

# Method to Assess Resilience of the Marine Transportation System

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US Army Corps of Engineers  
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# Overview

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2. Definitions of Resilience
  - a) Engineering
  - b) Ecological
  - c) Community
3. Resiliency of the MTS
4. Calculation of a Resilience Metric on a System-Scale
5. Summary



# Motivation: Chief of Engineers' Charge to the Coastal Engineering Research Board (CERB)\*, Sep 2013

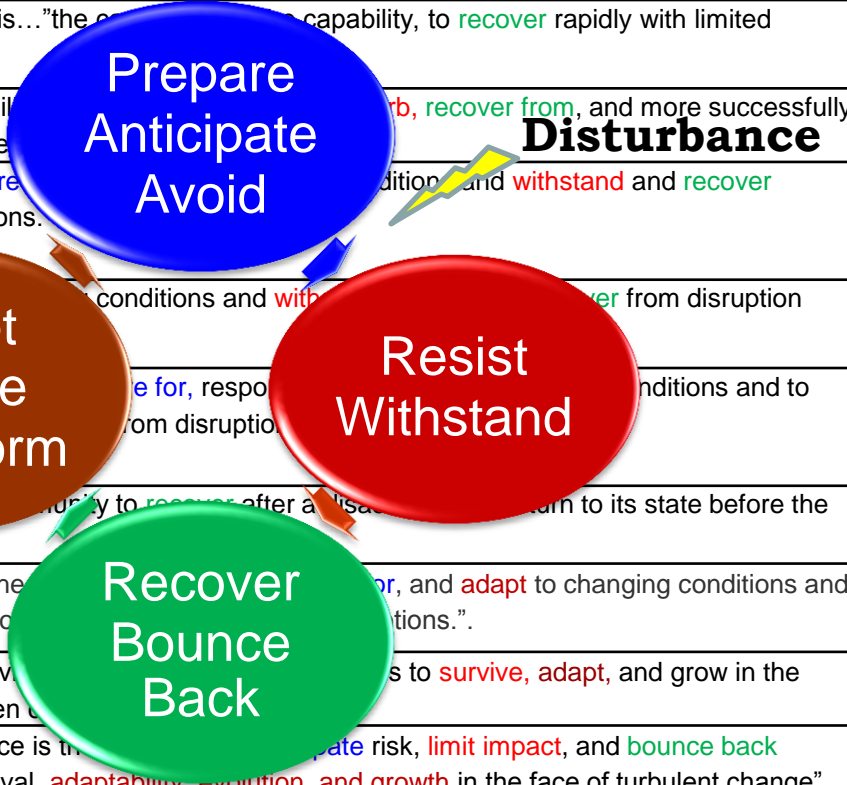
Identify a research and implementation strategy to:  
...**integrate resilience practices** with existing risk-reduction approaches.  
...provide specific guidance on **research needs** that will provide the technical basis for sound engineering capability.

*\*Established by law in 1963 to advise USACE on Coastal Engineering Research needs*



# Definitions of Resilience

Key words:  
 Prepare  
 Resist  
 Recover  
 Adapt



Study	Definition
American Society of Civil Engineers (2006) <a href="http://www.asce.org/Content.aspx?id=8478">http://www.asce.org/Content.aspx?id=8478</a>	"Resilience refers to the capability to <b>mitigate</b> against significant all-hazards risks and incidents and to expeditiously <b>recover</b> and reconstitute critical services with minimum damage to public safety and health, the economy, and national security."
National Disaster Recovery Framework, Strengthening Disaster Recovery for the Nation (FEMA 2011) <a href="http://www.fema.gov/media-library/assets/documents/24647?fromSearch=fromsearch&amp;id=5124">http://www.fema.gov/media-library/assets/documents/24647?fromSearch=fromsearch&amp;id=5124</a>	A resilient community has ... "an improved ability to <b>withstand</b> , respond to and <b>recover</b> from disasters."
The Infrastructure Security Partnership and Society of Military Engineers (SAME). "Understanding Resilience – Disaster Resilience Begins with You" (2012) <a href="http://tis">http://tis</a>	Disaster Resilience is... "the capability, to <b>recover</b> rapidly with limited damage."
Disaster Resilience (2012) <a href="http://www">http://www</a>	"Resilience is the ability to <b>adapt</b> , <b>withstand</b> , <b>recover from</b> , and more successfully <b>Disturbance</b>
Hurricane Sandy Region (2013) <a href="http://portal.hud">http://portal.hud</a>	"The ability to <b>prepare</b> , <b>withstand</b> , and <b>recover</b> rapidly from disruptions."
Infrastructure Resilience (2013) <a href="http://coastalm">http://coastalm</a>	"Ability to <b>withstand</b> conditions and <b>withstand</b> <b>Recover</b> from disruption
Coastal Risk Resilience (2013) Army Corps of Engineers <a href="http://www.corps">http://www.corps</a>	Ability to <b>withstand</b> conditions and to <b>Recover</b> from disruption
Urban Land Institute Resilience and Adaptability (2013) <a href="http://www.uli">http://www.uli</a>	"The capacity of a community to <b>recover</b> after a disturbance and <b>return</b> to its state before the event."
Presidential Executive Order (2013) <a href="http://www.white">http://www.white</a>	"Resilience means the ability to <b>withstand</b> , respond to, and <b>adapt</b> to changing conditions and situations."
Rockefeller Foundation (2013) <a href="http://www.rockefellerfoundation.org/blog/city-resilient">http://www.rockefellerfoundation.org/blog/city-resilient</a>	"The capacity of individuals and communities to <b>survive</b> , <b>adapt</b> , and grow in the face of changes, even catastrophic ones."
Community and Regional Resilience Institute (CARRI) (2013) <a href="http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf">http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf</a>	"Community resilience is the ability to <b>adapt</b> risk, <b>limit impact</b> , and <b>bounce back</b> rapidly through survival, <b>adaptability</b> , <b>evolution</b> , and <b>growth</b> in the face of turbulent change"
U.S. Army Corps of Engineers Safety of Dams, Policy and Procedures, ER 1110-2-1156 (2014) <a href="http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf">http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf</a>	"The ability to <b>avoid</b> , minimize, <b>withstand</b> , and <b>recover</b> from the effects of adversity, whether natural or manmade, under all circumstances of use."
Intergovernmental Panel on Climate Change Fifth Assessment Report, "Climate Change 2014: Impacts, Adaptation, and Vulnerability" (2014) <a href="http://ipcc-wg2.gov/AR5">http://ipcc-wg2.gov/AR5</a>	"The capacity of a social-ecological system to cope with a hazardous event or disturbance,

# Engineering Resilience

prepare, resist, recover, adapt



The ability of a *system* to **anticipate**, **resist**, **recover**, and **adapt** to achieve *functional* performance under the stress of disturbances.

## Engineering Resilience:

- Reliable, predictable performance
- Range of design forcing

*Most engineered systems do not naturally adapt*

New Orleans Storm Surge Barrier



Schultz, M. T., McKay, S. K., and Hales, L. Z. (2012) "The Quantification and Evolution of Resilience in Integrated Coastal Systems," ERDC TR-12-7, U.S. Army Engineer Research and Development Center, Vicksburg, MS.



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Innovative

Motivation

**Definitions**

MTS Resilience

Resilience Metric

Summary

# Ecological Resilience

prepare, resist, recover, adapt



The capacity of a system to **absorb disturbance** and **reorganize** while **undergoing change** so as to still **retain** essentially the **same function**, structure, identity, and feedbacks

**Ecological Resilience:**  
In general, changes must be gradual for successful adaptation



Walker, B., Holling, C. S., Carpenter, S. R., Kinzig, A. (2004). "Resilience, adaptability and transformability in social-ecological systems". *Ecology and Society* 9 (2): 5.



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Motivation

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# Community Resilience

prepare, resist, recover, adapt



Capability to **anticipate** risk, **limit impact**, and **bounce back** rapidly through survival, **adaptability**, **evolution**, and **growth** in the face of turbulent change.

**Community Resilience:**  
Humans have the capacity to learn and make conscious decisions to avoid future losses



Community and Regional Resilience Institute (CARRI) (2013).

“Definitions of Community Resilience: An Analysis,”

<http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf>



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# Best Management Practices for MTS Resilience

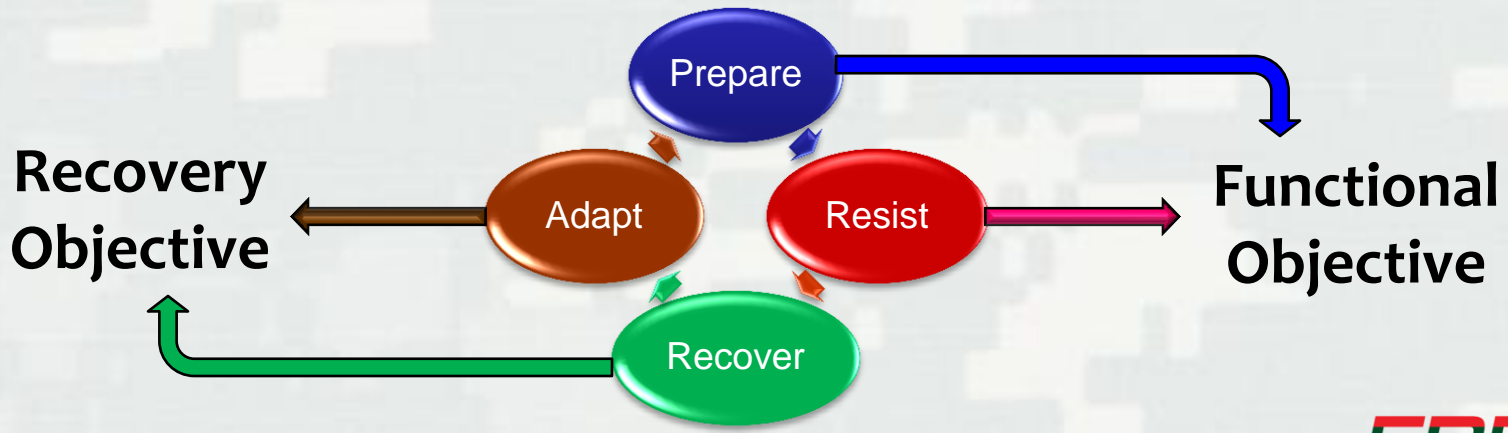
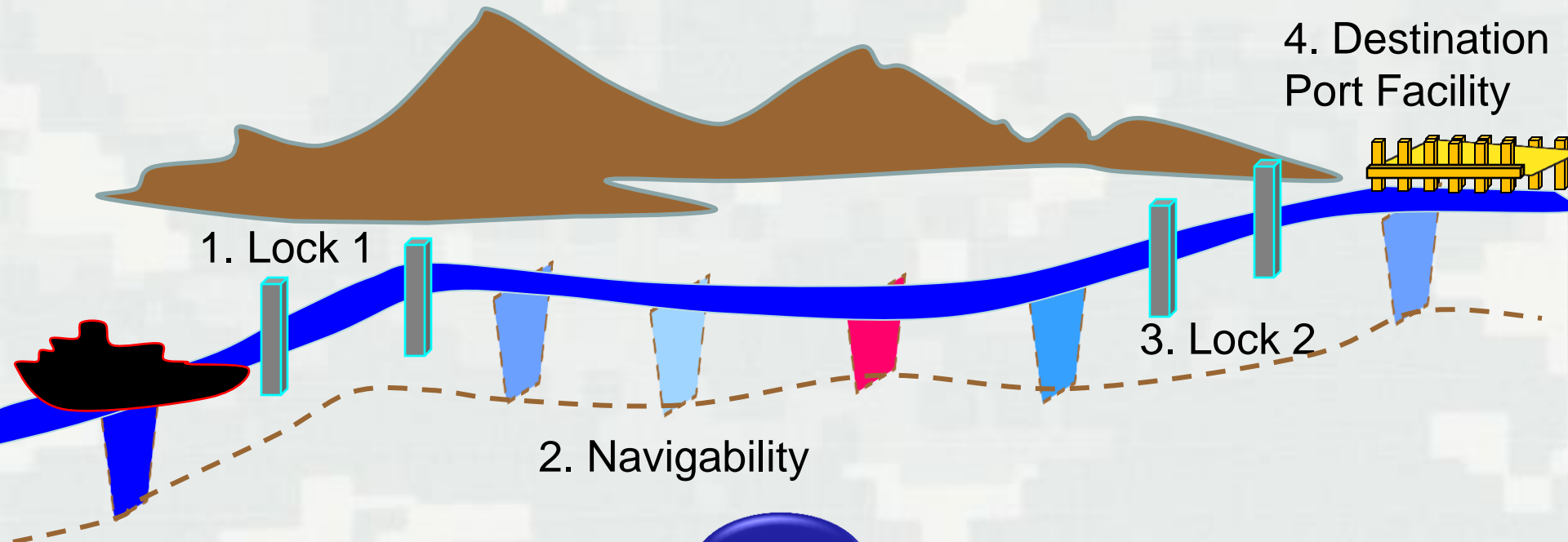


- **Anticipate** “weak links” in system
- Provide **diverse and redundant** protection
- Ensure the system has **modular networks**, with components that are independent of, and complement each other
- Consider **unknowns** associated with extended planning horizons (century-scale)
  - May evaluate 1000s of alternatives
  - Rapidly develop insights and group outcomes via tradespace analytics and big data mining
- Provide **readily-available information** for decision-making at local, state, and national levels





# Hypothetical MTS



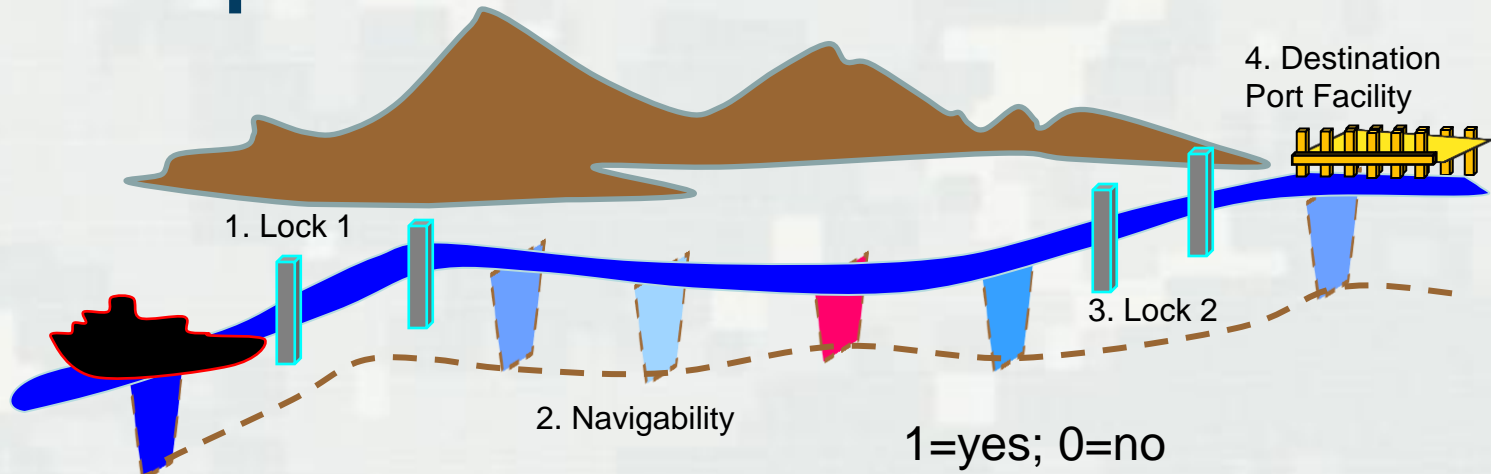
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Motivation	Definitions	MTS Resilience	<b>Resilience Metric</b>	Summary
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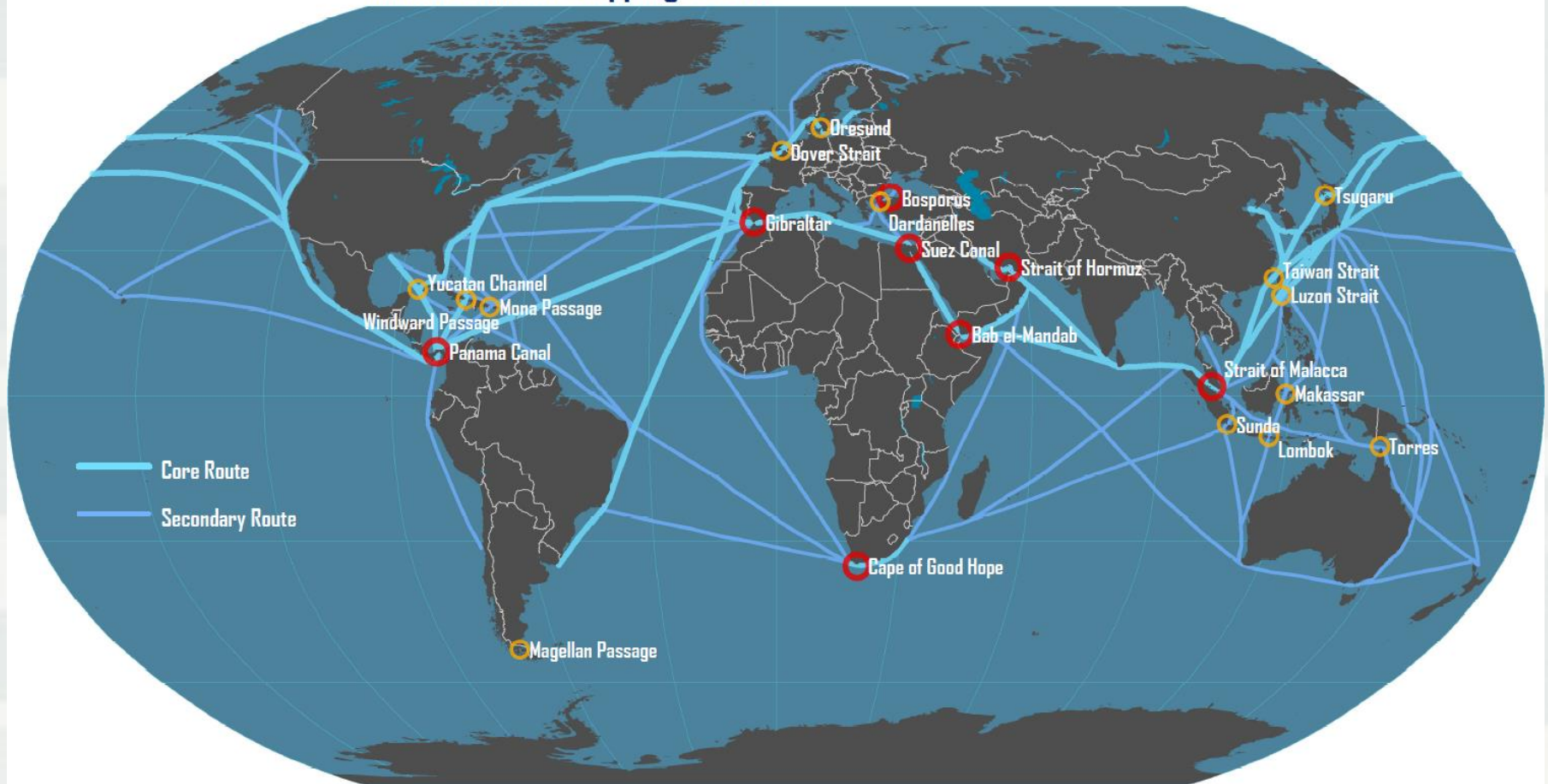
# Example Calculation: Resilience Metric



Critical Element	Functional Obj, F	Recovery Obj, R	Was F met?	Was R met?	F+R	Weighting, W
1. Lock & Dam 1	30 min passage	1 day	1	1	2	0.25
2. Navigable Channel	40-ft depth	1 week	0	1	1	0.3
3. Lock & Dam 2	30 min passage	1 day	1	1	2	0.25
4. Offload Ready	8 hr offload	1 day	0	1	1	0.2
<b>Resilience Metric = <math>\{(2)*0.25+(1)*0.3+(2)*0.25+(1)*0.2\}/2=</math></b>						<b>75%</b>

# International MTS Network

Main Maritime Shipping Routes



Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University.

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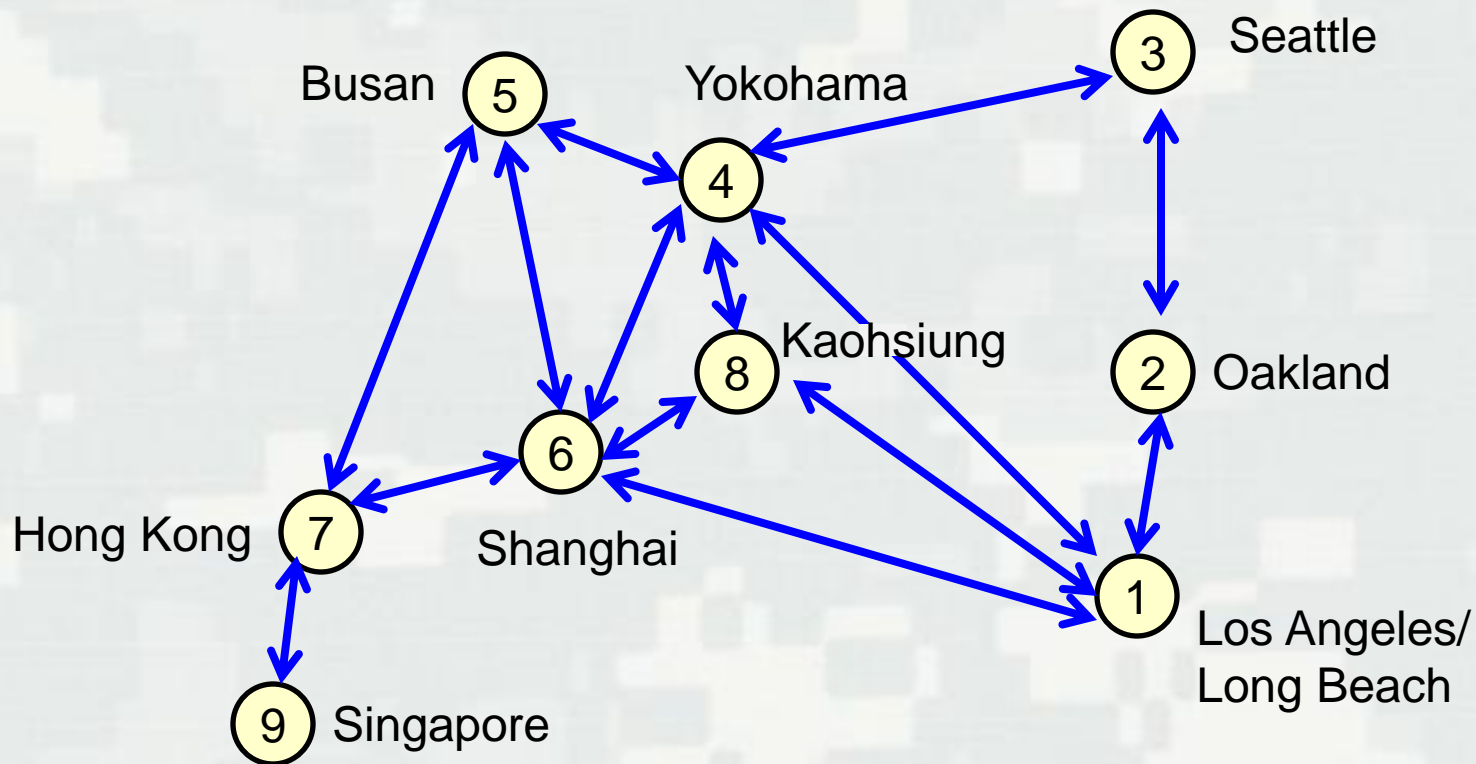
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# Calculating Resilience for a Network

(Omer, 2013)



Omer, M. 2013. "The Resilience of Networked Infrastructure Systems: Analysis and Measurement," World Scientific Pub. Co.



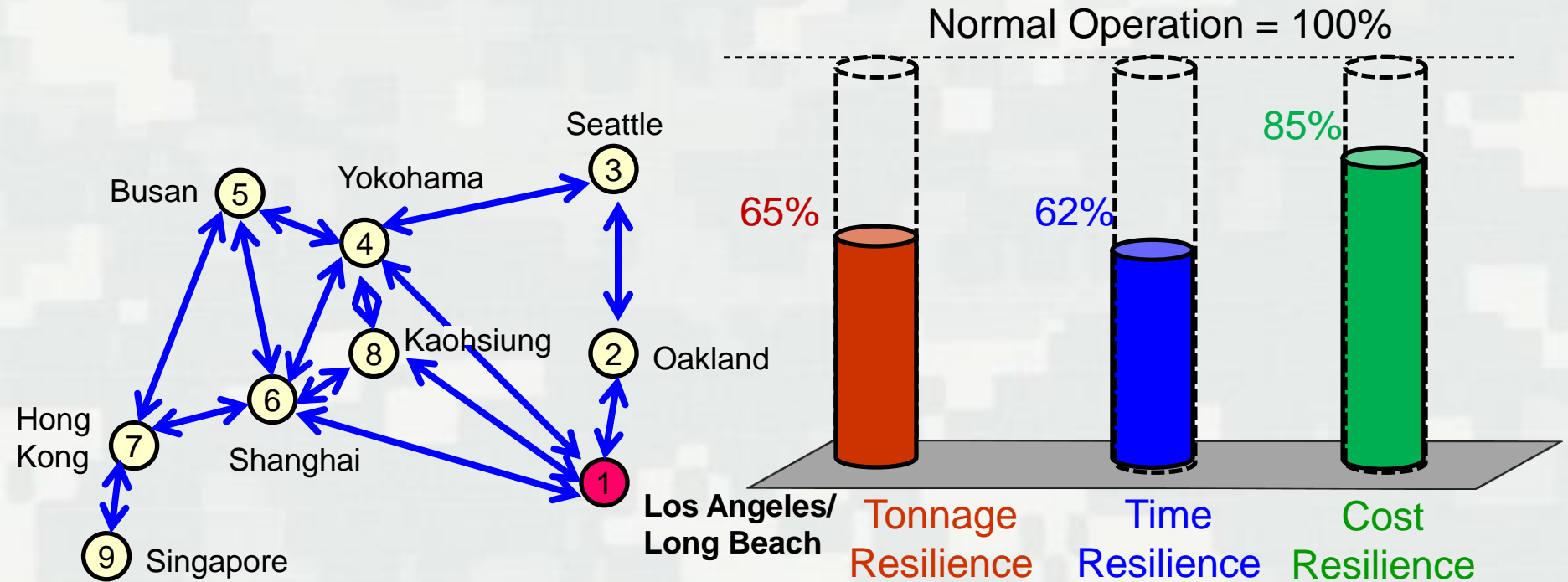
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# Disruption Occurs at LA/LB

(Omer, 2013)



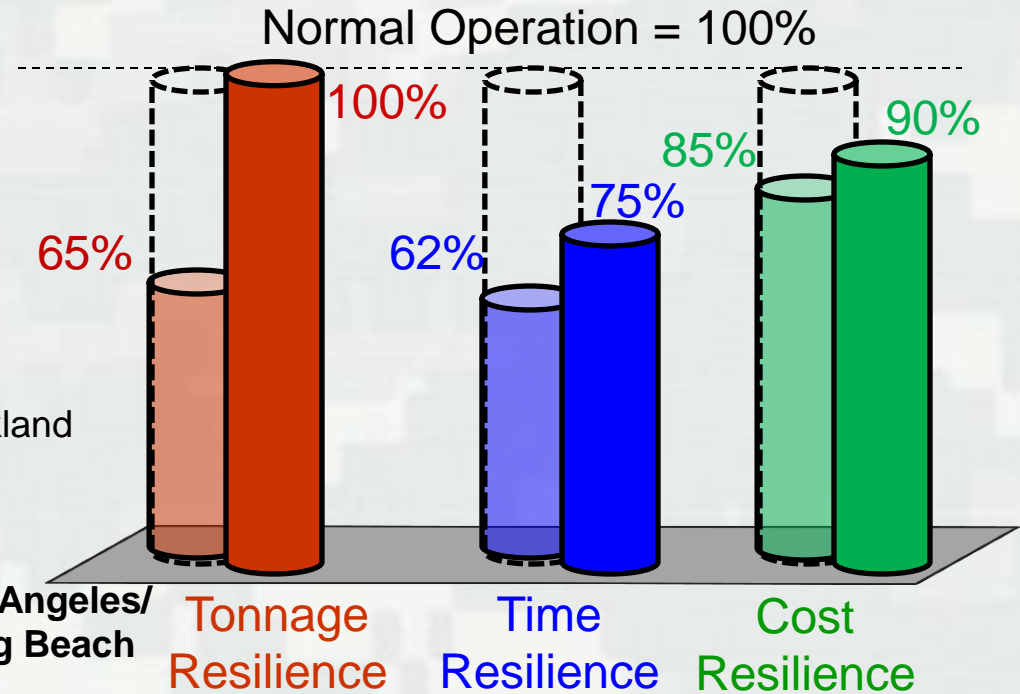
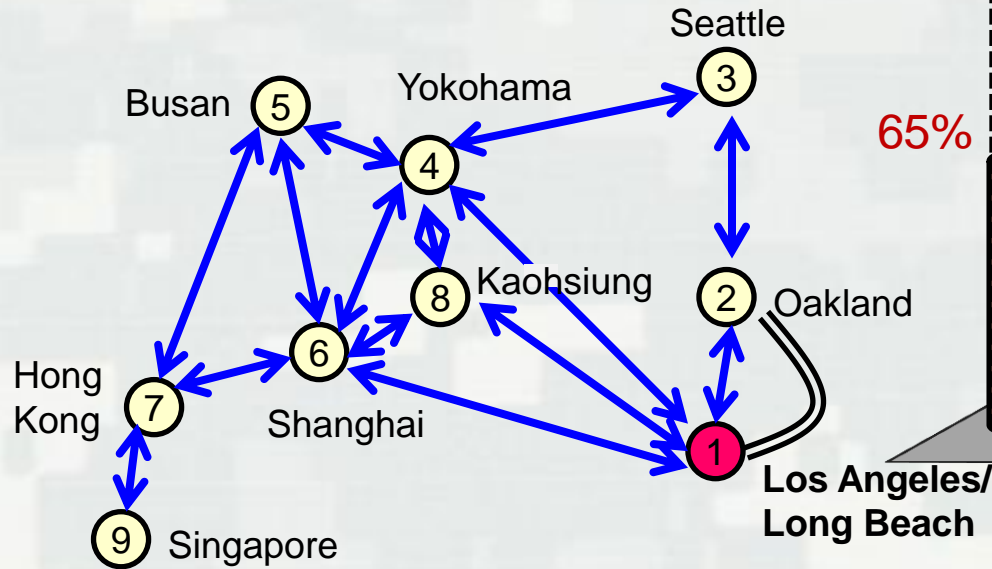
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# With Collaboration Resilience Scheme (Omer, 2013)

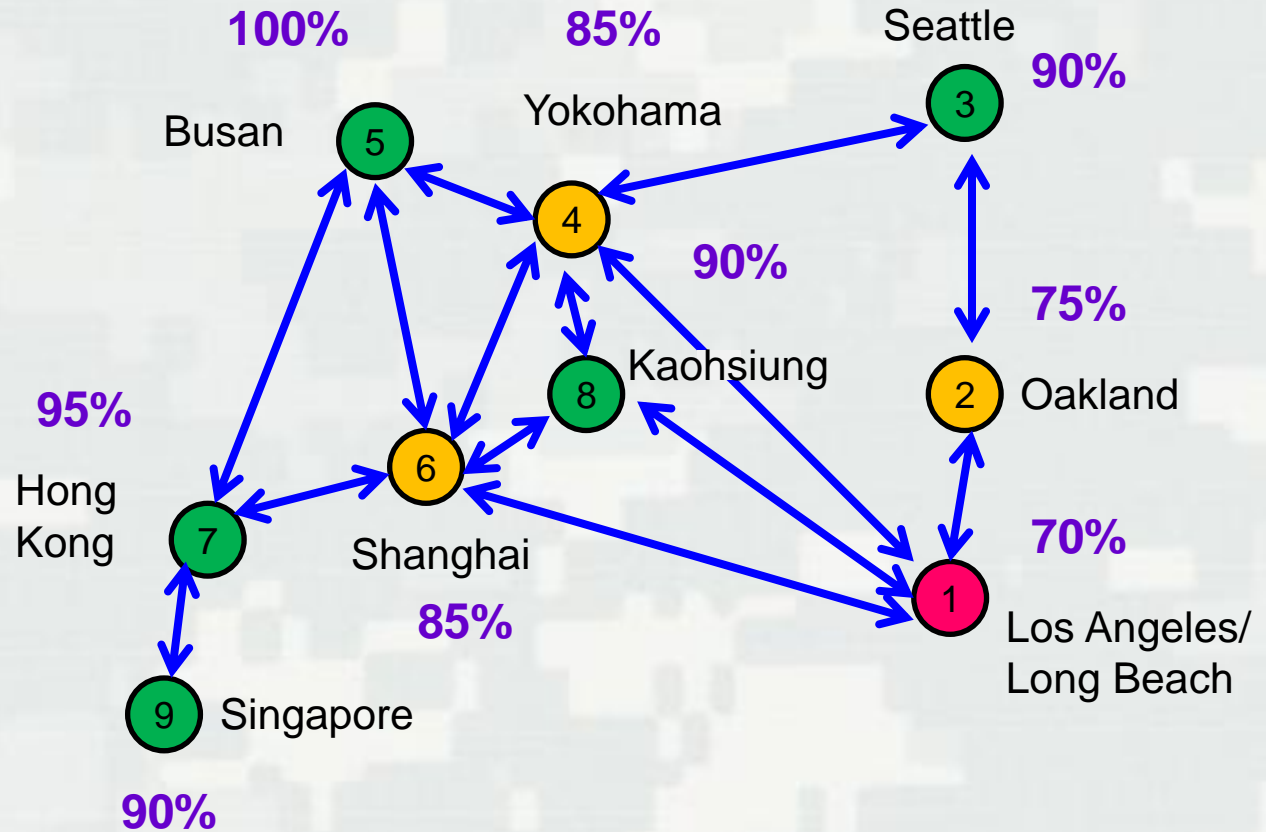
*Collaboration Resilience Scheme: using rail and road transport between LA/LB and Oakland*



# Integrating Network-Wide

## Prior to Resilience Scheme

**R = 79%**



**Resilience Key**

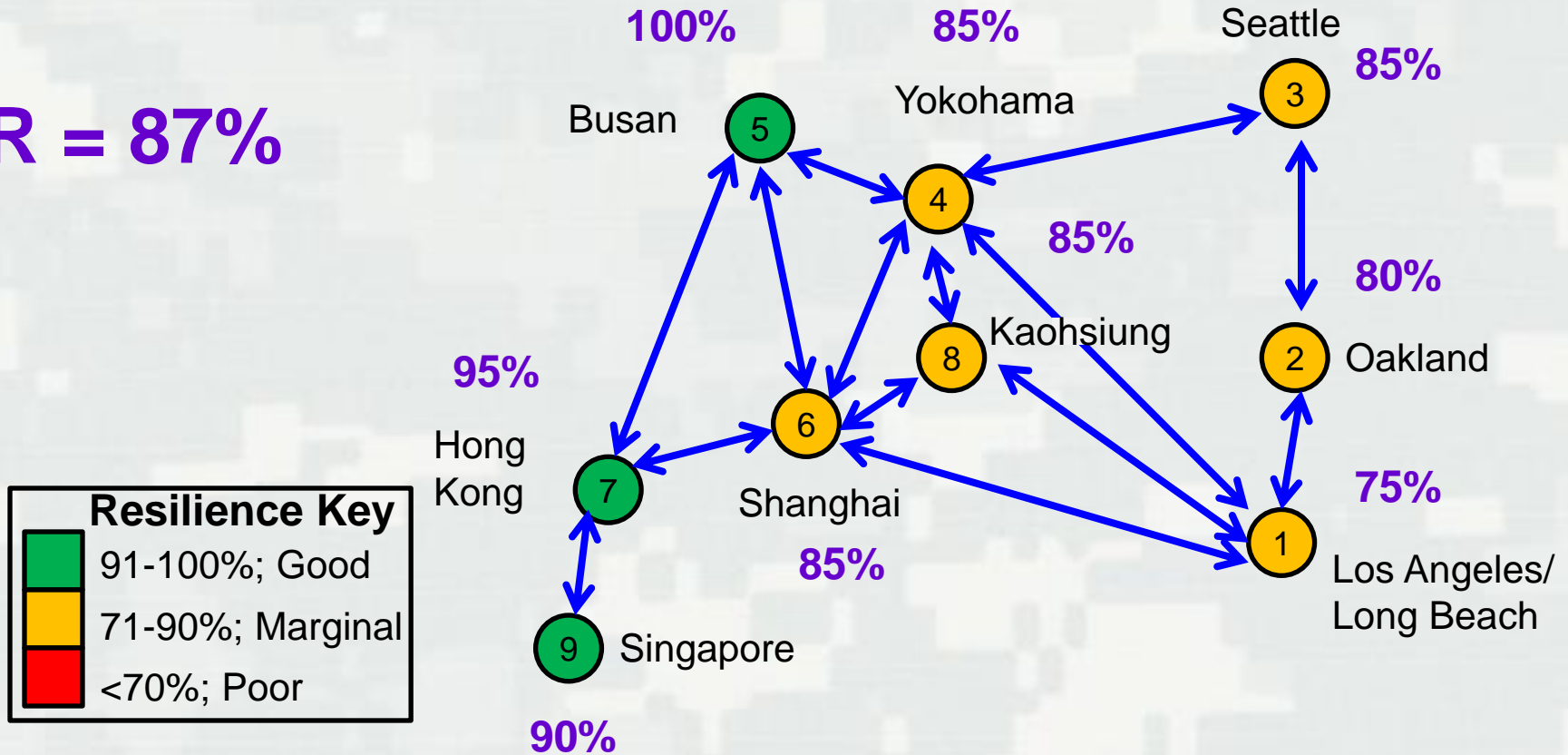
- 91-100%; Good
- 71-90%; Marginal
- <70%; Poor



# System Optimization for Resilience

## With Resilience Scheme (Port rerouting)

**R = 87%**





# Summary



- Chief of Engineers recognized significance of resilience and Charged the CERB:
  - ▶ Identify methods to integrate risk and resilience into coastal practice
  - ▶ Develop R&D needs for implementation of resilience
- Many definitions of resilience
  - ▶ Key words: **prepare**, **resist**, **recover**, **adapt**
- Method to calculate resilience metric based on:
  - ▶ Achieving Functional and Recovery objectives for each element
  - ▶ Weighting Factors that define relative importance of element
  - ▶ For MTS, can consider Tonnage, Cost, and Time Resilience
- Resilience Calculation Method can be applied to measure and optimize resilience of the MTS on *system-scales*

