COST Action
TU 1402

Quantifying the Value of Structural Health Monitoring

Assessment of Risk Mitigation Strategies for Attacks on Bridges

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DTU

ERDA
Engineering Risk and Decision Analysis

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Introduction

Scientific Mission: Decision and Value of Information Analyses in Conjunction with Manmade Hazards

- Host: Prof. Mark Stewart, The University of Newcastle, Callaghan, NSW, Australia
- Dates: 27 / November / 2017 - 22 / December / 2017

1. Decision scenario

We analyse the value of risk mitigation measures for terrorist attacks with Improvised Explosive Devices (IEDs) for an iconic bridge structure.

- Decision maker: Public authority responsible for the societal safety of the infrastructure.
- Decision point in time: Design phase (protect), Operation (control)
- Life cycle phases: Design and 100 years of operation
- Performance: Terrorist attack with an improvised explosive device
- Objective: Minimisation of risks and expected costs

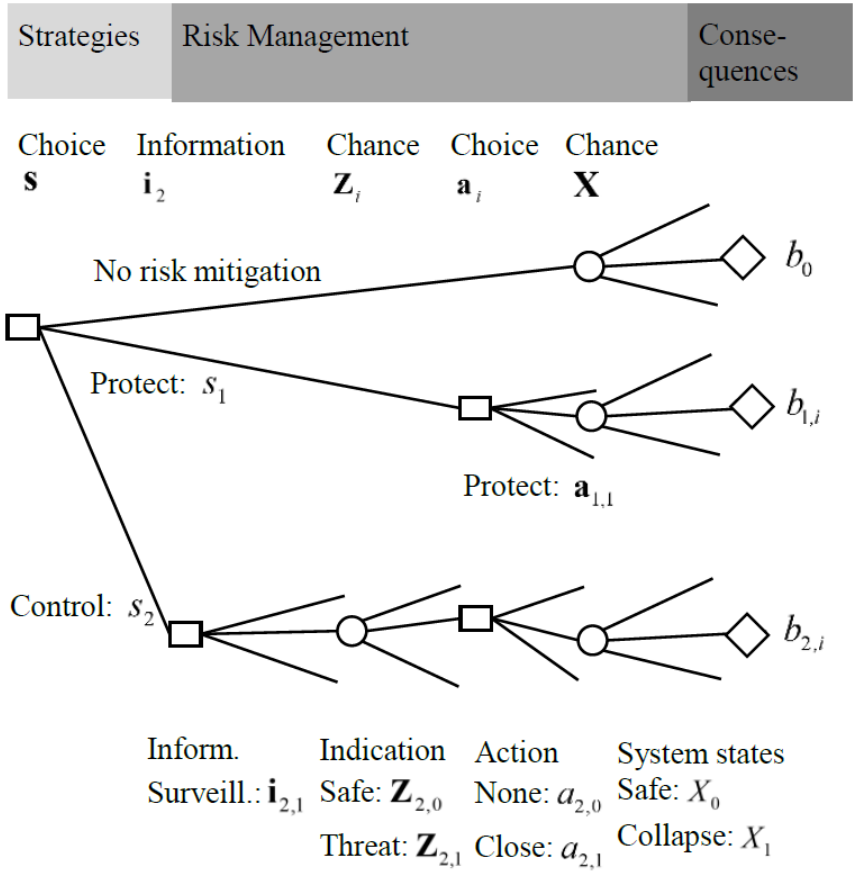
1. Decision scenario

We analyse the value of risk mitigation measures for terrorist attacks with Improvised Explosive Devices (IEDs) for an iconic bridge structure.

- Mitigation strategies are protection measures and control
- The probability of collapse is calculated with the hazard H and the threat T events

$$P(X_1) = P(X_1 \mid H) \cdot P(H \mid T) \cdot P(T)$$

- Direct and indirect (e.g. loss of lifes) consequences are considered

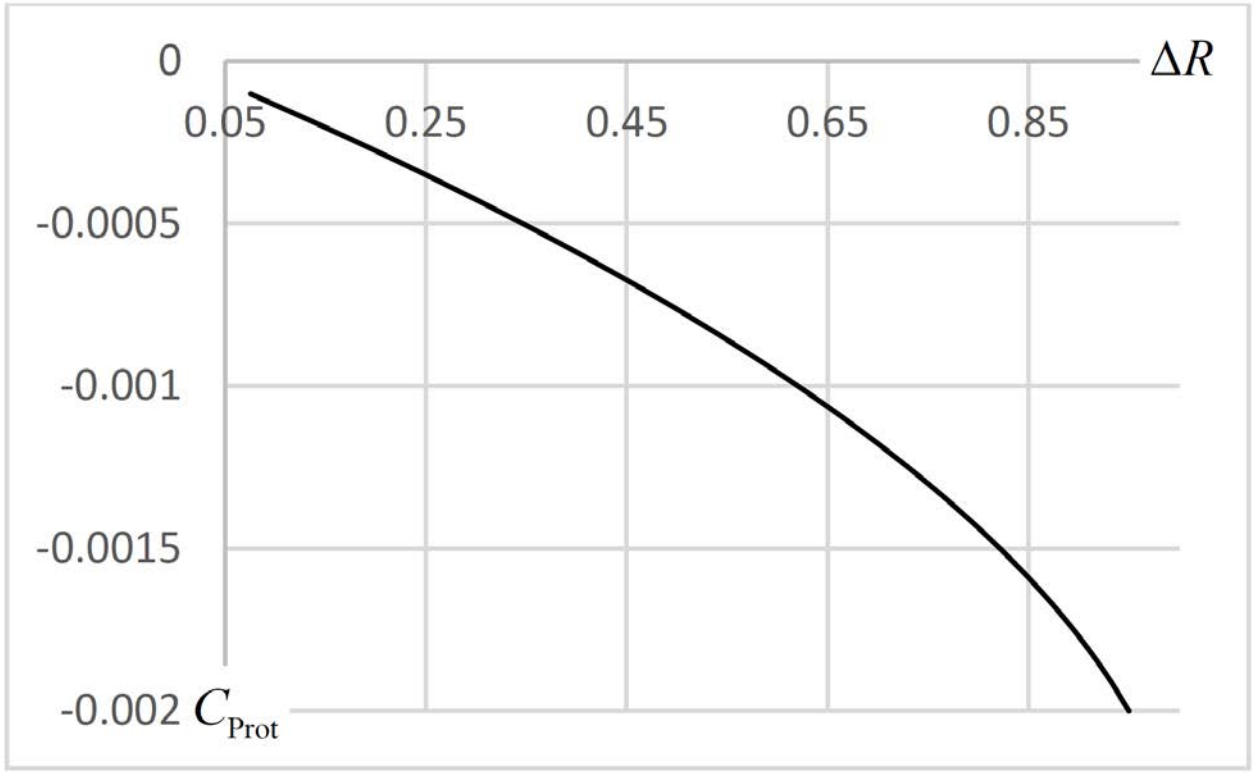


2. Models and methods: strategy “protect” in design phase

The protective measures are modelled with the annual costs and the risk reduction performance.

- 5.0% additional investment in a protective measure may lead to a risk reduction of 95%
- 3.3% investment may reduce the risk by 75%.
- The investment is annualized over 100 years with a discount rate of 4%.

2. Models and methods: strategy “protect” in design phase



2. Models and methods: strategy “protect” in design phase

Nodes, states		Consequences	Prob.
Protective actions	a_0	0	-
	$\mathbf{a}_{1,1}$	[-0.0001…-0.002]	$\Delta R(\mathbf{a}_{1,1}) = [0.075 \rightleftharpoons 0.95]$
System states	X_0	0	$1 - P(C)$
	X_1	U(-10.0,-5.0)	$P(C)$

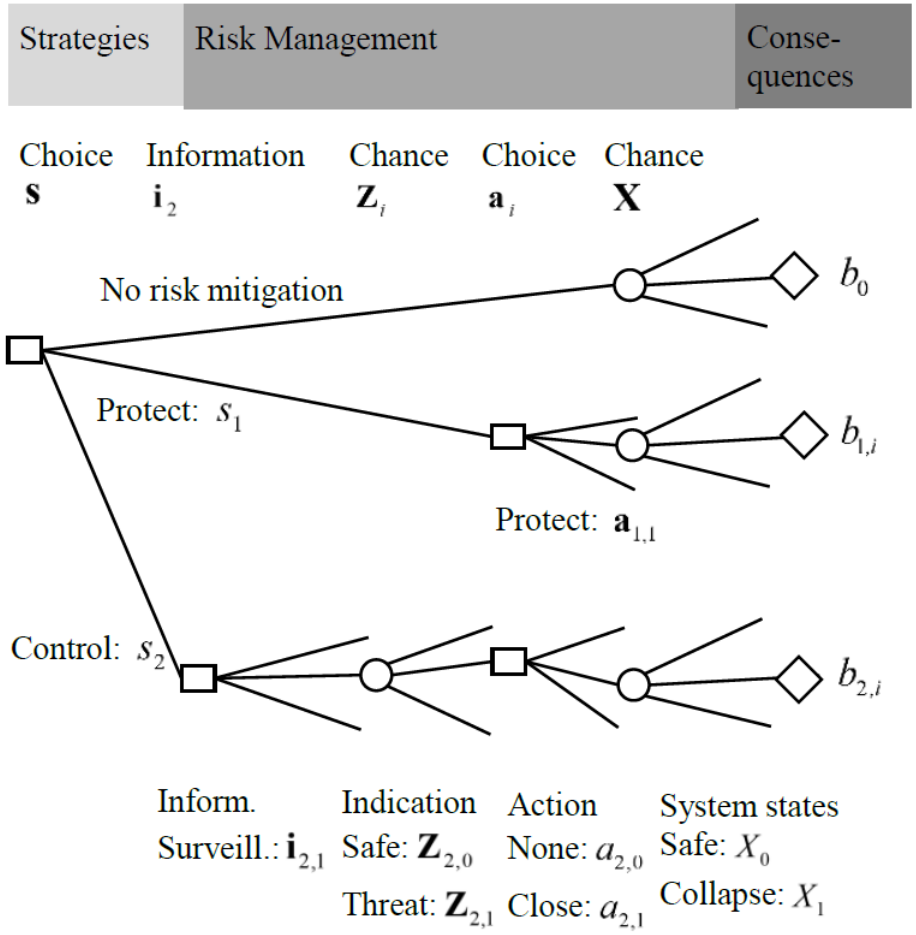
3. Results: Strategy “protect”

Depending on the threat probability, the optimal protect measures have been identified.

- Optimal for low considered threat probability: relatively low performing and low cost measures.
- Optimal for high considered threat probability: relatively high performing and higher cost measures.
- Co-benefits for protective measures may be found e.g. in a higher earthquake resistance.

$P(T)$	$\Delta R\left(a_{1,1}^{*}\right)$	$C_{\text{Prot}}\left(a_{1,1}^{*}\right)$
$1.7 \cdot 10^{-3}$	0.28	$1.49 \cdot 10^{-3}$
$2.0 \cdot 10^{-3}$	0.46	$1.66 \cdot 10^{-3}$
$3.0 \cdot 10^{-3}$	0.79	$1.97 \cdot 10^{-3}$

1. Decision scenario



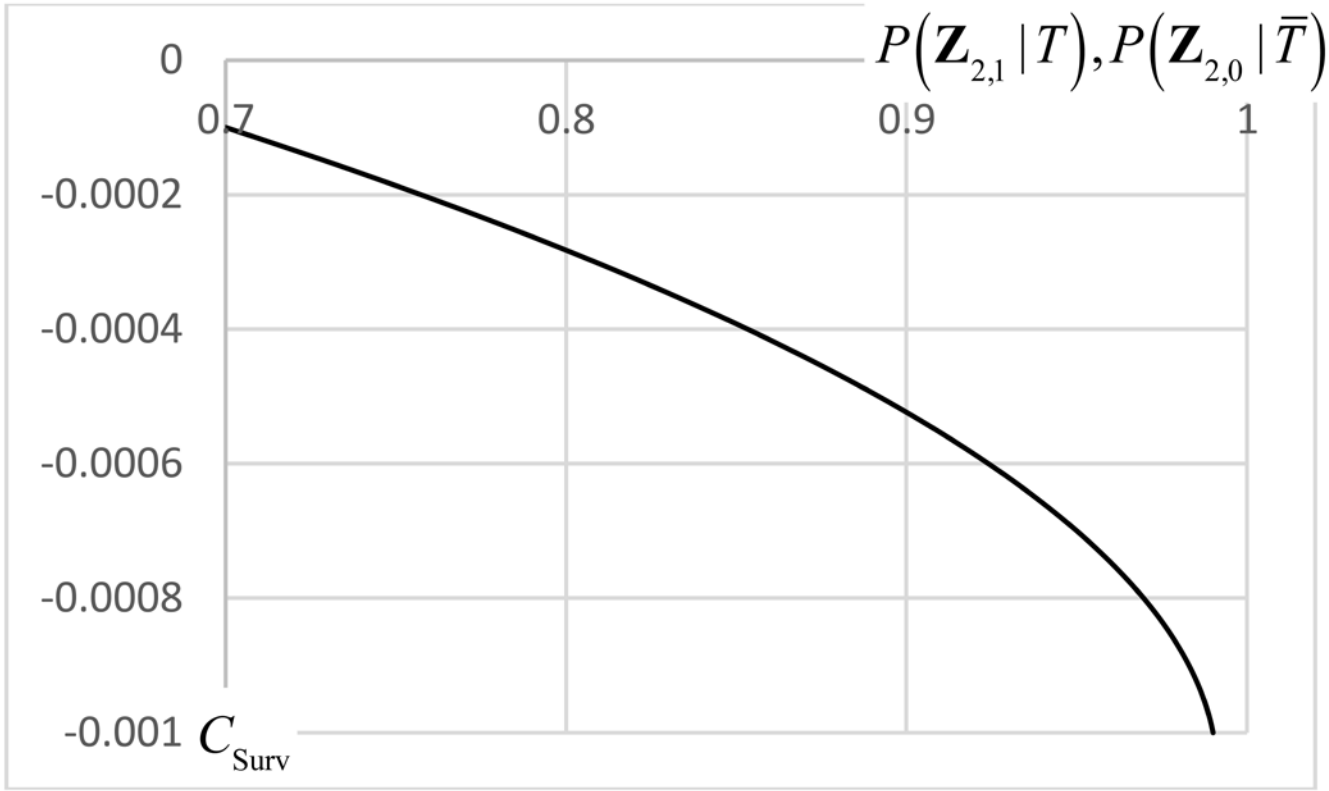
2. Models and methods: strategy “control” in operation

The strategy “control” is modelled with surveillance information in combination with bridge closure and detection actions.

Surveillance information described with detection performance and costs:

- Indication and no-indication probabilities of threats
- Costs of the surveillance system investment, operation and replacement every 10 years
- Bridge closure allows for detection actions; costs are accounted for (e.g. due to traffic diversion)
- The investment is annualized over 100 years with a discount rate of 4%.

2. Models and methods: strategy “control” in operation



2. Models and methods: strategy “control” in operation

States	Consequences	Prob.	
i_2	[-1.0E-4… -1.0E-3]	-	
		X_0	X_1
$\mathbf{Z}_{2,0}$	-	[0.7…0.99]	[0.3…0.01]
$\mathbf{Z}_{2,1}$	-	[0.3…0.01]	[0.7…0.99]
$a_{2,0}$	0	-	
$a_{2,1}$	2.72E-3	-	
X_0	0	$1-P''(C)$	
X_1	U(-10.0,-5.0)	$P''(C)$	
$X_1 \mid a_{2,1}$	U(-5.0,-1.0)	$P''(C)$	

3. Results: Strategy “control” in operation

Depending on the threat probability, the optimal control strategy has been identified.

- Optimal for low and high considered threat probabilities: relatively high performing and high cost surveillance.
- Cost efficiency of the strategy “control” can be influenced by pausing operation for periods with low threat probabilities.

$P(T)$	$P^*(Z_1 \mid T)$	C^*_{Surv}
$1.7 \cdot 10^{-3}$	0.93	$6.2 \cdot 10^{-4}$
$2.0 \cdot 10^{-3}$	0.94	$6.4 \cdot 10^{-4}$
$3.0 \cdot 10^{-3}$	0.95	$6.9 \cdot 10^{-4}$

4. Value of Information: Strategies “protect” and “control” in comparison

$P(T)$	Protect: s_1		Control: s_2	
	B_1	$\bar{V}_{s_1}$	B_2	$\bar{V}_{s_2}$
$1.7 \cdot 10^{-3}$	**$-1.49 \cdot 10^{-3}$**	**<1.00%**	**$-1.49 \cdot 10^{-3}$**	**<1.00%**
$2.0 \cdot 10^{-3}$	$-1.66 \cdot 10^{-3}$	7.60%	**$-1.61 \cdot 10^{-3}$**	**10.7%**
$3.0 \cdot 10^{-3}$	**$-1.97 \cdot 10^{-3}$**	**26.9%**	$-2.00 \cdot 10^{-3}$	26.0%

Conclusions

1. Any risk mitigation strategy should be implemented with the knowledge of threat probabilities.
   - The threat probability usually unknown to analysts but maybe known by police and security services.

2. The strategies “protect” and “control” are cost efficient for threat probabilities higher than $2.0 \cdot 10^{-3}$. The combination of both strategies will not be more cost efficient.

3. Below a threat level of $2.0 \cdot 10^{-3}$ protective measures and control strategies should not be implemented as the risk and expected cost reduction is insignificant.

Publication: Thöns, S. and M. Stewart (Accepted). Assessment of Terrorism Risk Mitigation Measures for Iconic Bridges. IABMAS 2018 - 9th International Conference on Bridge Maintenance, Safety and Management, Melbourne, Australia

Open questions addressed to decision makers

What is your experience with security measures for bridges?

How are security measures enforced? Are they enforced?

Thank you for your attention

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