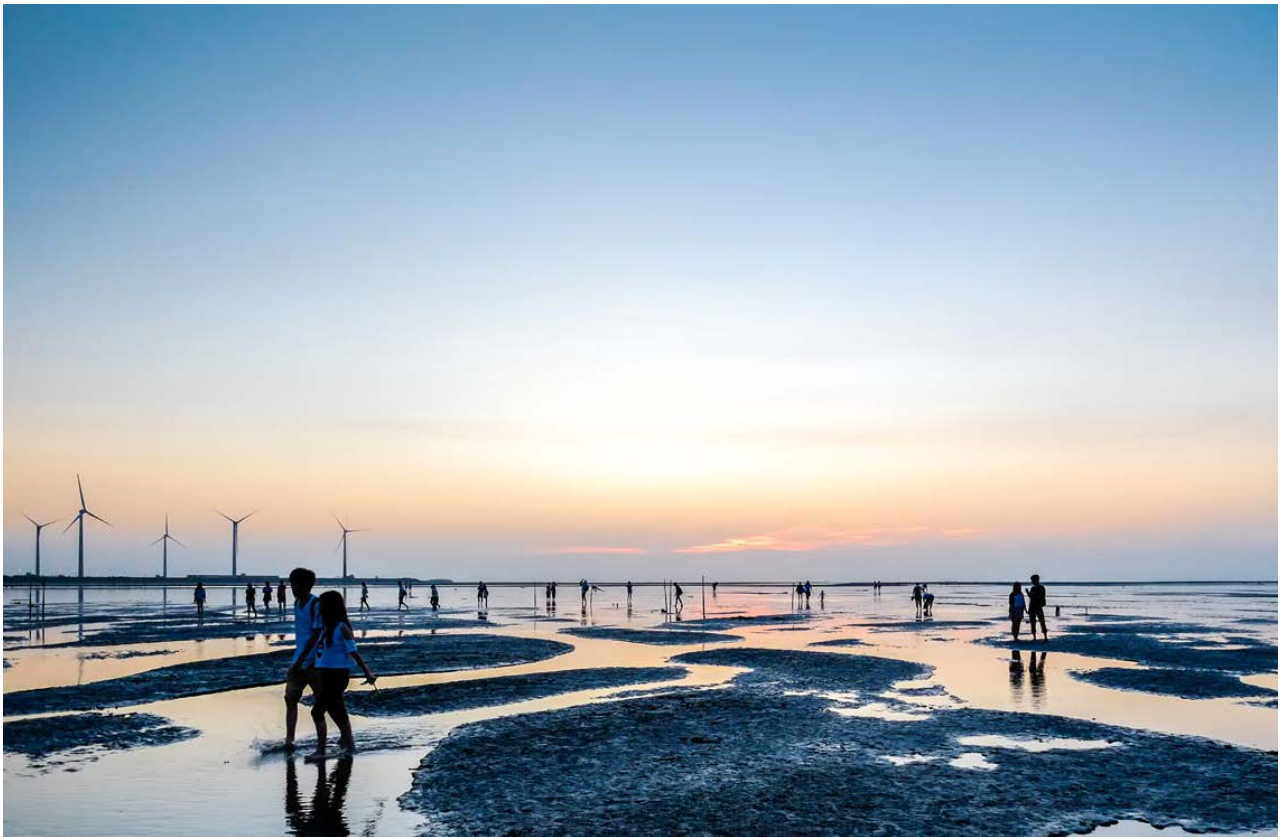


Resilience Return on Investment (RROI)

Agenda Setting Scoping Studies Summary Report



Drafted by Peter J. Hall, Colin Carter, Eric C. Bill, Mark O'Connor, Dr. Murray C. Simpson

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Table of contents

Introduction	4
Definitions	5
Overview.....	5
Resilience and Resilience Engineering.....	5
Methodologies.....	9
Overview.....	9
Selected methodologies	9
Method 1 – ‘Economic resilience’	9
Method 2 – Resilience engineering defined as a systems approach (Hollnagel).....	11
Method 3 – Cost Benefit Analysis used for resilience (CBA)	12
Selected applications of methodologies.....	13
Application 1 – Air traffic management system (Sweden).....	13
Outline.....	13
Comment	13
Application 2 - Resilience of the urban transport system (Florence, Italy)	14
Outline.....	14
Comment	14
Application 3 - Flood resilience	14
Outline.....	14
Comment	15
Practice	16
Overview.....	16
Current understanding of resilience	16
Defining resilience engineering.....	16
Expenditure/finance	16
Metrics in development.....	17
Spatial analysis	17
Digital Twin	18
Techniques	19

THE RESILIENCE SHIFT

Probabilistic approach to risk	19
Types of impacts included in the cost benefit analysis	19
Applications for practices	19
Sectors and organizations that use cost benefit analysis for resiliency planning	19
Geographies that use cost benefit analysis	19
Opportunities	21
Summary of messages from theory and experience	21
Main elements of an approach to a RROI metric	21
RROI Framing strategy	22
Implementation	22
Proposed features of applications	22
Conclusion	24

Introduction

Amec Foster Wheeler and Impact Infrastructure have prepared this scoping research to help accelerate the integration of resilience by promoting resilience engineering as the new normal for infrastructure projects.

The aim of the scoping work in this study was a review and gap analysis of applicable resilience engineering practices. The aim is to document how global engineering firms, infrastructure owners, governments, and development organizations are currently quantifying value associated with a performance-based design approach for resilience engineering. The focus on this scoping study pertains to the concept of ‘Resilience Return on Investment’ (RROI) within infrastructure projects – specifically, reviewing approaches to quantify the value of resilience engineering.

An important output from this scoping study is a review and assessment of baseline current practices, ‘state of the art’ study and the analysis of the gaps documenting the RROI within infrastructure projects which are expected to be key driver behind a paradigm shift within traditional engineering projects.

Definitions

Overview

The definitional space for resilience is still developing and hence there is some variety in the conceptions that can be used for resilience engineering. This section identifies the elements where resilience and resilience engineering overlap.

Resilience and resilience engineering

Definitions for resilience engineering vary, but thematically are fairly consistent overall. For example, Lloyd's Register Foundation, 100RC and Rockefeller Foundation definitions overlap:

*“Emergent property, or attribute, that some systems have which allows them to **withstand, respond and/or adapt to a vast range of disruptive events.**”*

Lloyd's Register Foundation

*“the capacity of individuals, communities, institutions, businesses, and systems within a city **to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience.**”*

100RC and Rockefeller Foundation

More generally, the broader concept of resilience underlies resilience engineering and sets the context for resilience engineering objectives. The wider perspectives related to resilience are highlighted in “Disaster Vulnerability and Resilience: Theory, Modelling and Prospective”¹.

This notes that:

“Resilience is a concept with multiple origins and conceived of as a response to vulnerability.”

“Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions [IPCC]”

“Resilience is more usefully understood as a process—derived from ongoing actions—than as an outcome, despite this common usage (Kaplan 1999 cited in Manyena 2006). While the latter entails a fixed state, the former can be understood as ongoing, dynamic and perpetually changing.”

Resilience shares some perspectives with risk and the differences are important as well established methodologies exist for risk which are partially applicable.

¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287456/12-1298-disaster-vulnerability-resilience-theory.pdf

THE RESILIENCE SHIFT

In “An introduction to the IRGC Resource Guide on Resilience”², the following distinctions are drawn:

“risk and resilience analysis are grounded in a similar mindset of (a) avoiding negative consequences of bad things happening and (b) reviewing systems for weaknesses and identifying policies or actions that could best mitigate or resolve such weaknesses”

“a traditional risk analysis approach would seek to identify the range of possible scenarios in an ad hoc or formalized manner, and protect against negative consequences of an event based upon the event’s likelihood, consequences and availability of funding”

“Resilience analysis differs in a temporal sense from traditional risk analysis by also considering recovery of the system once damage is done.”

“Instead, a traditional risk analysis project constructs the ideal set of policies that, given available money and resources, would offer the best path forward for risk prevention and management. Attention to longer term and lower probability threats is often neglected in favor of more intermediate and likely dangers, with only limited emphasis or focus on the need for infrastructural and organizational resilience building”

Resilience has an important temporal dimension which affects assets and processes which need operating modes which survive the event and cover the recovery period. Resilience is related to both acute and chronic conditions as well as the relationship between them. Resilience over time implies different functional forms of society, corresponding, for example, to situations pre and post flood. Resilience engineering inherently contributes to maximizing the possibility of different social and technical solutions. The current system can be seen as a result of a particular perspective of resilience taken by society in the past, consciously, unconsciously or subconsciously.

² <https://www.irgc.org/wp-content/uploads/2016/04/Linkov-Trump-Fox-Lent-Resilience-Approaches-to-Risk-Analysis-and-Governance-1.pdf>

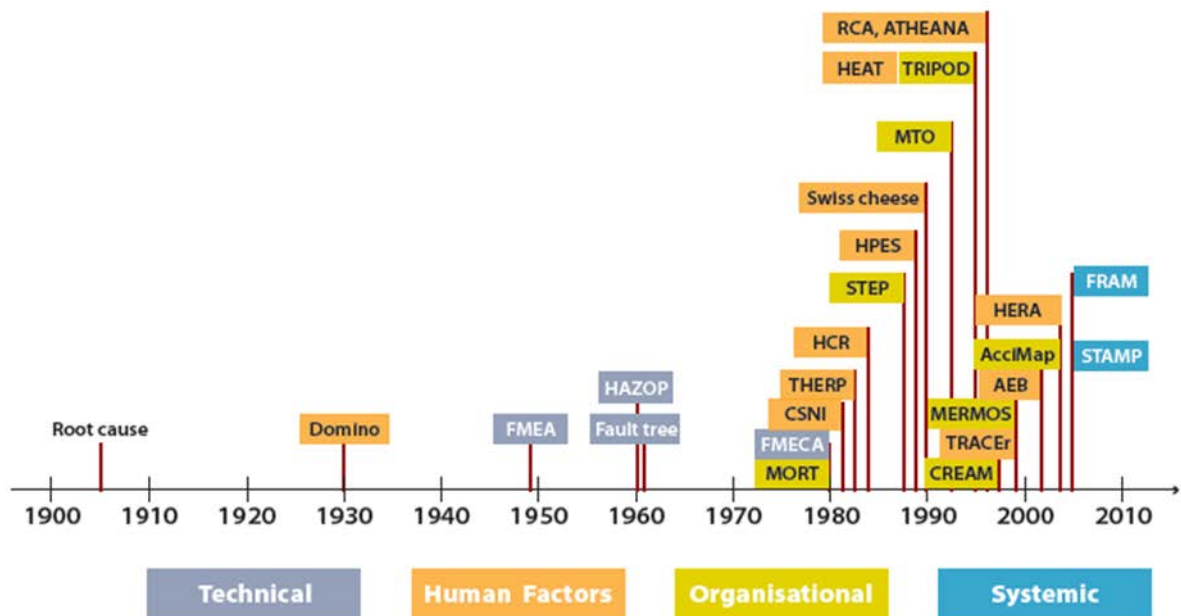
THE RESILIENCE SHIFT

The National Academy of Science definition of resilience identifies the following temporal phases:

NAS phase of resilience	Resilience Feature	Description by Application Domain			
		Socio-Ecological	Psychological	Organizational	Engineering & Infrastructure
Plan	Critical function	A system function identified by stakeholders as an important dimension by which to assess system performance			
		Ecosystem services provided to society	Human psychological well-being	Goods and services provided to society	Services provided by physical and technical engineered systems
Absorb	Threshold	Intrinsic tolerance to stress or changes in conditions where exceeding a threshold perpetuates a regime shift			
		Used to identify natural breaks in scale	Based on sense of community and personal attributes	Linked to organizational adaptive capacity and to brittleness when close to threshold	Based on sensitivity of system functioning to changes in input variables
Recover	Time	Duration of degraded system performance			
		Emphasis on dynamics over time	Emphasis on time of disruption (i.e., developmental stage: childhood vs adulthood)	Emphasis on time until recovery	Emphasis on time until recovery
Adapt	Memory/Adaptive Management	Change in management approach or other responses in anticipation of or enabled by learning from previous disruptions, events, or experiences			
		Ecological memory guides how ecosystem reorganizes after a disruption, which is maintained if the system has high modularity	Human and social memory, can enhance (through learning) or diminish (e.g., post-traumatic stress) psychological resilience	Corporate memory of challenges posed to the organization and management that enable modification and building of responsiveness to events	Re-designing of engineering systems designs based on past and potential future stressors

Figure 1 – Resilience features common to socio-ecology, psychology, organizations, and engineering and infrastructure, which are related to the temporal phases from the National Academy of Science definition of resilience (discussed in Connelly et al 2016 – forthcoming)

Resilience engineering as a discipline draws on the methods of achieving safety more generally. The concept of resilience engineering as a development of an approach to safety is illustrated in the work of Erik Hollnagel. This is summarised in his declared aim for resilience engineering to “not only to



prevent things from going wrong, but also to ensure that things go right.” The range of approaches to Accident Analysis and Risk Management is put in a broad historical perspective with a sequence over time from approaches focusing first on technical factors, then human and organizational factors, and latest the systemic factors³.

Figure 2 - Accident Analysis and Risk Assessment Methods

In this context, resilience engineering is a later approach which falls within the group known as ‘systemic’. It is described as providing ‘an additional perspective on safety assessment and management’ which complements existing tools but goes beyond ‘classical safety issues’.

The elaboration of a resilience engineering approach in response developed includes the following elements:

- A broadening of focus from a simple concern with operational focus to a set of concerns covering organization, technology, design and maintenance, and understanding of upstream and downstream influences through the supply chain.
- A recognition of system characteristics resulting from factors such as: system change faster than it can be described; tight coupling between functions; unknown modes of operation.

For these reasons, systems encountered nowadays are described as more likely to be ‘intractable’ in comparison to earlier ‘tractable’ systems and this conditions the success of an approach to them.

³ <http://www.eurocontrol.int/sites/default/files/article/content/documents/nm/safety/safety-a-white-paper-resilience-engineering-for-atm.pdf>

Methodologies

Overview

There are a wide range of approaches that attempt to characterise and quantify resiliency in engineering projects, from value based approaches, to systems modelling, to a variety of economic analysis approaches.

The literature review considered over 90 sources, aiming to draw out insight on current and better practices for improving and promoting investment in resilience and resilience engineering.

Three methodologies are highlighted here and three applications. The methods collectively provide a summary of the main approaches while the applications, because of the many practical choices that need to be made, supplement the methodologies and extend the understanding of how possible a generic approach to operationalising resilience can be.

Selected methodologies

The three methods below are selected because, although they are inherently approaches to the wider subject of resilience, they outline the main families of concepts and influences framing the more specific subject of resilience engineering.

Method 1 – ‘Economic resilience’⁴

This methodology seeks to set resilience within a conventional framework of neo-classical economic thinking. It focuses on the overall welfare of society, recognizes both macro- and micro-economic effects on resilience, and proposes measures based on ‘rules of thumb’.

Resilience in this context is the ‘minimization of welfare losses’, which while simple and apparently self-evidence, implies a reference to and incorporation of an extensive and pre-established conceptual architecture relating to the definition and analysis of welfare more generally.

This framework explicitly focuses on ‘economic resilience’ and excludes direct health and human impacts. As regards timeframes, ‘instantaneous’ and ‘dynamic’ resilience is distinguished, the first relating to preservation of function while the second is related to reconstruction and recovery over a longer subsequent term.

The definition in the methodology suggests that what are often known as ‘direct’ and ‘indirect’ effects is replaced by ‘asset losses’ and ‘output losses’. The drivers of asset losses and hence asset values will be important to resilience engineering perspectives. More specifically, the following output losses are identified:

⁴ <http://documents.worldbank.org/curated/en/350411468149663792/pdf/WPS6852.pdf>

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- ***Business interruptions***
- ***Production losses***
- ***Supply-chain disruptions***
- ***Macro-economic feedbacks***
- ***Long-term adverse consequences [on] economic growth***
- ***Increased production.***

The loss in asset value is seen as equivalent to the loss in output from that asset.

The first two types of output loss ('business interruptions' and 'production losses') are most directly relevant to resilience engineering and have the potential to be included in methodologies focused on traditional asset investment and development.

For resilience engineering, this implies the need to understand how damage to assets will be reflected in scenarios used for valuation. In particular values pre and post an event. An important point is that the marginal values normally used to estimate change in the economy may significantly underestimate the losses from major changes in which resilient infrastructure has heightened values.

The diffusion of shocks through the economy was also identified as important, with examples of losses for small businesses related not to structural damage but to customer access, employee access and shipping delays.

The macro-economic perspectives affect resilience engineering less but represent for example the loss in consumption for the total economy (foregone luxuries) required to replace the damaged assets (buildings).

At the micro-economic level, the structure of vulnerable populations as well as a range of other regional effects is relevant.

Method 2 – Resilience engineering defined as a systems approach (Hollnagel)⁵

In broad terms this can be seen as a model of processes. ‘Four basic abilities [also called ‘potentials’ and ‘cornerstones’]’ are defined for ‘how an organization functions’ covering “how it responds, how it monitors, how it learns, and how it anticipates.”

These are considered to be deployed or exhibited in “systems” which are categorised (coincidentally) as being of four different kinds.

- **Systems of the First Kind** are the simplest and sustains their existence by reacting appropriately to a stimulus, particularly an unexpected stimulus.
- **Systems of the Second Kind** work in a similar way but include the ability to modify their responses.
- **Systems of the Third Kind** look ahead and are able to anticipate and predict changes.
- **Systems of the Fourth Kind** are able to respond, monitor, learn, and anticipate and hence are defined as resilient by Hollnagel.

This methodology is a process model and the main question it raises is what to apply it to. Systems of all four kinds will already exist. The value of upgrading a system from one kind to another needs to be established and identifying a bounded or other description of the relevant system is also required. The hierarchy implies that:

- systems of higher kinds make potentially make use of more information, or at least select more carefully from a potential range of information;
- systems of higher kinds may also include more processes, as they are required to a range from ‘responding’ to ‘anticipation’, whereas simpler systems may just cover responding.

For use in with a resilience engineering perspective, the general theme with its four abilities [response, monitor, learn, and anticipate] provides a structure for organising the application of engineering techniques.

Functional Resonance Analysis Method (FRAM)⁶ is a precursor and related method which provides a framework for analysis which assesses resonance potential through consideration of a system defined in terms of six essential system functions.

⁵ <http://erikhollnagel.com/ideas/resilience-engineering.html>

⁶ <http://functionalresonance.com/>

Method 3 – Cost Benefit Analysis used for resilience (CBA)

Cost benefit analysis (CBA) is an established economic approach for comparing the benefits and costs of a given project or activity. CBA involves identifying, quantifying, monetising and summing in dollars to the extent possible the value of incremental costs and benefits over the life of a project.

The importance of CBA for decision makers is that its results provide a quantitative measure of a project's worthiness.

While not a decision-making tool, CBA is an industry standard decision-support tool used to inform and improve public policy, programmes and projects. Essentially, the approach helps prioritize projects in a standardized way, as well as provide insights as to the impacts on various project stakeholders.

CBA is used extensively in disaster risk reduction due to its ability to recognize the added value of both structural and non-structural activities or investments in mitigating the negative environmental, social, and economic impacts of natural hazards. The benefits of disaster risk reduction and hazard mitigation investments are numerous, significant, and demonstrably valuable. They include:

- **Physical benefits**
- **Human benefits**
- **Social benefits**
- **Environmental benefits**

When CBA is combined with probabilistic approaches to account for uncertainty, investment can be assessed not only against *current* threats, but a range of known and unknown *future* threats and hazards.

- CBA has been used to assess projects where issues of resilience have arisen including post disaster case studies and a number of international organisations make substantial use of it such as Homeland Security in the US, the United Nations and the Australian government.

The concerns with CBA regarding the assessment of natural disasters are highlighted below.

Inclusion and scope of risks

Data limitations

- ***Resource allocation and sustainability***
- ***Multiple stakeholders and concerns***

However, CBA is a widely-used technique and has been used to address natural disasters.

Selected applications of methodologies

The applications below illustrate use of particular methodologies in specific sectors.

Application 1 – Air traffic management system (Sweden)⁷

Outline

This study reports the use of the Hollnagel framework to implement Resilience Engineering in the air traffic management (ATM) sector.

In application, the study looked at the four Hollnagel ‘abilities’ (METHOD 2) and used a questionnaire approach to assess LFV:

- **Respond (relabelled as ‘Actual’)**
- **Monitor (‘Critical’)**
- **Anticipate (‘Potential’)**
- **Learn: (‘Factual’)**

Comment

The study is itself an example of learning in practice.

The justification reported for the study is that “a new discipline dealing with safety management has evolved” called Resilience Engineering which “aims at making safety more proactive,”.

Monitoring was identified as the one of the four abilities that could be improved - “There are well defined indicators in the different units but they can be improved and more can be introduced.”

It was noteworthy that cost was mentioned in connection with only one of the four abilities, the same ability for monitoring.

The Hollnagel framework in effect provided a screening tool which identified that an increased resilience would arise in this instance from better monitoring which would provide better critical information at the time. The ability to anticipate was covered more briefly, but would also benefit from better monitoring.

⁷ <http://www.diva-portal.org/smash/get/diva2:694400/FULLTEXT01.pdf>

Application 2 - Resilience of the urban transport system (Florence, Italy)⁸

Outline

The assessment reviewed the vulnerability and resilience of the urban transport system. The methodology used the 11 common performance conditions defined by Hollnagel, (originally as part of the FRAM approach).

At an overarching level, the assessment identified features affecting resilience levels due to

- Lack of attention/capability to coupling between functions
- Silos existing in the provision of technological and organizational capabilities
- Weak and unrepresentative planning scenarios due to over-use of hypothetical inputs

An example is provided on the independence of the decision by the roads maintenance division to construct a yard without consulting other stakeholders, such as the department responsible for mobility which needs to be aware of the changes to the road network. Furthermore, there are no official procedures or technological support (such as digital information systems) to accommodate and incorporate such changes and communicate information to citizens or private business. The lack of information resources risks adding to uncertainty and contributing to a potential catastrophic disruption of provision in circumstances where transport is essential.

Comment

The issues in this case study shows how generic guidelines can be operationalised to frame an understanding of a situation. The actual result was a specific investment in information systems.

More generally, the information system can be seen as the start of a virtual model which would coexist alongside and represent in an abstracted from the physical processes related to transport.

Application 3 - Flood resilience⁹

Outline

The introduction to this study on resilience related to flooding states resilience as capturing the broad intention to “learn to live with floods and to manage flood risk and not seek to avoid it”.

⁸ <https://www.irgc.org/wp-content/uploads/2016/04/Bellini-Nesi-Ferreira-Operationalize-Data-driven-Resilience-in-Urban-Transport-Systems.pdf>

⁹ <https://www.irgc.org/wp-content/uploads/2016/04/Zevenbergen-Flood-Resilience-2.pdf>

THE RESILIENCE SHIFT

Two approaches to resilience are contrasted: traditional, with resilience being an outcome reflecting properties such as robustness, and a second with a broader holistic systems approach.

This has led to a paradigm shift in understanding, based on a recognition that an apparently simple event, a flood, is part of a complex system with incomplete knowledge, a need for ongoing learning with participative and collective action, and many possible interventions. An overall balance between protection, prevention and preparedness is required.

The traditional metrics of resilience are the probability of flooding and relationship with the direct impacts of loss. The broader perspective seeks to use proxy metrics which represent the resilience from economic resources, assets and skills, information and knowledge, support and supportive networks, and access to services.

The overall resilience depends on the whole set of indicators, which provide in effect a simplified characterization for understanding possible system behaviours. They cannot be aggregated directly.

Comment

This application shows how the development of thinking has driven a new characterization which has the double benefits of being better suited to newly recognized complexity and is itself a simplified model of this complexity.

Although the metrics cannot be aggregated directly into a single 'resilience score', they allow a representation then allows development of scenarios using them, and these can in principle be valued using an appropriate valuation model.

This example also provides some ad-hoc evidence of the level at which approaches to resilience characterizations can be genericized and operationalized.

Practice

Overview

Current practice is introduced through the results of our survey, providing a 'state of the nation' view on resilience and resilience engineering.

Current understanding of resilience

A number of interviews were conducted across industry to determine the range of opinions that currently exist with regards to resilience engineering.

There were a number of views of what resilience engineering is, including the following quotes:

- *“Resilience engineering is the creation of assets/structures with resilience in mind e.g. climate change, usage changes. The design is flexible and future proofed.”*
- *“Resilience engineering is protecting infrastructure/developments from climate change effects.”*
- *“In addition, there was some discussion with regards to the difference between resilience engineering and resilient infrastructure. It was considered that resilience engineering is the process by why resilient infrastructure is designed and implemented.”*
- *“The importance of regulations was consistent across the interviews, however there was concern that rapid changing conditional may not be captured in regulation immediately.”*
- *“Analytics which help translate climate risk exposure into financial vulnerability.”*

Defining resilience engineering

- *“Resilience engineering is the creation of assets/structures with resilience in mind e.g. climate change, usage changes. The design is flexible and future proofed”*
- *“Resilience engineering is about the process rather than the outcome. It is the process in developing resilience rather than creating a piece of resilient infrastructure.”*

Expenditure/finance

- *“On projects, often resilience engineering elements are the first to be cut during cost saving exercised”*
- *“Innovative finance mechanisms have high transaction costs which, when coupled with the new nature of a resilience project, can make them difficult”*

THE RESILIENCE SHIFT

- *“Most project investment decisions come down to the ability to justify the allocation of resources”*
- *“Our work is all about evaluating broader, important benefits that are often ignored as “intangibles””*
- *“Greater demand for real-time monitoring/performance metrics instead of static inspections of assets”*
- *“The move is to proactive responses rather than reactive and monitoring is seen as an early warning for the Infrastructure Managers to be better prepared for future threats/opportunities”*
- *“Resilience planning anticipates a range of events that may shock a community”*
- *“New infrastructure has the benefit of updated design and operating models so it could be suggested that resilience has been embedded in the design”*
- *“By default we do consider resilience in our projects, however it is not branded as resilience engineering; it is considered business as usual”*
- *“Infrastructure is becoming much more digital and IT is seen as a method to implement resilience engineering”*
- *“Regulation helps to embed resilience into design”*
- *“Engineering partners focus on climate resilience and the dynamic shocks and stresses infrastructure faces on a day to day basis. There is little thought about what the impact on society will be.”*

Metrics in development

Spatial analysis

Economists are increasingly looking to value both the traded and non-traded goods and services that nature provides. Business is also seeking to recognise dependencies in their supply chains that depend on nature and cannot be so easily mitigated through financial mechanisms such as insurance. The focus these perspectives have on natural capital valuation and ecosystem services valuation is inherently and intimately concerned with spatial questions.

Despite this, economists rarely incorporate this spatial relationship within the answers they provide (Bateman, Jones, Lovett, Lake, & Day, 2002). Spatial context plays a major role in natural processes and their outcomes – and thus the value that they generate for society.

Tobler's first law is 'everything is related to everything else, but near things are more related than distant things'. Geographic Information Systems (GIS) based on digital mapping are increasingly used to present and quantify spatial dependencies that underlie the sources of natural value. Merging data-

rich tools based on GIS into analysis methods with theoretical structures that did not assume them (such as CBA) is an emerging – and mostly theoretical – field (Heidkamp, 2008)¹⁰.

Recently there has been progress in the development of spatially contextual environmental valuation tools. The practitioners that are likely to be concerned with implementing resilience are also likely be familiar with the use of GIS and other spatial analysis tools.

Nevertheless, the missing piece to the puzzle in all of these powerful tools seems to be the lack of ability to incorporate a CBA structure into them – thus they fail to show the costs and benefits over the lifecycle of the project or which stakeholders are the winners and losers over time. Ultimately, a spatial CBA would rectify this and provide a much-needed technical interdisciplinary innovation that has the ability for projects to proactively enhance resiliency, rather than having to respond reactively.

Digital Twin

The 'digital twin' captures the idea that a virtual model represents and lives alongside the physical situations and processes.

A CBA-BIM is a summary term for the representation of a combination of asset information and the costs associated with the asset. CBA-BIM allows the evaluation of the costs, benefits and risks of proposed infrastructure systems while they are being designed, using 3D digital representations of physical and functional characteristics of projects (Parker, 2014)¹¹. Integrating a CBA into BIM is an advantage as it integrates all disciplines throughout the project. Designers, planners, architects and engineers already use BIM (and related GIS) for infrastructure projects as it increases efficiency throughout the planning, design and operations phases.

Economists, in contrast, are not using spatial data and often are only involved during the early design stages of a project. CBA analysis at this stage be costly and, as a result, is focused at a high level and used to compare the main project options.

Engineered systems and nature are interconnected, but these interdependencies are rarely accounted for. The major benefit of a CBA-BIM is that BIM defines relationships between objects and keeps changes consistent and coordinated, so that as the design changes, so can the economic costs, benefits, and risks. Where CBA is embedded with BIM, these design changes can be valued and revalued, allowing stakeholders to see the value added of better design over the life cycle of the project.

The CBA-BIM tool is an example of the implementation of the much wider 'digital twin' concept with cover all implementations with the ongoing ability to record and store project details over time, including the project's value.

¹⁰ Heidkamp, C. P. (2008). A theoretical framework for a spatially conscious economic analysis of environmental issues. *Geoforum*, 39(1), 62–75. <http://doi.org/10.1016/j.geoforum.2007.01.010>

¹¹ Parker, J. C. (2014). *Triple Bottom Line Business Case Analysis for Infrastructure Planning and Design*

Techniques

Probabilistic approach to risk

Risk analysis is an important consideration in the RROI concept and underlying CBA approach. Probability event scenarios, the consideration of future probabilities of events, identification of direct and indirect risk exposure, frequency, and magnitude should be incorporated into the RROI assessment.

Types of impacts included in the cost benefit analysis

According to the World Bank, estimating the direct costs of disasters is not sufficient. To establish the total cost of a disaster, its indirect costs also need to be estimated. Calculating both direct and indirect costs, however, in addition to non-economic impacts, can prove to be challenging.

It must be recognized that cost-benefit analyses require the collection of extensive and reliable data, as well as data that are standardized; however, this data collection and organization can be costly. This can certainly be a “road-block” when performing a CBA

Applications for practices

Sectors and organizations that use cost benefit analysis for resiliency planning

There are many sectors interested in resiliency, and specifically the CBA framework for resiliency planning. These include, but aren't limited to:

- Insurance companies (e.g., Zurich Insurance Group)
- Governments/Regulatory (e.g., Australian government, US Homeland Security, United Nations)
- Financial institutions (e.g., World Bank)
- Non-profit organizations/Aid (e.g., Red Cross)

Geographies that use cost benefit analysis

Cost benefit analysis in resiliency engineering should be used globally, and currently is being employed in jurisdictions all over the world.

- Initiatives exist globally, such as those in Latin America, where a Network of Ministries of Finance on Disaster Risk Reduction is emerging as the platform for information exchange and capacity building for integrating disaster risk into public finance. In the Indian Ocean Region, a similar approach is being contemplated through a regional collaboration of Ministries of

Finance which would also hold potential for mutual learning to accelerate the integration of cost-benefit analyses into public investment and risk financing strategies for disaster risk reduction.¹²

- This will allow for improved decision-making by learning from the economic assessments of other countries and by applying the results of research made elsewhere. To facilitate this learning, a more systematic collection and dissemination of relevant applied research and economic analysis needs to be put in place.¹³

¹² <http://www.wcdrr.org/uploads/Public-Investment-in-Disaster-Risk-Reduction.pdf>

¹³ *ibid*

Opportunities

Summary of messages from theory and experience

Based on the state of practice and research, along with interviews across key sectors, it is clear that a generally applicable framework where resilience can be evaluated across critical infrastructure using an RROI conception is lacking. Enhancing the current CBA model to now address resilience represents a paradigm shift.

Key gaps to date in the development and application of an RROI resilience metric include:

- Variability of projects and the range of types of benefits they provide
- Ad-hoc characterisation of situations and contexts on a case-by case basis
- Perceived risk in “double-counting” resilience co-benefits
- Limitations to data availability
- There are large uncertainties on indirect disaster costs
- No driver for an RROI metric as a requirement of funding by financial institutions
- Difficulty in representing stakeholders’ near-term and long-term time horizonse

Although there are numerous examples of resilience engineering that generate resilience dividends, there remains a need for a consolidated, consistent framework that defines key processes, impact categories and database metrics for valuation.

Main elements of an approach to a RROI metric

The methodology that most suggests itself as relevant to a search for an RROI perspective is that of risk. Respondents to this study included those that thought of them as similar if not identical. However key difference between resilience and risk are highlighted in “An introduction to the IRGC Resource Guide on Resilience”¹⁴, particularly:

- ***The need to comprehensively consider all possibilities***
- ***The focus on the recovery phase***

¹⁴ <https://www.irgc.org/wp-content/uploads/2016/04/Linkov-Trump-Fox-Lent-Resilience-Approaches-to-Risk-Analysis-and-Governance-1.pdf>

Timing and phasing is also highlighted in the more formal economic methodology of the World Bank¹⁵ which also shows that economic assessment is difficult to adapt to circumstances where resilience is the concern and various conceptual approximations are required. A suggestion is made that average values (prices) may be more appropriate than marginal values as a metric when resilience is being assessed.

Also, the issue of long-lived and perpetual assets is a difficult component in traditional economics, with different approaches giving very different values. Valuing new investments which will deliver resilience over the longer term requires a perspective which recognises that resilience values may coexist with other values and in some cases, may already be embedded in existing assets.

Methods for resilience need to be practical and need to work within an existing financial system. The use of CBA for problems similar to resilience problems, including scenario analysis and risk assessment makes it an obvious candidate for consideration.

RROI framing strategy

The need for practicality in daily decisions over resilience investment opportunities is behind the suggestion that an RROI metric could be formed through acknowledging and using the following:

- ***Families of generic situations.***
- ***Metrics and characterisation specific to each generic situation.***
- ***A specific (and potentially standardised) approach to unit value metrics.***
- **Use of CBA, to model [circumstances from the generic situations] using [metrics and characterisations] and [unit values/prices relevant to resilience] as the main method.**

Implementation

Based on the evidence and suggestions presented here, it would be logical to look at pilot project for a generic situation defined for a critical infrastructure area that illustrates and addresses the issues raised in the methodologies in specific ways. The application of the RROI approach would be expected to be customised first to projects and sectors in similar generic situations and then developed for a wider set of generic situations.

In each of these, a review of opportunities, key partners and priorities is required to move the RROI framework into practice and create a resilience shift in this sector, including observations from the Resilience Dividend Valuation Model¹⁶.

Proposed features of applications

¹⁵ <http://documents.worldbank.org/curated/en/350411468149663792/pdf/WPS6852.pdf>

¹⁶ <https://www.rockefellerfoundation.org/blog/valuing-resilience-dividend/>

THE RESILIENCE SHIFT

Quantifying the “Resilience Return on Investment” (RROI) for critical infrastructure is a critical component in the building and financing of resilient projects.

An RROI can drive better projects that can access financing, achieve multiple co-benefits (stakeholders) and viability of the communities these projects support. Based on our research a consistent RROI approach that can be adopted by the financial sector can play a key role in the Resilience Shift.

Conclusion

The scoping study has highlighted the need to promote resilience engineering to integrate resilience practices into infrastructure projects.

It is recommended that the framing strategy for RROI be further expanded and applied to a critical infrastructure case study (pilot) to prove out the required metrics, process and outputs.

Next steps include:

- Identifying 3 pilot projects to apply the RROI tool and process.
- Identify key stakeholders to include in the process and tool development.
- Pilot the RROI as a mechanism to embed resilience within the infrastructure project delivery framework of a global engineering firm (Amec Foster Wheeler E&I Ports Sector)
- Develop the RROI tool process map and engagement model
- Identify the initial RROI “impact categories” and “design input” that are baseline requirements for adoption
- Develop the initial CBA tool for RROI and apply to a pilot project to benchmark and output development