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H2020 FORESEE

Future proofing strategies For RESilient transport networks against Extreme events

JASPERS Networking Platform

Third workshop on Climate Change Adaptation in the Transport Sector

Experiences from Project Preparation and Network Management

FORESEE PROJECT

- **Virtual meeting - WebEx**
- **7 April 2022**

Introduction to the FORESEE project

The overall objective of FORESEE is to provide cost effective and reliable results to improve resilience of transport infrastructure, as the ability to reduce the magnitude and/or duration of disruptive events.

FORESEE has developed and applied:

- New methodologies
- Technologies
- Tools
- Resilience squemes

Aimed to anticipate, absorb, adapt to, and/or rapidly recover from a potential disruptive event.

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Introduction to the FORESEE project

Disruptive events covered in FORESEE








- Earthquakes
- Landslides
- Floodings
- Accidents
- Fires
- Cyberattack
- Fog
- Wind
- Others

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Introduction to the FORESEE project

20 partners and 5M€ budget

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FORESEE Key exploitable Results

1. Guidelines to select resilience and service indicators set target objectives.
2. Governance module
3. Risk mapping tool
4. Virtual Modelling platform and asset failure prediction
5. SHM BIM based alerting SAS platform
6. Assessment of traditional solutions in drainage and sustainable drainage systems in linear infrastructures
7. Traffic module
8. Fragility Functions + Decission Support module.
9. New family of permeable pavements
10. Smart and integral slope stabilization protection systems
11. Flooding Methodology
12. Algorithm to determine optimal restoration and risk reduction intervention programs
13. Hybrid data assessment applied to transport infrastrucutre management
14. Methodology for the generation of shakemaps from semiempirical approach
15. SHM algortihms
16. FORESEE toolkit
17. C2. Command and control
18. Design, construction and remediation plans
19. Operational and maintenance plans
20. Management and contigency plans
21. Flooding assesment
22. Cybertacck Asessment
23. Standardisation in the FORESEE project

ETHZ's guidelines are public results avaialable in: https://foreseeproject.eu/publications/. They have been used to launch a standardization process (CWA 17819) on infrastructure resilience. Result public in: https://www.cencenelec.eu/news-and-events/news/2021/eninthespotlight/2021-11-22-infrastructure-systems-resilience/

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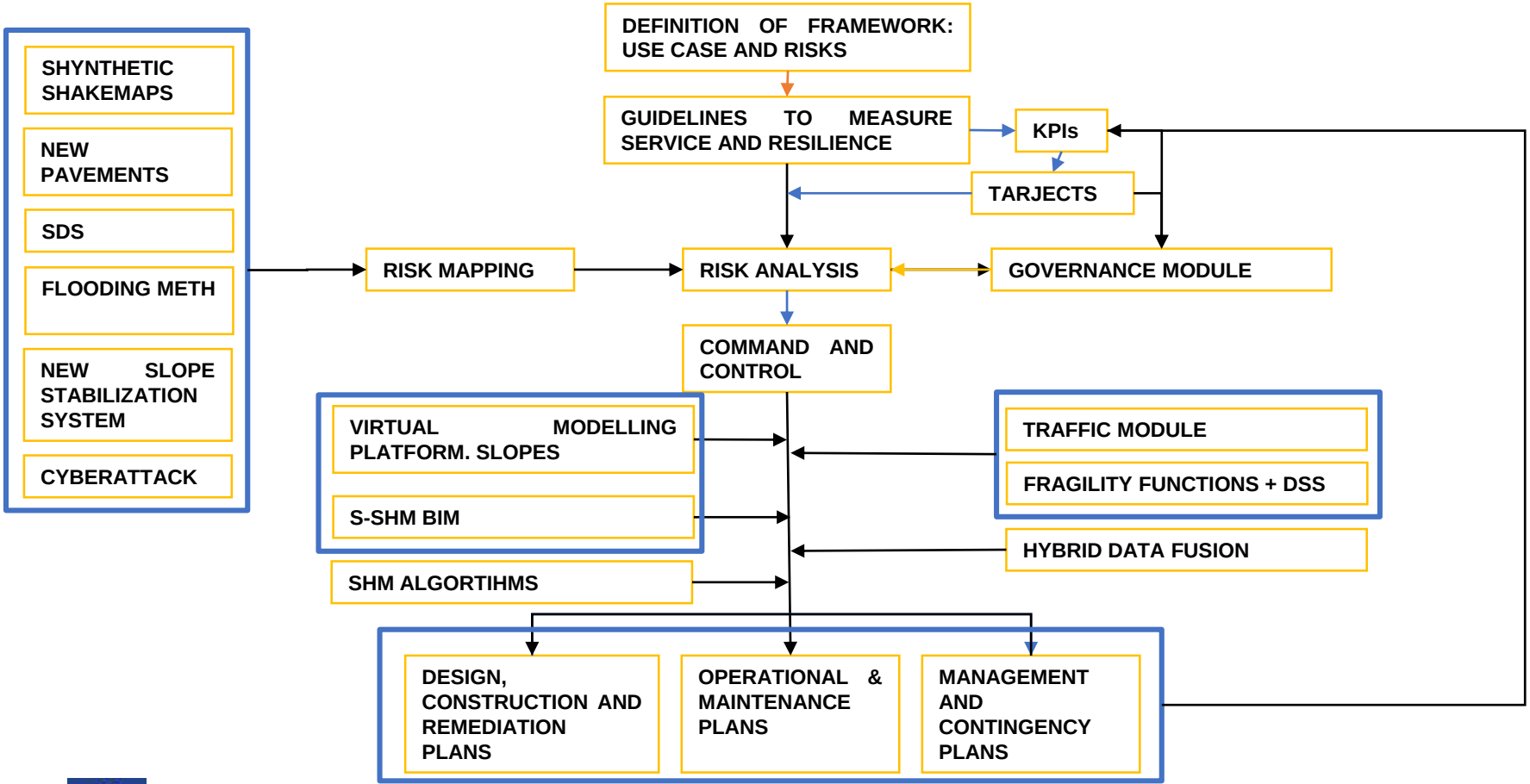
FORESEE TOOLKIT



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- D1.1 Guideline to measure levels of service provided by, and resilience of, transport infrastructure
- D1.2 Guideline to set the target levels of service provided, by and resilience of, transport infrastructure

https://www.infoticker.ch/artikel/der-bergsturz-bondo-und-seine-folgen-106354

Best practical example on a fictive CS, a section of the A16 highway, in Italy

Indicators & targets are defined, calculated, measured and others

“Estimating the resilience of, and targets for a transport system using expert opinion”
https://www.icevirtuallibrary.com/doi/epdf/10.1680/jinam.20.00029
Claudio Martani, ETHZ

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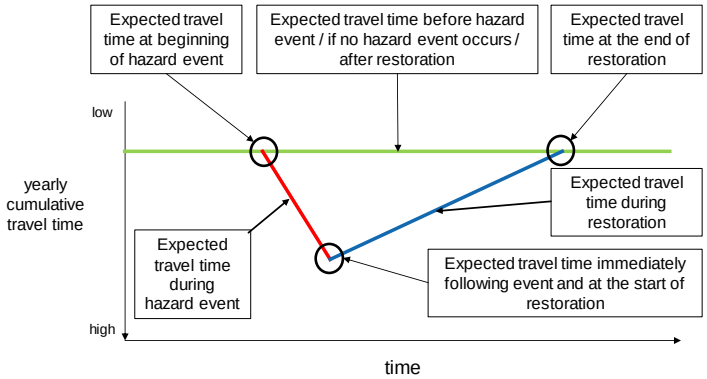
Results if resilience measured directly using loss of service and additional intervention costs

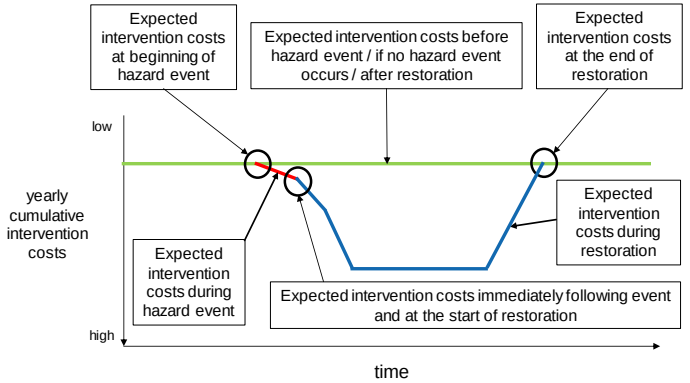


In this guideline, **service** is defined as

the ability to perform an activity in a certain way.

With this definition in mind, the service to be provided by transportation infrastructure, is the safe and sustainable mobility of persons and goods. This service can be operationalised, for example, as the ability to transport from A to B,

- goods and persons within a specific amount of time, and
- goods without being damaged and persons without being hurt or losing their lives.



In this guideline, **resilience** is defined as,

the ability to continue to provide service if a hazard event occurs.

Resilience, with this definition, is to be measured, using

- each measure of service deemed relevant, in order to assess how service is being affected, and
- the cost of the interventions required to ensure that the infrastructure once again provides and adequate service.

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D1.1 Measuring the service and resilience

Example resilience indicators

Part	Indicator	Relation to phase	Values from best to worst	Meaning
Infra-structure	Design resistance to hazard	Absorb phase - How an asset will react during hazard event	5	Design code level 5
			4	Design code level 4
			3	Design code level 3
			2	Design code level 2
			1	Design code level 1
	Condition state of bridge	Absorb phase - How an asset will react during hazard event	5	Like new
			4	Slightly deteriorated
			3	Average
			2	Poor
			1	Alarming
Environment	Seismic zone	Absorb phase – How an asset will be affected during a hazard event	5	Very low seismic zone
			4	Low seismic zone
			3	Average seismic zone
			2	Moderate seismic zone
			1	Severe seismic zone
	Regulatory framework	Recover phase – Consequences after hazard event	3	Very few administrative hurdles to be crossed after the hazard occurs
			2	Some administrative hurdles to be crossed after the hazard occurs
			1	Significant administrative hurdles to be crossed after the hazard occurs
Organisation	Frequency of monitoring	Recover – Consequences during hazard event	4	Regular frequent monitoring
			3	Regular but infrequent monitoring
			2	Irregular monitoring
			1	No monitoring
	Quality of emergency plan	Recover phase – Consequences during hazard event	3	Bridge specific plan
			2	Generic plan
			1	No plan

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D1.1 Measuring the service and resilience

Indicator	Description	Likely effect on measures of service and intervention costs		An increase in the value of the resilience indicator, therefore, means there is … resilience
		An increase in the value of the resilience indicator is likely to result in … the expected additional … costs		
		intervention	travel time	
Design resistance	The higher the value of the design resistance indicator, the higher the expected design resistance of the bridge.	a decrease in	a decrease in	an increase in
Condition state	The higher the value of the condition state indicator, the better the condition state of the bridge.	a decrease in	a decrease in	an increase in
Seismic zone	The higher the value of the seismic zone indicator, the more likely it is to have an earthquake of magnitude x.	an increase in	an increase in	a decrease in
Regulatory framework	The higher the value of the regulatory framework indicator, the less likely it is that the responsible organisation will have difficulties restoring service following an earthquake of magnitude x.	an increase in	an increase in	a decrease in
Frequency of monitoring	The higher the value of the frequency of monitoring indicator, the more likely it is that the responsible organisation can react quickly to limit transport disruptions following an earthquake	no change in	a decrease in	an increase in
Quality of emergency plan	The higher the value of the quality of the emergency plan indictor, the faster the restoration is likely to take place and, therefore, the lower the additional travel time due to the earthquake.	no change in	a decrease in	an increase in

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D1.

Intervention costs/ measure of service	Description	Costs: $\times 10^3$ €		
		Estimate	Equation	Estimate
Intervention costs (I_i)	The impact of executing restoration interventions	12 040	($C_i \times L_i$)	12 040
Travel time (I_{tt})	The impact of travel condition in terms of time lost and the impact of travel condition on the vehicle cost for work and leisure	**2430**	($P_w \times$ Dpud $\times$ $C_{wt} \times D$)	2970
		540	($P_w \times$ Dpud $\times$ $C_{lt} \times D$)	
Safety (I_s)	The impact due to the user being involved in an accident divided by property damage, injury and deaths	3000	$[(\frac{Ppd}{100}) \times PDp \times P]$	**54 000**
		1000	$[(\frac{Ppd}{100}) \times Ip \times P]$	
		50 000	$[(\frac{Ppd}{100}) \times Dpp \times P]$	
Socio-economic activities (I_{se})	The impact of people and goods not being able to travel	450	($P \times$ Dpud $\times D \times$ SECp)	1260
		810	($G \times$ Dpud $\times D \times$ SECg)	
Total		70 270	$(I_i + I_{tt} + I_s + I_{se})$	**70 270**

Indicator	Costs and reductions in service: $\times 10^3$ €					Weight total:[a] %
	Inter. costs	Measures of service			Total	
		Travel time	Safety	Socio-econ.		
1.1.1 – the possibility of building a temporary alternative route for vehicles	—	1931	—	819	2750	65
1.1.2 – the possibility of using another means to satisfy transport demand	—	2079	—	882	2961	70
1.1.3 – the number of possible existing alternative ways to deviate vehicles	—	1149	—	488	1637	39
1.1.4 – the presence of a warning system	—	2138	—	907	3046	72
1.1.5 – the presence of a safe shutdown system	—	1961	—	832	2792	66
1.1.6 – the presence of emergency/evacuation paths	—	1040	—	441	1481	35
1.1.7 – the presence of special measures to help evacuate persons	—	802	—	340	1142	27

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D1.2 The guideline: Measuring and setting resilience and service targets

In this guideline, **target** is defined as

A level of service or resilience that stakeholders consider acceptable and for which they are willing to take due actions.

Process to set targets:

- Gather all relevant stakeholders
- Determine legal requirements
- Determine stakeholder requirements
- Set targets

The choice of target and target setting method depends on, among other things

- the specific problem to be addressed
- the time frame at disposition
- the expertise available
- the availability of data, and
- how the level of service and resilience are measured.

The specific method to be used to set targets, i.e. task 4, depends on:

- how resilience is measured, i.e. using simulations or indicators, and
- whether or not cost-benefit analysis is to be used.

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D1.2 The guideline: Measuring and setting resilience and service targets

Type of target	Description
Maximum increase in intervention costs or decrease in service	Maximal allowed increase in intervention costs or reduction in service after a hazard event, e.g. no more than X additional hours of travel time
Shape of increase in intervention costs or decrease in service	Shape of the intervention costs increase or service decrease curve, e.g. within the first 20 minutes of the hazard event, the travel time is only allowed to increase by X hours, but if the hazard duration is longer, further increases in travel time are permissible.
Shape of intervention costs or reductions of service curve during restoration	Shape of the service restoration, e.g. the service should be restored to 80% of full service within X days, but it is permissible to restore the remaining 20% in Y weeks
Maximum allowed restoration time	A target can be set on the service restoration time, e.g. the service has to be restored fully within X weeks from the beginning of the hazard event.
Maximum total intervention costs or reductions in service	A target can be set on the area underneath the service reduction and restoration curve (which represents the total reduction of service), e.g. the area should be no more than X.

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D1.2 The guideline: Measuring and setting resilience and service targets

Part	Indicator	Values from best to worst	Meaning	Target	Measurement
Infrastructure	Design resistance to hazard	5	Design code level 5	Legal requirement: 2 Agreed upon target: 3	A one-time inspection by an external expert
		4	Design code level 4		
		3	Design code level 3		
		2	Design code level 2		
		1	Design code level 1		
	Condition state of bridge	5	Like new	Legal requirement: 2 Agreed upon target: 3	Yearly inspection by an external expert
		4	Slightly deteriorated		
		3	Average		
		2	Poor		
		1	Alarming		
Organisation	Frequency of monitoring	4	Regular frequent monitoring	Agreed upon target: 4	An external audit every 5 years
		3	Regular infrequent monitoring		
		2	Irregular monitoring		
		1	No monitoring		
	Quality of emergency plan	3	Bridge specific plan	Legal requirement: 2 Agreed upon target: 3	An external audit every 5 years
		2	Generic plan		
		1	No plan		

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D1.2 The guideline: Measuring and setting resilience and service t

Table 13. Setting targets based on net benefit for the condition state of the protective barriers

Possible value	Costs: $\times 10^3$ €	Target	Max per value	Measures of resilience: $\times 10^3$ €						Net benefit: $\times 10^3$ €
				Avoided intervention costs	Avoided reductions in service				B/C	
					Travel time	Safety	Socio-econ.	Total		
			Max	*9391*	*2317*	*42 120*	*983*	*54 811*	*N/A*	N/A
0	0		0	0	0	0	0	0	0.00	0
1	3000		1	1878	463	8424	197	10 962	3.65	7962
2	5000	**5**	2	1878	463	8424	197	10 962	2.19	5962
3	5000		3	1878	463	8424	197	10 962	2.19	5962
4	7000		4	1878	463	8424	197	10 962	1.57	3962
5	10 000		5	1878	463	8424	197	10 962	1.10	962

Table 14. Targets proposed for the 31 resilience indicators considered to be in the control of the infrastructure manager

ID	Indicator	Scale	Actual value	Target value	Costs to reach target: $\times 10^3$ €	Benefit of reaching target: $\times 10^3$ €	B/C	Net benefit of reaching: $\times 10^3$ €
1.1.1	The possibility of building a temporary alternative route for vehicles	2	0	**0**	0	0	0.00	0
1.1.2	The possibility of using another means to satisfy the transport demand	2	1	**1**	1200	1481	1.23	281
1.1.3	The number of possible existing alternative ways to deviate vehicles	1	1	**0**	0	0	0.00	0

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D1.2 The guideline: Measuring and setting resilience and service targets

1. select the types of targets to be set for restoration intervention costs and each measure of service
2. develop possible sets of targets, keeping in mind the legal restrictions
3. determine the scenarios of how the targets in each target set are to be reached
4. estimate the costs of achieving the targets sets and the benefits of each scenario in terms of the restoration intervention costs and measures of service
5. evaluate the ability of each scenario to achieve the target sets taking into account the legal requirements and select the best one with respect to the benefits and costs.

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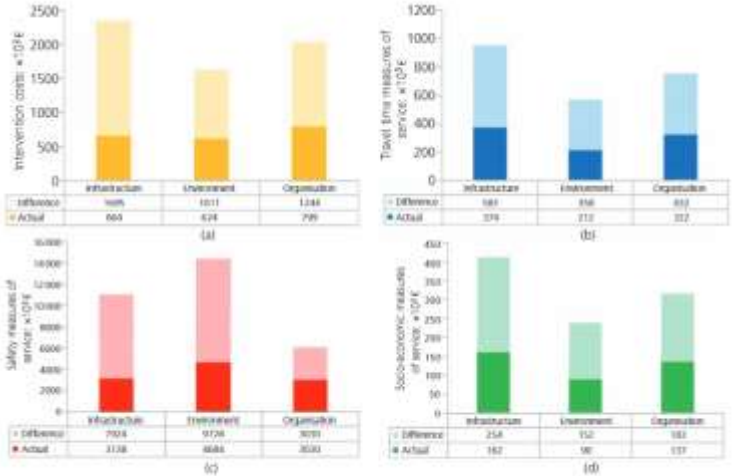


Figure 9. Difference between measures of resilience for the infrastructure, environment and organisation categories using only (a) intervention costs, (b) the travel time measure of service, (c) the safety measure of service and (d) the socio-economic measure of service

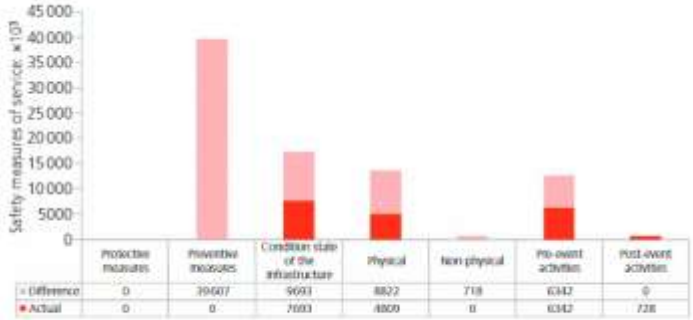


Figure 10. Difference between measures of resilience for the indicator categories condition state, protection measures, preventive measures, physical and non-physical environment and pre- and post-event activities

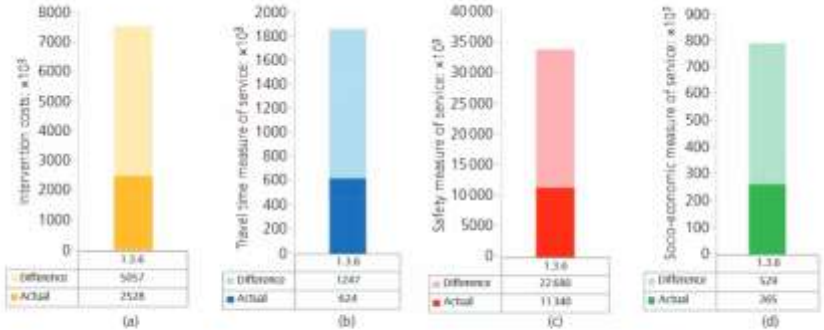
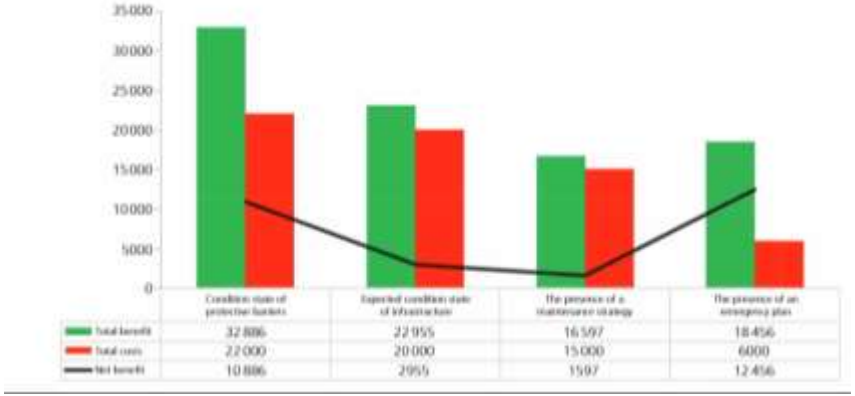


Figure 11. Difference between measures of resilience for the indicator expected condition state of protective barriers (1.3.6): (a) intervention costs; (b) travel time measure of service; (c) safety measure of service and (d) socio-economic measure of service



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