- Flood depth are obtained using Risk Mapping, Assessment and Planning (RiskMAP) data

Annual exceedance Probability	Flood Elevation (ft)	Flood Depth (ft)
0.002	–3.4	3.6
0.01	–3.9	3.1
0.02	–4.2	2.8
0.1	–4.7	2.3

Results (Landlord Costs)

The landlord's expected annual costs for the range of freeboard increments

Freeboard (ft.)	Freeboard Cost (Loan/Annual)	Building Annual Premium	Building AAL	Landlord Building AAL	NFIP Building AAL	Annual Rental Loss
0.0	$0	$1,616	$3,383	$298	$3,085	$328
0.5	$151	$1,616	$738	$66	$672	$64
1.0	$302	$822	$154	$15	$139	$0
1.5	$446	$822	$24	$0	$24	$0
2.0	$591	$503	$0	$0	$0	$0
2.5	$741	$503	$0	$0	$0	$0
3.0	$892	$391	$0	$0	$0	$0
3.5	$1,043	$391	$0	$0	$0	$0
4.0	$1,194	$361	$0	$0	$0	$0

- Adding only one-foot of freeboard decreases the annual losses from $5,327 for BFE to $1,278, yielding an annual avoided loss of $4,049
- Beyond 2 ft., landlord annual losses depend only on the freeboard cost and building premium

Results (Tenant Costs)

The tenant's expected annual costs for each freeboard increment

Freeboard (ft.)	Content Annual Premium	Content AAL	Tenant Content AAL	NFIP Content AAL	Annual Displacement Cost	Annual Moving Cost
0.0	$346	$258	$15	$243	$49	$35
0.5	$346	$48	$0	$48	$10	$0
1.0	$240	$0	$0	$0	$0	$0
1.5	$240	$0	$0	$0	$0	$0
2.0	$208	$0	$0	$0	$0	$0
2.5	$208	$0	$0	$0	$0	$0
3.0	$208	$0	$0	$0	$0	$0
3.5	$208	$0	$0	$0	$0	$0
4.0	$208	$0	$0	$0	$0	$0

- Tenant losses are relatively small and are eliminated in the first one foot of freeboard. This is because tenant losses consider only for depths above the FFE

Results - Life-cycle BCA

BCA results are presented as NB and NBCR for each freeboard scenario using both real discount rates

Freeboard (ft.)		Tenant		Landlord		NFIP		Total	
		3%	7%	3%	7%	3%	7%	3%	7%
0.5	NB	$1,544	$978	$6,773	$4,288	$51,183	$32,404	$59,500	$37,670
	NBCR	0.5	0.5	2.3	2.3	17.3	17.3	20.1	20.1
1.0	NB	$3,983	$2,522	$21,567	$13,654	$62,461	$39,544	$88,012	$55,720
	NBCR	0.7	0.7	3.6	3.6	10.6	10.6	23.5	14.9
1.5	NB	$4,003	$2,534	$19,031	$12,049	$64,825	$41,041	$87,859	$55,624
	NBCR	0.5	0.5	2.2	2.2	7.4	7.4	15.9	10.0
2.0	NB	$4,630	$2,931	$22,508	$14,250	$65,231	$41,298	$92,369	$58,479
	NBCR	0.4	0.4	1.9	1.9	5.6	5.6	12.6	8.0
2.5	NB	$4,630	$2,931	$19,553	$12,379	$65,245	$41,306	$89,427	$56,616
	NBCR	0.3	0.3	1.3	1.3	4.5	4.5	9.7	6.2
3.0	NB	$4,630	$2,931	$18,790	$11,896	$65,245	$41,306	$88,665	$56,133
	NBCR	0.3	0.3	1.1	1.1	3.7	3.7	8.0	5.1
3.5	NB	$4,630	$2,931	$15,832	$10,023	$65,245	$41,306	$85,707	$54,260
	NBCR	0.2	0.2	0.8	0.8	3.2	3.2	6.6	4.2
4.0	NB	$4,630	$2,931	$13,462	$8,523	$65,245	$41,306	$83,337	$52,760
	NBCR	0.2	0.2	0.6	0.6	2.8	2.8	5.6	3.6

Results - Life-cycle BCA - continued

- All freeboard scenarios outperform the BFE scenario
- The optimal freeboard is 2 ft. where life-cycle NB is at its highest value at $58,479, assuming a 7% discount rate, and $92,369 in NB, using a discount rate of 3%
- Elevating the home to the optimal height of 2 ft. results in a landlord life-cycle NB of $14,250 using a 7% discount rate, and $22,508 assuming a discount rate of 3%
- At 2-ft. of freeboard, tenant’s life-cycle NB is $2,931, assuming a 7% discount rate and $4,630 using a 3% discount rate
- For a 2-ft. freeboard, the total NFIP NB is $41,298, assuming a 7% discount rate, and $65,231, using a 3% discount rate

Results - Life-cycle BCA (Premiums)

Premiums BCA results for each freeboard scenario using both real discount rates

Freeboard (ft.)		7%	3%
0.5	NB	$0	$0
	NBCR	0	0
1.0	NB	$11,168	$17,640
	NBCR	3.0	3.0
1.5	NB	$11,168	$17,640
	NBCR	2.0	2.0
2.0	NB	$15,524	$24,520
	NBCR	2.1	2.1
2.5	NB	$15,524	$24,520
	NBCR	1.7	1.7
3.0	NB	$16,914	$26,715
	NBCR	1.5	1.5
3.5	NB	$16,914	$26,715
	NBCR	1.3	1.3
4.0	NB	$17,286	$27,303
	NBCR	1.2	1.2

- The optimal freeboard is 2 ft. where life-cycle NB is at its highest value at $15,524, assuming a 7% discount rate, and $24,520 in NB, using a discount rate of 3%

Conclusions and Contributions

- The results show that elevating the rental home to the optimal height of 2 ft. eliminates annual building and rental losses for landlord, and similarly, eliminates tenant’s annual content, displacement, and moving losses
- At 2-ft. of freeboard, the total life-cycle NB is $58,479 with 8:1 NBCR, assuming the discount rate of 7%, and life-cycle NB of $92,369 with 12:1 NBCR, using the discount rate of 3%
- The landlord will experience other benefits, including higher demand, increased occupancy, and higher property value
- Tenants will experience unvalued such as preventing forced relocation, and avoiding stress
- Being informed of the full risk, the mitigation options, and the economic implications enhances investment and occupation decisions

Limitations

- Flood loss assessments rely on uncertain variables such as the unpredictable nature of flood and the generality of flood loss and restoration time functions
- These types of analyses are highly constrained by flood data quality and availability
- Life-cycle BCA requires future projections of highly uncertain discount rates
- Risk Rating 2.0 insurance premium is not used

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Question (?)