

Can transport system resilience and sustainability be economically efficient?

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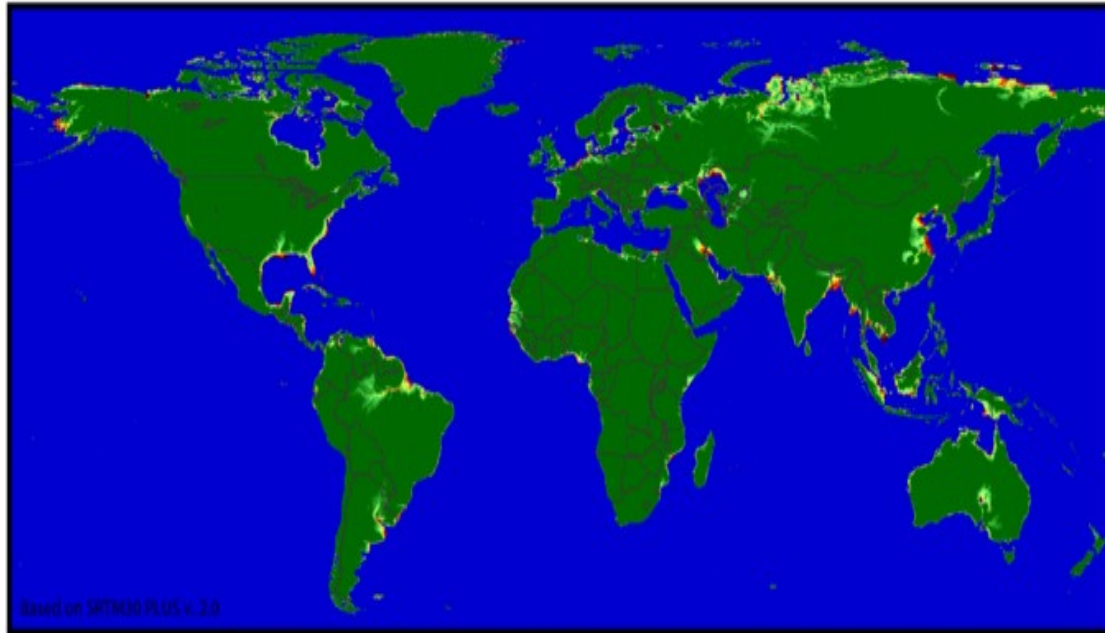


Presentation Overview

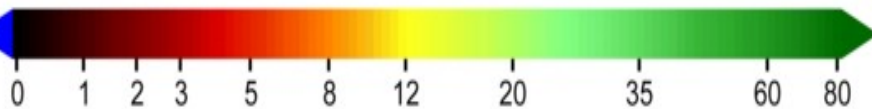
- Climate predictions
- Implications for transport systems
- Defining four key terms:
 - - resilience
 - - sustainability
 - - adaptation
 - - economic efficiency
- Is there a conflict between resilience/sustainability and economic efficiency?
- Conclusions

Hard Science...

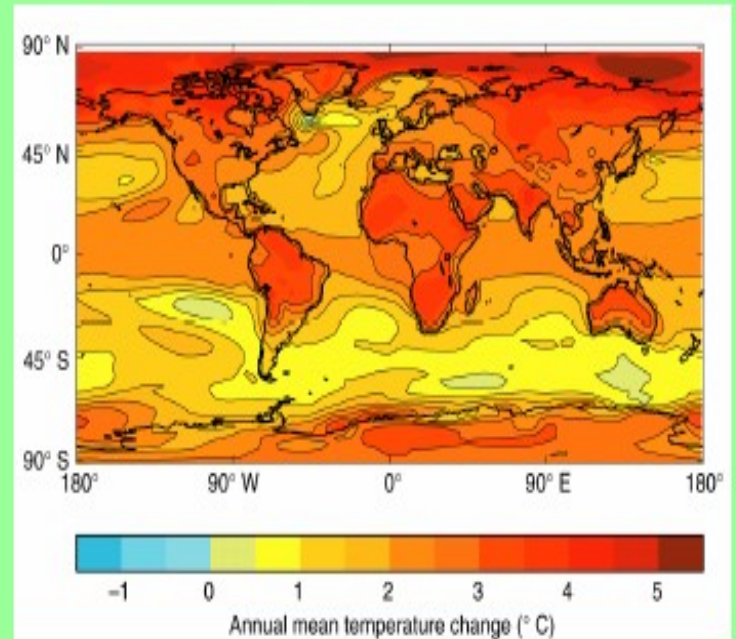
Regions Vulnerable to Sea Level Rise



Height Above
Sea Level (m)



Change in annual temperatures for the 2050s



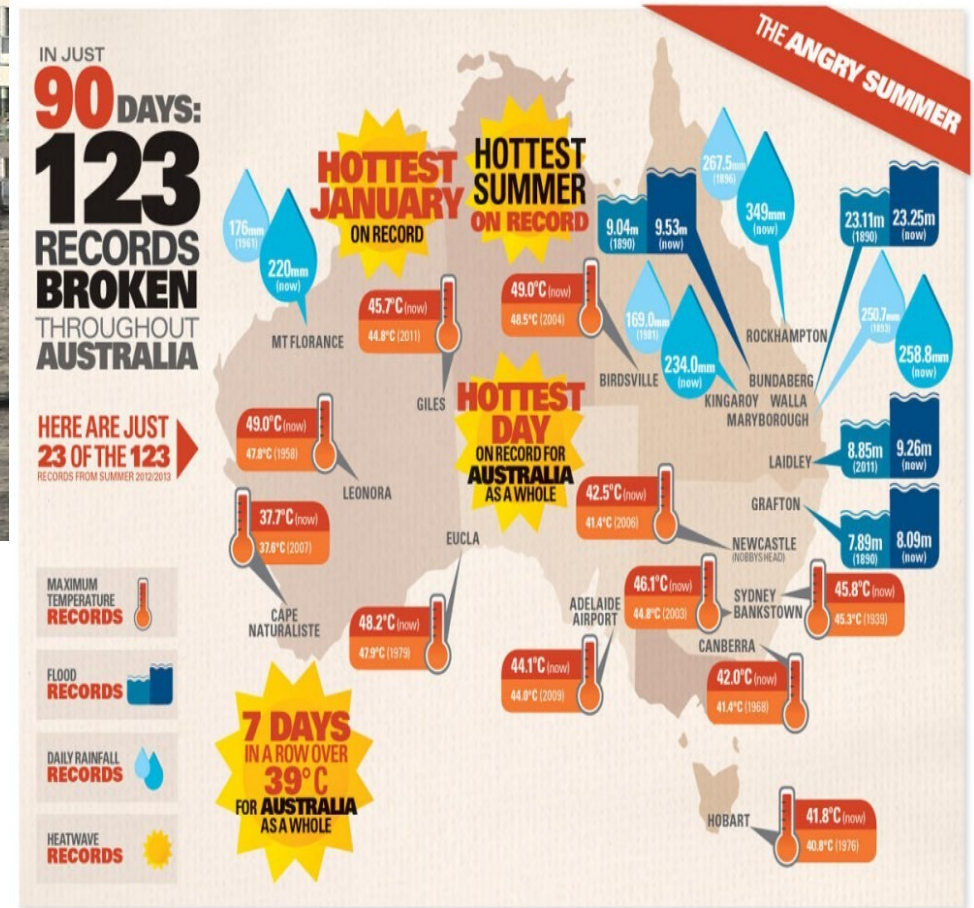
The change in annual temperatures for the 2050s compared with the present day, when the climate model is driven with an increase in greenhouse gas concentrations equivalent to about a 1% increase per year in CO₂. The picture shows the average of four model runs with different starting conditions.

The Met.Office Hadley Centre for Climate Prediction and Research

Expected climate change outcomes – already underway and worsening

- Increases in mean temperature levels. 2 degrees C is happening. Trying to avoid 4-5 degree 'catastrophic' increases.
- Increases in variability of temperature around the mean, i.e. more extremes of heat and, less often, cold
- More 'extreme' weather events such as cyclones and intense rainfall
- Sea level rise due to hotter oceans expanding and polar ice cap melt

Signs of the times....



- Clockwise from left – Brisbane Floods 2011 (Courier Mail); 2012/13 Summer heat records (indymedia.org.au); Victoria bushfires 2009 (The Age);

Likely impacts of climate change on transport systems

- Temperature-related infrastructure and material stresses such as greater freeze-thaw cycles, buckling due to intense heat etc.
- Temperature-related user stresses such requiring more use and employment of ventilation, air-conditioning etc.
- Water-related infrastructure stresses such as flooding, saltwater intrusion, moisture damage from humidity, bank erosion due to heavy rainfalls etc.
- Extreme weather impacts, e.g. hailstorms.

...An example of potential infrastructure impact



Flood map shows the extent of flooding of Brisbane Airport in 2100 if sea levels rise 1m. Picture: OzCoast, AustralianOnline Coastal Information Source: The Courier-Mail

Transport stresses: New York City

Transportation

Roadways

Temperature

- Increased road material degradation, resulting in increased road maintenance

Precipitation

- Declining level of service from flooded roadways^f
- Increased hours of delay from increased congestion during street flooding
- Insufficient pumping capacity and associated increased energy use for additional pumping to remove excess water to prevent flooding

Sea level rise

- Declining "level of service" from flooded roadways
- Increased hours of delay from increased congestion during street flooding episodes
- Insufficient pumping capacity and associated increased energy use for additional pumping to remove excess water to prevent flooding

Transit

Temperature

- Increased use of cooling equipment
- Increased rail degradation and equipment deterioration, resulting in increased maintenance
- For commuter rail, increase in transit accidents from train collisions with overhead lines sagging

Precipitation

- Insufficient pumping capacity and associated increased energy use to remove excess water for the prevention of flooding
- Mean Distance Between Failure (MDBF) decreases producing delays
- Increase in number of stops due to emergencies

Sea level rise

- Increase in number of emergency evacuations
- Increased rail degradation and equipment deterioration from saltwater inundation, resulting in increased maintenance

Transport stresses: King County, WA, USA

Climate change and related policy will have impacts to transit operations in King County.

- Changes in weather may increase storm events (e.g., flooding, ice, wind, snow) that may disrupt bus service and impede regional mobility.
- Increased summer temperatures could reduce the comfort level and public health of buses that lack air conditioning. (See "Public Health" section.)

Climate change will have impacts to roads and related infrastructure in King County.

- Changes in precipitation patterns and sea level rise may cause greater damage to roadways, bridges and seawalls from erosion, landslides, and flooding.
- Increased temperatures will not have a direct effect on transportation infrastructure. However, increased summer droughts could decrease the survivability of plantings used in wetland and stream mitigation or roadside landscaping, and could increase fire danger along roadways.
- Change in weather may increase other storm events (e.g., ice, wind, snow) that also require ongoing responses from road maintenance crews in order to maintain public safety and mobility.
- Increased demands on staff in response to storm damaged infrastructure reduces the available staff and equipment resources available to carry out normal day-to-day operations.
- Construction of infrastructure projects relies on predictable and reliable weather patterns in order to schedule and complete weather sensitive types of work. Variable and unpredictable patterns of weather will create scheduling conflicts for critical project work and will impact available resources. This will necessitate longer contract durations to complete

The relevance of resilience

- Since climate change is already causing a number of demonstrable effects, and these effects are expected to worsen, many are speaking of the need for transport systems (and human/infrastructure systems more generally) to be designed to be more 'resilient'.
- "Resilience" is a term with many definitions but one concept by Holling focuses on system homeostasis and the ability to return to an initial state of dynamic equilibrium. Speed of return (elasticity), and the closeness between initial and return state (malleability) are key elements.
- Social psychologists (e.g. Reich 2006) look at human ability to cope with and adapt to disaster.
- Both senses can be applied together when speaking of transport system resilience.

Sustainability

- Some theorists argue that resilience, by itself, is too narrow since it focuses only on restoring a prior state rather than attaining a superior state to the status quo.
- This is the essence of sustainability which, it can be argued, contains resilience within it, but allows for evolution towards 'higher' states.
- Some resilience theorists such as Holling, and Petersen do note that resilience allows for both improvement and, its basic prerequisite, existence of function.

Adaptation

- Finally there is a great deal of talk of climate change adaptation.
- The Australian Government's Climate Change Adaptation Program speaks of "helping Australians to better understand and manage risks linked to the carbon pollution which continues to increase in our atmosphere and to take advantage of potential opportunities" and "projects and assessments to improve our knowledge of the impacts of climate change; strengthen the capacity of decision-makers to respond; address major areas

Economic efficiency

- Economists have their own benchmark to measure states of affairs: economic 'efficiency'.
- Conceptually this is pretty simple and consists of maximising consumer 'welfare' which itself is defined as satisfying consumer desires (which are taken as given) subject to resource constraints:
- Max 'U' = $f(n)$ s.t. Resource constraint where U= 'utility'.
- Any action that does not meet this condition is said to be economically 'inefficient'

Is resilience and sustainability necessarily economically efficient?

- This is the argument that some economists seem to make and some economic analysis tools, such as benefit-cost analysis, seems to imply.
- To be sure, the necessity of survival (existence, to use the words of some resilience experts) and the desirability of dealing with increasing risks are not argued against by anyone.
- But specific measures to 'adapt' to climate change or ameliorate it often are seen as 'sacrifices' involving of economic output, productivity and growth.
- In other words, they are 'necessary evils'.

Understanding resilience more fully

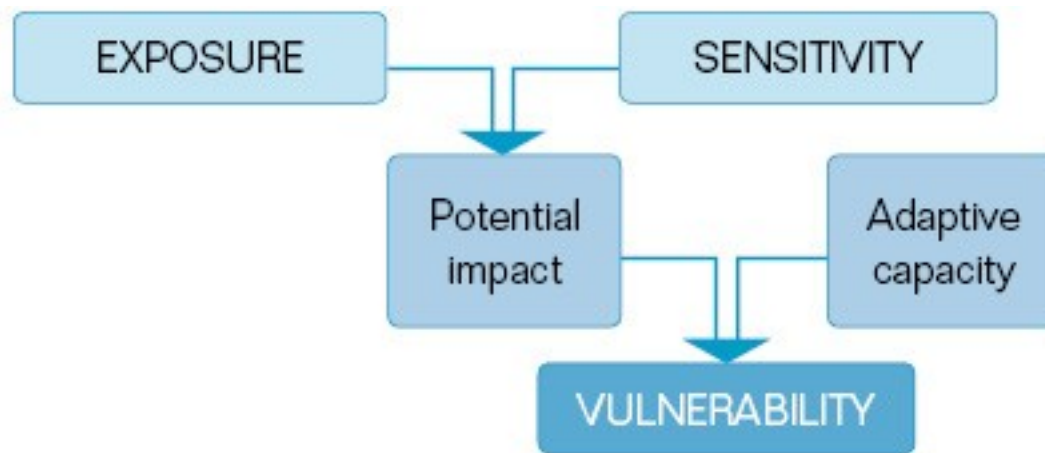
- There are a number of dimensions to the resilience-efficiency debate:

- (1) what factors build up resilience and what are the 'efficiency' implications of those factors?
- (2) what sorts of actions increase resiliency and what are their 'efficiency' implications?
- (3) how 'efficient' is the status quo ex ante to begin with?
- (4) is the 'efficiency' baseline itself sensible?

(1) Resilience factors

- Transport system resilience relies on capabilities (i.e. the general ability to respond and adapt to changes) and capacity (the ability to deliver a certain quantity and quality of service).
- These are important for efficiency as well (e.g. business theorists speak of core capabilities and capacity underlying competitive advantage) so there is no inherent conflict here between the two.
- Example: building redundancies are seen as inefficient. But resilience and sustainability both require proactive capacity and not just reactive capacity and Rice and Caniato 2003 speak of both flexibility and redundancy, and surely no redundancy at all is inefficient simply due to thermodynamics and entropy.

- A key issue is how consider what changes are coming and how to organize both capacity and capability to respond to those changes AND, if possible, to improve system outcomes overall.
- Reducing 'vulnerability' is the term of art here.



Source: Garnaut Report chapter 6

(2) Efficient actions to enhance resilience

- There are, of course, inefficient ways to prepare for and adapt transport systems to climate change.
- Climate 'security' measures, such as hardening of facilities or building spare capacity that sits idle most of the time are examples of what economists call generators of 'deadweight loss'.
- Some of this is certainly necessary but more emphasis should be placed on building of efficient capacity, e.g. spare capacity that can be useful even in non-emergency situations, such as interoperability for freight and transport rail.

- Of course some resilience and adaptation measures can be 'cost neutral', such as painting surfaces of transport facilities white rather than a darker color, to reflect rather than absorb heat.
- Other measures, such as urban agriculture and greening around transport lines, may have immediate co-benefits that outweigh their costs regardless of whether they will ever be used in resilience adaptation.
- The US GAO refers to policy measures such as energy efficiency that have such benefits as 'no regrets' policy.

Figure 3: Rain Garden in King County, Washington



Source: King County Department of Transportation Road Services Division.

This rain garden, which is under construction, treats roadway runoff using natural vegetation and certain types of soil.

Figure 2: New York City Department of Parks and Recreation Green Roofs at Five Borough Technical Services Facility

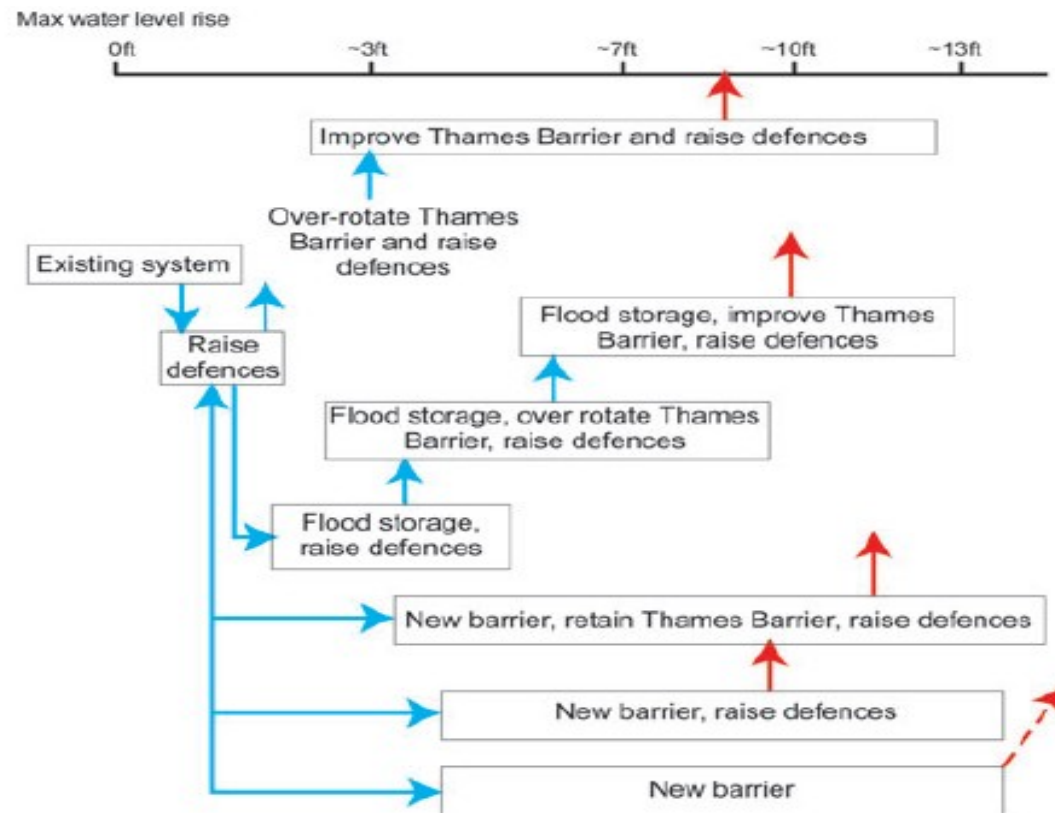


Source: GAO.

Sedum (left) and native plants (right) are used in the green roof at the Five Borough Technical Services Facility.

Source: USGAO

- Even where 'hardening' or large engineering works are needed and which are generally have little productive capacity other than needed 'insurance' against catastrophe, phasing of works might be possible, as is the case with the Thames of London.



Source NYAS

Figure 2.3. Iterative adaptation strategies to protect London from coastal storms. Source: Greater London Authority.

(3) How efficient is the status quo anyway?

- Economists generally assume that market forces will lead to the most efficient allocation of resources and that government induced climate adaptation actions, however desirable in other ways, will move the market off that efficiency.
- However there is a lot of non-market activity already and even in private markets there is what economists refer to as 'X-inefficiency' which compares how theory suggests firms should behave with how they actually behave. Often these differences can be traced back to strategies to deal with real-world uncertainty such as 'satisficing'.

(4) Is the 'efficiency' baseline sensible?

- This is a fundamental question.
- Some eco-theorists argue completely against the use of economic theory and method when dealing with ecological policies.
- However this is strong position that may throw out a useful concept which, however, has flaws in the face of fundamental climate change and itself needs to be adapted.
- Yoh and Leichenko (2010) speak of altering the efficiency baseline to one of having responses that work well for a wide variety of outcomes rather than optimally for any particular one.

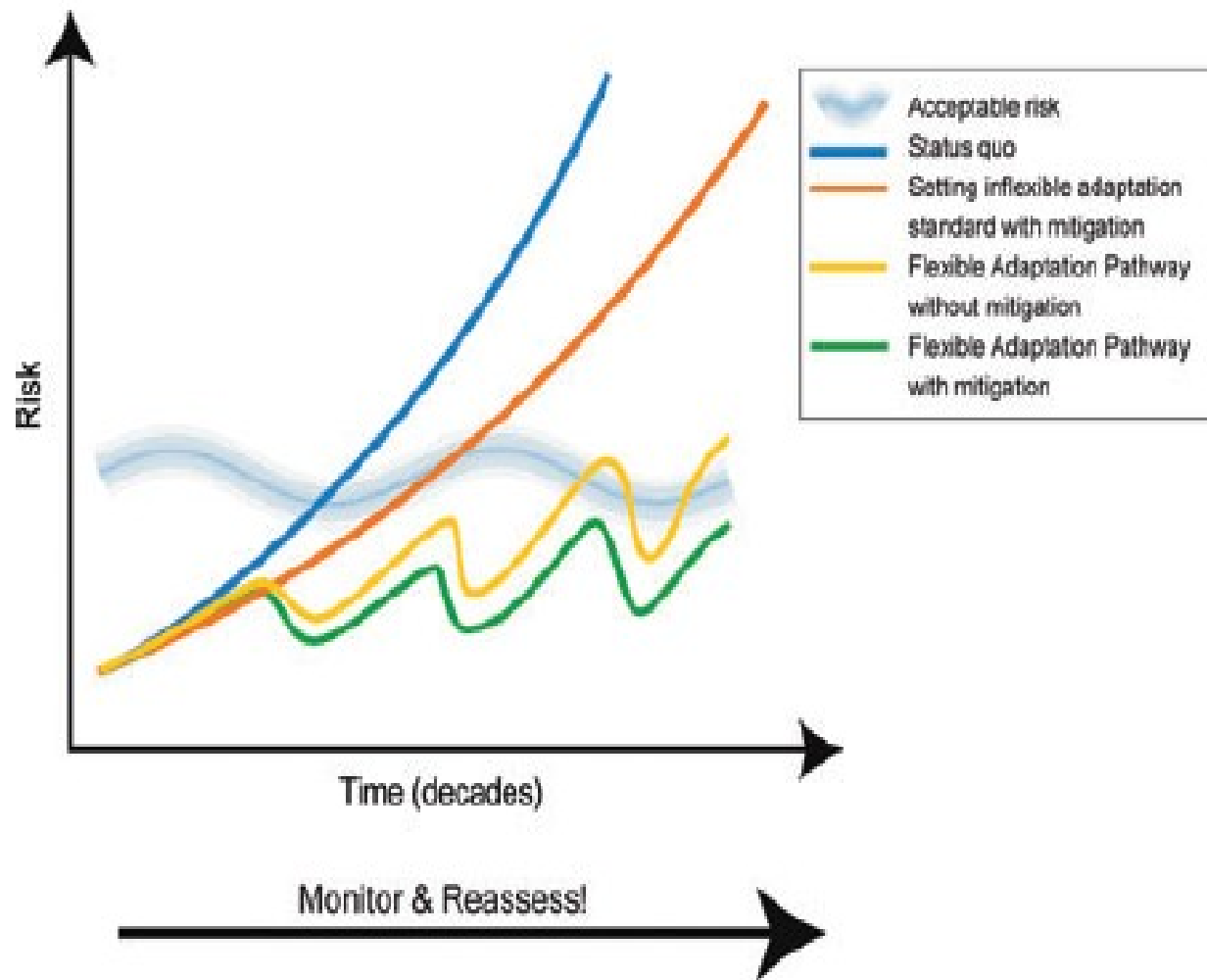


Figure 2.1. Flexible adaptation and mitigation pathways. Adapted from City of London, "The Thames Estuary 2100 Plan," April 2009.

The fundamental question of values

- At the core of the economic efficiency idea are consumer preferences which are taken as given and not explained.
- In a real sense economic efficiency is very changeable according to consumer wants.
- If these wants change towards more 'sustainable' choices, then the conflict between resilience/sustainability and efficiency is eliminated.
- However while policies to change preferences might be useful one should not define them away.

Conclusions

- Resilience and sustainability in transport systems are not inherently at odds with economic efficiency.
- Some adaptations may in fact increase efficiency if done well.
- However, there certainly will be a tradeoff between the two given the changes we are seeing and some sacrifice for survival is needed.