MEASURING SUSTAINABLE RESILIENCE IN PROPERTY MAINTENANCE

CIB Conference 2014, Copenhagen

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Motivation

- *There is increased interest in improving the resilience of current building stock to extreme weather events*
- *There is also a strong interest in the design of sustainable buildings, as well as refurbishment of current building stock, to reduce carbon footprint*

Outline

- *We investigate the concept of sustainable resilience*:
  - *Definitions of both resilience and sustainability*
  - *Definition of sustainable resilience*
  - *how to measure it*
  - *How to adapt the concept for property management*
- *We provide a simplified example to illustrate the method*

Why resilience is important for facilities management?

Even a well-managed building portfolio can be disturbed by extreme weather events, which increase emergent maintenance cost and may place the owner of the building in financial difficulty.

What do we know about resilience?

- Resilience defines the characteristics which are required for a building
- To be able to measure resilience we should know resilience of what to what?(Carpenter S. 2001)
- Resilience can be measured over a period of time (using current and future climate scenarios)
- Often quantified using risk

How has resilience of buildings to climate change been studied before?

Definition of Resilience

A building's resilience is a measure of how well a building continues to function during or after an event, and, if the function of the building has been affected, how fast the building can regain its function.

- What is the event?
- The magnitude of the event
- Duration of the event
- The function of the building affected
- The time to the regain the function
- The cost of the damage and lost of function

Definition of Sustainability

1. "development that meets the needs of the present without compromising the ability of future generations" by Brundtland Commission in 1987

2. "Sustainability is about the ability of our own human society to continue indefinitely within natural cycles of the earth" " by K. Baxter, A. B. (2010). *Sustainability Primer*

Why is sustainability (not) important for facilities management?

- Most of the maintenance and operation strategies in practice do **not** yet deal with climate change and the sustainability agenda, beyond simple energy savings
- To make a building more resilient **and sustainable** is **not** easy to express in monetary terms

What do we know about the sustainability?

- Holistic approach (Ecological, Economical, Social)
- It can be measured by
  - Different sustainability indicators
  - Environmental assessment tools
  - Sustainability index
- Sustainability can be measured
  - quantitative
  - qualitative

How to measure **sustainable resilience**?

Resilience

We view resilience as defining what characteristics are required for a building

Sustainability

We view sustainability as defining how these characteristics are provided

Measuring ***resilience*** – a simplified illustrative example

Investigating the vulnerability of a building to heat waves in Denmark

*Measuring **resilience*** - Example

6 steps approach

1. Determine the resilience of the building to high temperature
2. Determine the loss of the function of the building and the cost associated with it
3. Determine the probability of the event
4. Determine the expected cost associated with the current resilience
5. Determine the remedial solutions
6. Apply cost benefit analysis to select or not a solution

Measuring ***sustainable*** *resilience -* Example

- The 5 step is expanded:

  (a) Determine capital and operating costs, as before

  (b) Determine direct/indirect ecological costs, e.g. carbon tax, etc.

  (c) Determine intangible costs to say, reputation

- Add (a)-(c) to determine total cost, then go to Step 6

Step 4 – Determine cost of event
Annual cost of lost of productivity

	Current DRY	A1B 2050	A1B 2100	A2 2100	B2 2100	E2 2100
Above 25	0	0	0	0	0	0
Above 26	36,400	62,400	94,800	136,800	106,400	86,400
Above 28	20,400	51,600	140,400	157,200	116,400	94,800
Above 30	6,000	16,000	56,000	66,000	34,000	24,000
Above 32	0	0	14,000	19,600	8,400	5,600
Total annual cost in DKr	62,800	130,000	291,200	360,000	256,800	205,200

Hourly cost per senior employee	800
Hourly cost of support staf	400
number of senior employees	20
number of support staf	10

Above 25	0%
Above 26	2%
Above 28	6%
Above 30	10%
Above 32	14%

Step 4 - Risk = expected annual cost o lost of productivity

	Current DRY	A1B 2050	A1B 2100	A2 2100	B2 2100	E2 2100
ΔT C°	0	1.32	2.9	3.2	2.5	2
Probability	100	90%	25%	25%	25%	25%
Total annual cost in DKr	62,800	130,000	291,200	360,000	256,800	205,200
$R = \sum_{i=1}^{n} P_i * C_i$	62,800	123,280	278,300			

R_{2100} =0.25*291,200 + 0.25*360,000 + 0.25*256,800 +0.25*205,200 =278,300

Quantifying sustainable resilience

- How can we incorporate sustainability with risk?

Sustainability

- BREEAM, LEED or DGNB etc. do not explicitly consider cost
  - Point systems.
- However, client's choice is ultimately based on cost
- Risk analysis makes this explicit

The cost of (un)sustainability

- Why do companies choose sustainable solutions?
- Expected future costs, e.g.
  - Carbon tax
  - Carbon credits
- Reputational cost
- These can be included in a risk analysis

Step 4 - Annual cost of lost of productivity

	Current DRY	A1B 2050	A1B 2100	A2 2100	B2 2100	E2 2100
ΔT C°	0	1.32	2.9	3.2	2.5	2
Probability	100	90%	25%	25%	25%	25%
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$R = \sum_{i=1}^{n} P_i * C_i$	62,800	123,280	278,300			

R_{2100} =0.25*291,200 + 0.25*360,000 + 0.25*256,800 +0.25*205,200 =278,300

Step 4 - Annual cost of possible carbon tax

	Current	2050			2100		
Probability of carbon price	25%	25%	50%	25%	25%	50%	25%
Price of carbon per ton ($)	20	40	60	90	120	160	200
Price of carbon per ton Dkr.)	108	217	325	488	650	867	1084
Annual consumptio of CO2 t	7	13	13	13	24	24	24
Annual Carbon cost	759	2818	4228	6341	15610	20813	26016
annual cost of carbon prices	190	4,404			20,813		

Step 4 - Annual cost due to loss of reputation

Reputational loss	**Current**	**2050**	**2100**
Probability of reputational cost	30%	70%	90%
Annual cost of reputation in revenue	100,000	100,000	100,000
Price of carbon per ton Dkr.	30,000	70,000	90,000

- We assume that the business makes a profit of 1,000,000Dkr.
- The cost of loss of reputation we assume to be 10%.
- The annual cost due to reputational loss is 100,000Dkr.
- The probability of reputational loss is 30% in present, 70% in 2050 and 90% 2100

Step 4

- These three costs can then be added together to determine expected risk

$$\sum_{f=1}^{n} P_{fr} * C_{fr} + C_{c+o} + \left(\sum_{f=1}^{m} P_e * C_e + \sum_{f=1}^{l} P_i C_i \right)$$

- Expected risk =
  - Expected cost of lost productivity +
  - Expected cost of carbon tax +
  - Expected cost of reputational loss

Having calculated the expected cost of failure i.e. the risk, we now consider the cost of remedial solutions

Step 5 - Remedial solutions

We now consider two remediation options:

(i) installation of air-conditioning

(ii) a/c plus carbon-neutral onsite energy generation

Step 5

Cost of Option (i)

- Capital cost of a/c = 300,000 Dkr.
- Annual running cost of a/c = 6,480 Dkr.
- Expected annual cost of carbon tax = 190 Dkr.
- Expected annual cost due to loss of reputation = 30,000Dkr.

Cost of Option (ii)

- Capital cost of a/c = 300,000 Dkr. + Capital cost of electricity generation onsite = 30,000Dkr.
- Running cost of a/c = 0
- Carbon annual credit ?
- Expected reduction in cost due to loss of reputation= 30,000 - 30,000 = 0 Dkr.

How to measure sustainable resilience?

We suggest incorporating sustainability as a risk, where each remedial solution has a probability and cost of failure must be

$$\sum_{f=1}^{n} P_f * C_{fr} < \sum_{f=1}^{n} P_{fr} * C_{fr} + C_{c+o} + \left(\sum_{f=1}^{m} P_e * C_e + \sum_{f=1}^{l} P_i C_i\right)$$

- C_f - cost of failure under current conditions
- P_{fr} – probability of failure with the remedial solution
- C_{fr} - cost of failure with the remedial solution
- C_{c+o} – capital and operational cost of the remedial solution
- P_e – probability of introduction of carbon prices or environmental cost
- C_e - ecological cost of the solution
- P_i – probability of intangible cost
- C_i – intangible cost of the solution
- m – number of environmental cost we decide to include
- F- number of reputational cost we decide to include

Conclusion

- Resilience defines what is needed
- Sustainability defines how the need is provided
- Risk analysis and return on investment provide familiar frameworks with which to decided between solutions
- Sustainability can be incorporated into risk by explicitly representing intangible and future costs, e.g. reputational cost and possible future prices of carbon

Thank you for your attention