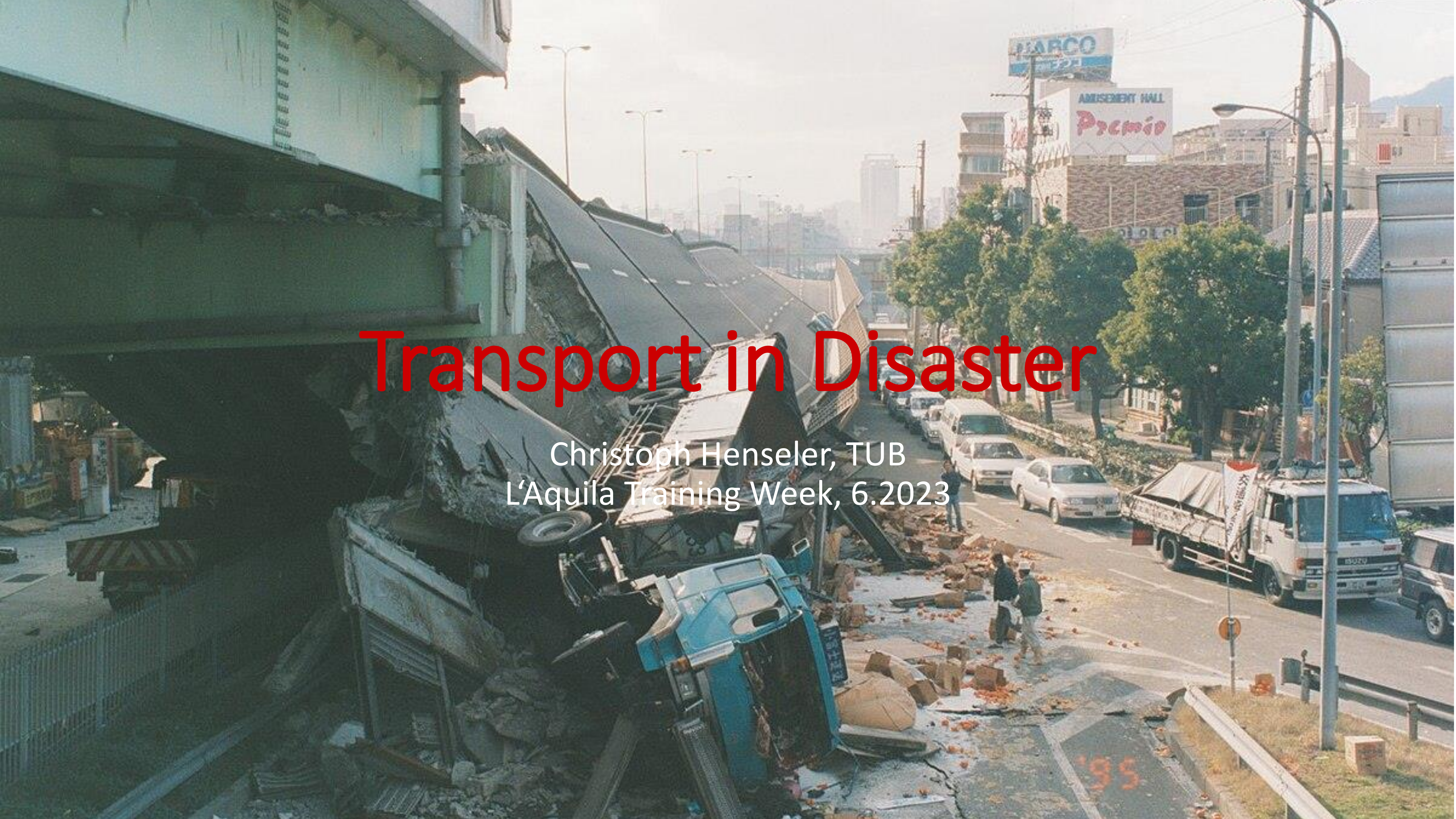

Transport in Disaster

Christoph Henseler, TUB
L'Aquila Training Week, 6.2023

Outline

- Transport Systems
- Hazards and Disasters
- Response and Recovery

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Transport Systems

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Transport as a System

The transport system is a **complex socio-technological system**.

- *System:* it consists of many parts which are interrelated
- *Technological:* different technologies are involved in providing its function
- *socio-:* 1. people and organizations are involved, 2. Laws, regulations etc. are part of the system and necessary for it's functioning
- *Complex:* it is a system of systems, in particular a system of interrelated Transport Modes

Transport Mode: a system made up of

1. Vehicle
2. Infrastructure
3. Service

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- Thinking about transport systems
  - Transport systems as systems: interlinked modes
  - Modes as systems: vehicles – infrastructures – services
  - Infrastructures (vehicles and services)

- Infrastructures in historical perspective

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Modes of Transport

			
	Walking	**Rail**	**Road (Truck)**
Vehicle	-	Train	Truck
Track Infrastructure	Trails	Rail network	Road network
Energy Infrastructure	Food	Electric Grid	Fuel Distribution
Other		Train Station	
Flexibility	High	Low	High
Speed	Very low	High	Medium
Load	Very low	High	medium
Cost Infrastructure	Very low	High	High
Cost Vehicles	none	high	Medium

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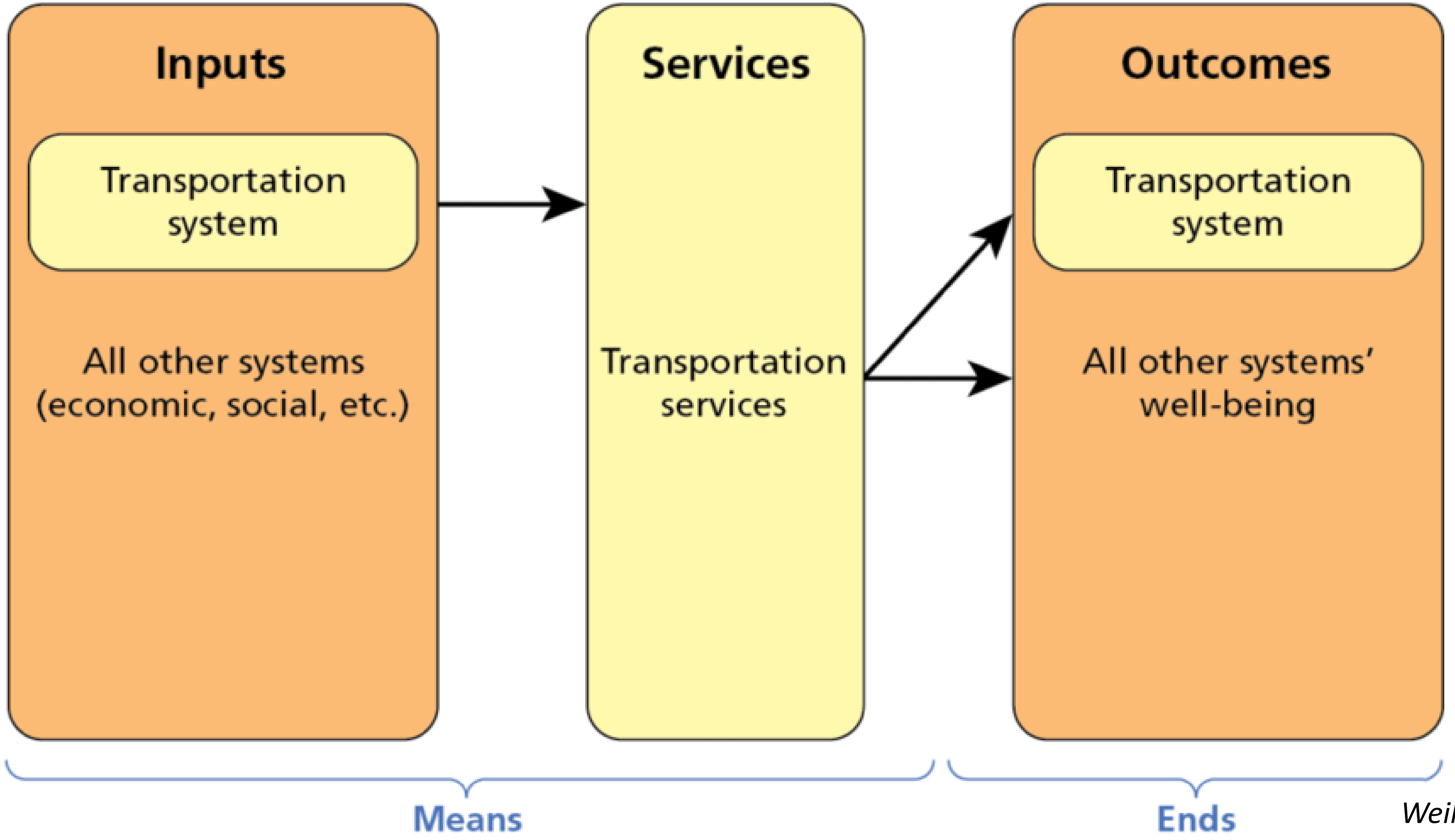
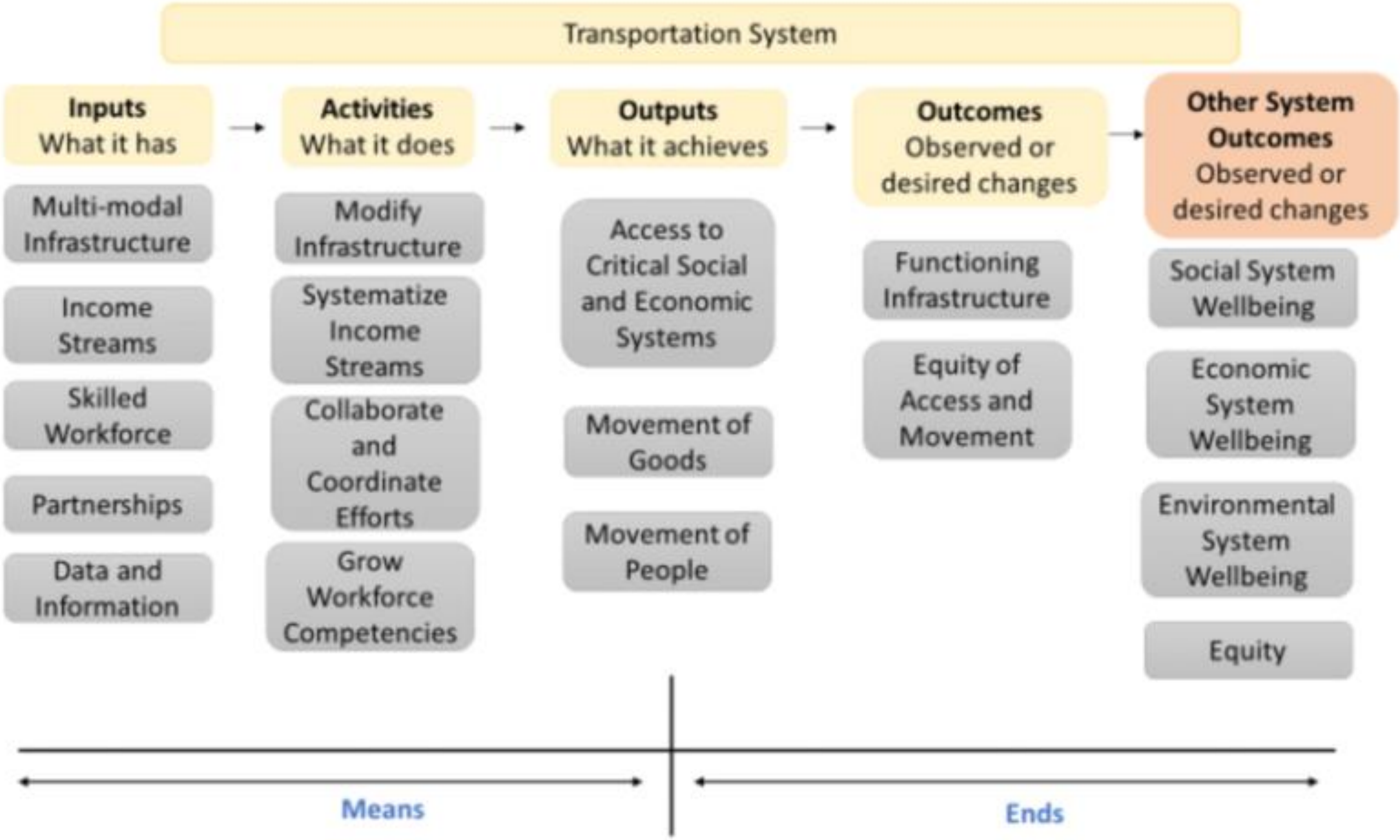
Transport System as Means and Ends



Weilant, Strong, Miller 2019



Weilant, Strong, Miller 2019

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Function – Service – Vehicle – Infrastructure

Function
- Mobility need

Service
- The ride / transportation service

Vehicle
- The vehicle with wich the service is provided

Infrastructure
- Infrastructure (other systems) needed for it to work

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Examples

	Example 1	Example 2	Example 3
Function	Getting to work	Getting food home	Getting food home
Service	Train Ride		Food delivery
Vehicle	Train (Locomotive and wagons)	Car	Truck
Infrastructure	Tracks, Train Stations, Electricity Grid,…	Road network, petrol stations, traffic rules, …	Road network, petrol stations, traffic rules, …

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Infrastructures

- Transport Infrastructure
  - Roads
  - Bridges
  - Traffic Lights
  - Train Stations
  - Harbors
  - Airports
  - …
- Energy infrastructure
  - Electric
    - Electricity Generation
    - Transmission Networks
    - Interfaces: Sockets et al.
    - (Batteries)
    - …
  - Fuel
    - Gas stations
    - Fuel delivery: Trucks, pipelines
    - Fuel production: wells, refineries
    - Tanks
    - …

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Hazards, Disasters, Resilience

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Natural Hazards and Human Disasters

- There are natural phenomena, which pose hazards (earthquakes, floods, …)
- They become disasters only if they meet vulnerable populations

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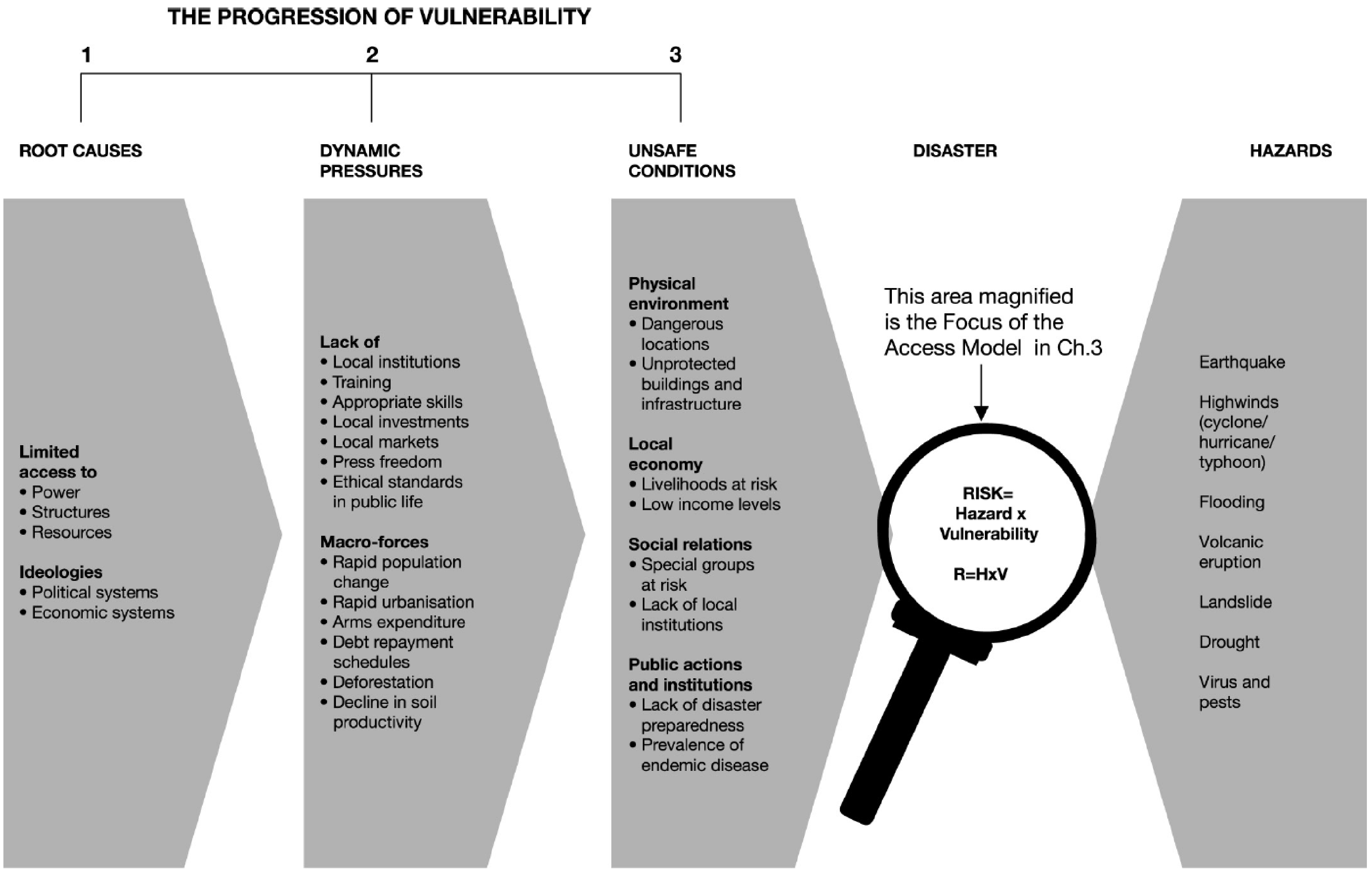

Wisner, Blaikie et al. 2003

Figure 2.1 Pressure and Release (PAR) model: the progression of vulnerability

Disasters and hazards

Table 1.1 Hazard types and their contribution to deaths, 1900–1999

Hazard type in rank order	*Percentage of deaths*
Slow onset:	
Famines – drought	86.9
Rapid onset:	
Floods	9.2
Earthquakes and tsunami	2.2
Storms	1.5
Volcanic eruptions	0.1
Landslides	<0.1
Avalanches	Negligible
Wildfires	Negligible

Source: CRED at www.cred.be/emdat

Wisner, Blaikie et al. 2003

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Term	Interpretation/analysis	References
Vulnerability	It is defined as the susceptibility to damage or perturbation – especially where small damage or perturbation leads to disproportionate consequences. It is also regarded as the property of a transportation system which may weaken or constrain its ability to endure, handle and survive threats and disruptive events that originated both within and outside the system boundaries.	Asbjørnslett & Rausand (1999); Blockley et al. (2012)
Adaptability (or adaptive capacity)	It is defined as one of the functions of a resilient system, reflecting its flexible ability to response to new pressures. Its main features lie in response to changes reflecting the dynamic nature of complex systems.	Bhamra et al. (2011); Dalziell & McManus (2004); Fiksel (2003); Pettit et al. (2010)
Robustness	It is the property of being strong, healthy and hardy. Thus, it is generally defined as the ability to withstand or absorb disturbances and remain intact when exposed to disruptions.	Blockley et al. (2012); Faturechi & Miller-Hooks (2014b)
Flexibility	It's the ability of a system to respond to shocks and adjust itself to changes through contingency planning after disruptions. It is also referred to as an ability to reconfigure resources as well as to cope with uncertainties. As such, connotations of flexibility are opposite to that of robustness which emphasises the ability to endure these changes rather than to adapt to them.	Berle et al. (2013); Cox et al. (2011); Faturechi & Miller-Hooks (2013); Faturechi & Miller-Hooks (2014a); Goetz & Szyliowicz (1997)
Reliability	It is generally defined as the probability that a network remains operative given the occurrence of a disruption event. It can be either a pre-disruption or post-disruption metric for measuring system performance.	Barker et al. (2013); Faturechi & Miller-Hooks (2014a); Shinozuka et al. (2004)
Recoverability (or the ability to recover)	It has been discussed the most in terms of the research of transportation resilience. It is defined as the ability of a network to recover functionality in a timely manner. It is regarded to as an important feature of secure and highly functioning transport networks.	Baroud et al. (2014)
Redundancy	It indicates the ability of certain components of a system to take over the functions of failed components without adversely affecting the performance of the system itself. In the context of transportation, redundancy is generally viewed as the existence of optional routes between origins and destinations. It is commonly accepted that the more redundancy a system has, the more resilient it will be.	Haimes (2009); Fiksel (2003); Tukamuhabwa et al. (2015); Omer et al. (2012)

Source: Zhou, Wang, Yang 2019

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Survivability	It is generally defined as the ability to withstand sudden disturbances while meeting original demands. Survivability techniques have been considered as an access to mitigating the vulnerability of a network or system.	Baroud et al. (2014); Barker et al. (2013); Faturechi & Miller-Hooks (2014b)
Preparedness	It refers to "*prepare certain measures before disruption happens*", and it enhances the resilience of a system by lessening potential negative impacts from disruptive events. It can be subdivided as emergency preparedness and response preparedness.	Berle et al. (2011); Jin et al. (2014)
Resourcefulness	Resourcefulness is defined as the availability of materials, supplies, and crews to restore functionality in a study of transportation resilience. Resourcefulness was treated as one of stabilizing measures in resilience. It indicates the level of preparedness in effectively resisting an adverse event.	Adams et al. (2012); Francis & Bekera (2014); Reggiani (2013)
Responsiveness	It is regarded as an important factor to the resilience of transportation networks. Similar to redundancy, responsiveness factors of a system may also increase the costs although it is able to improve the service level of a system.	Klibi et al. (2010); Ivanov et al. 2014)
Rapidity	It is a well-studied concept in the "*resilience triangle*", a framework that has been applied in civil infrastructure for decades. It contains a hidden meaning of recovery, but with more emphases on the speed to recover. It affects the duration of reduced performance of a system.	Adams et al. (2012); Dorbritz (2011).

Source: Zhou, Wang, Yang 2019

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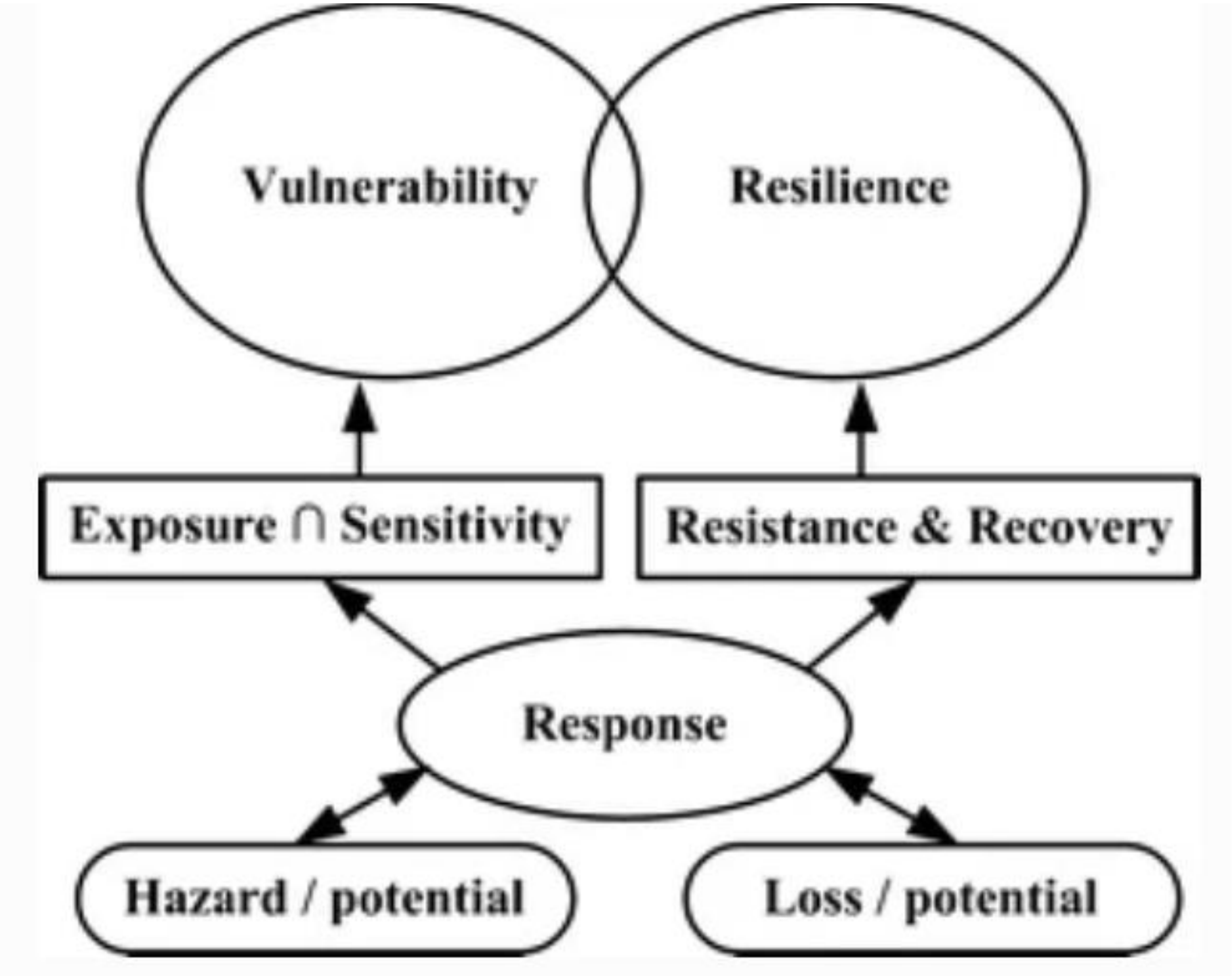
Resilience and Vulnerability



Lei, Wang, Yue 2014

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Disaster Management Cycle

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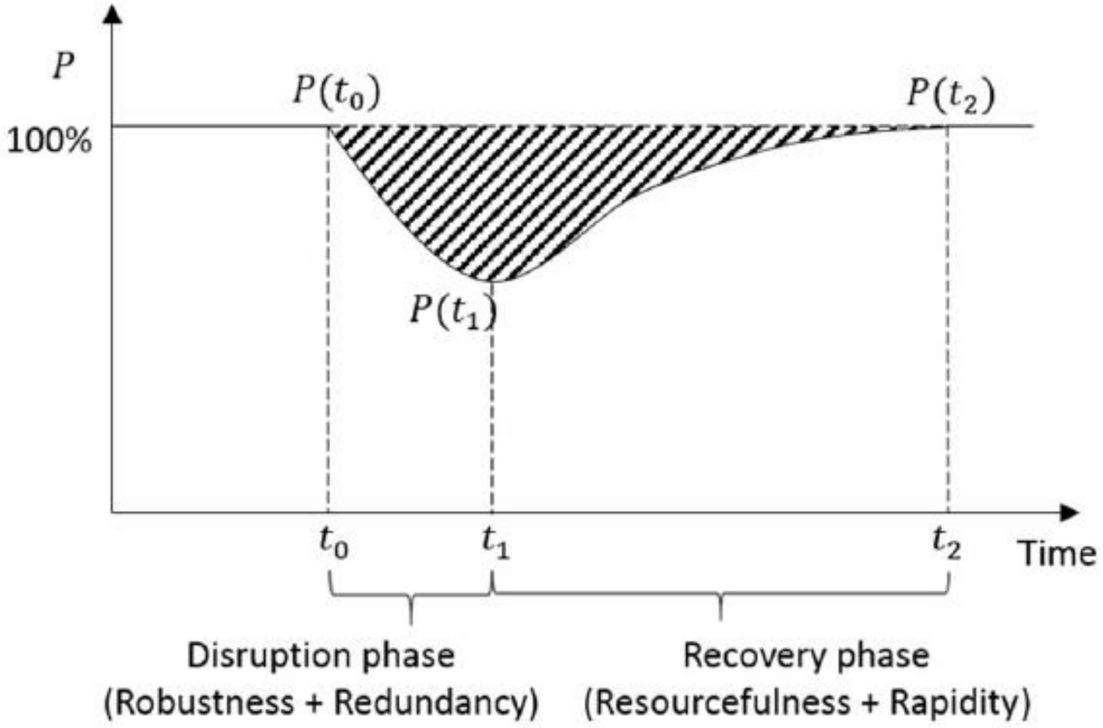
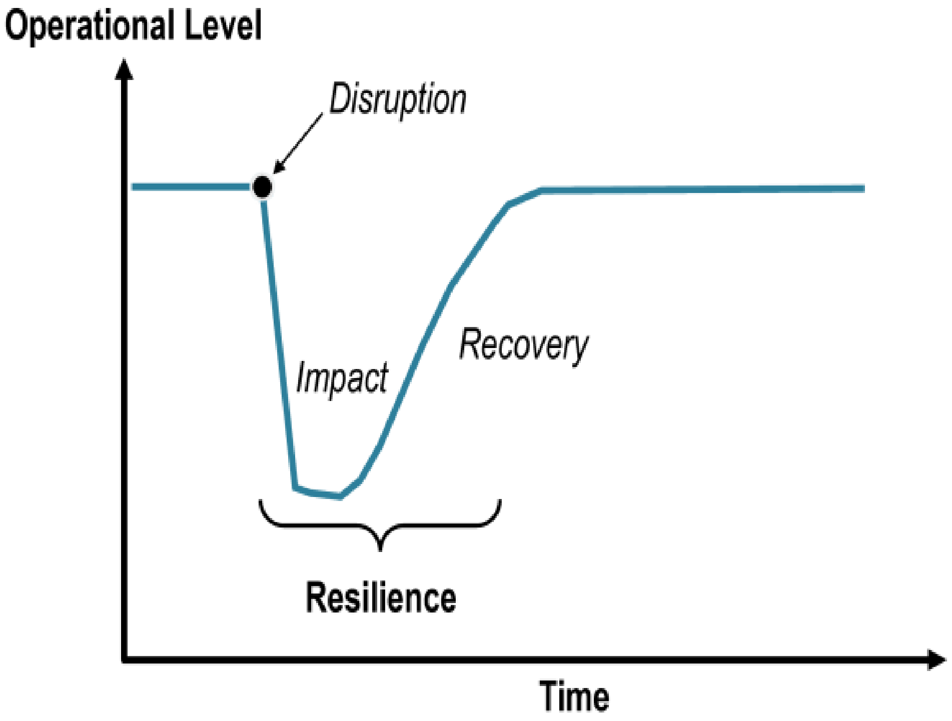
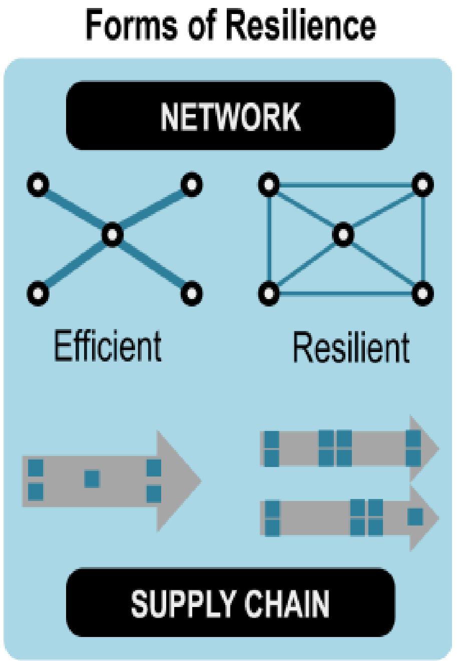


Fig. 3. Two phases of resilience measurement (Adapted from [103])

Zhou, Wang, Yang 2019

Resilience in Transport





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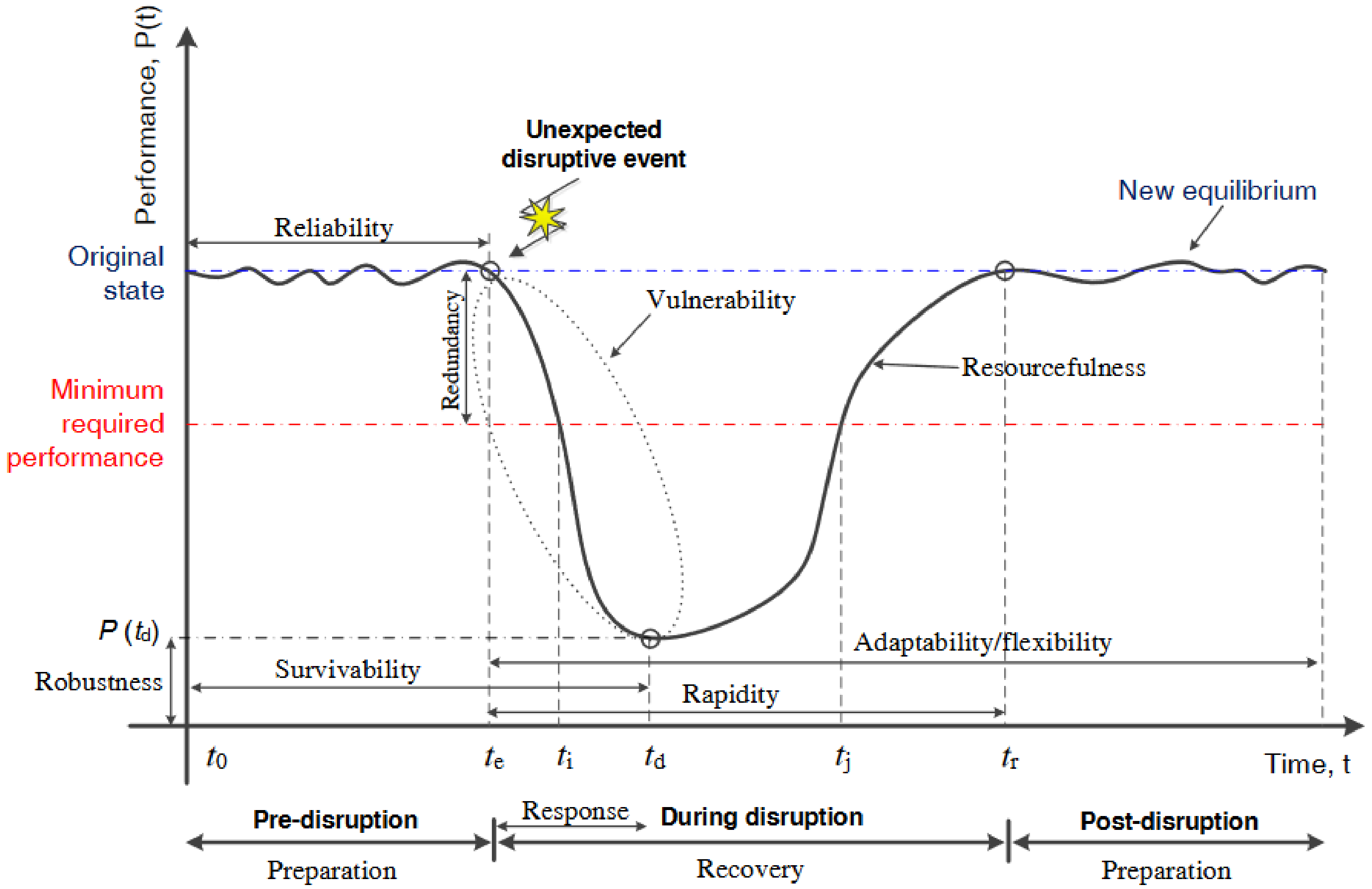
Everything in context



Wan 2017

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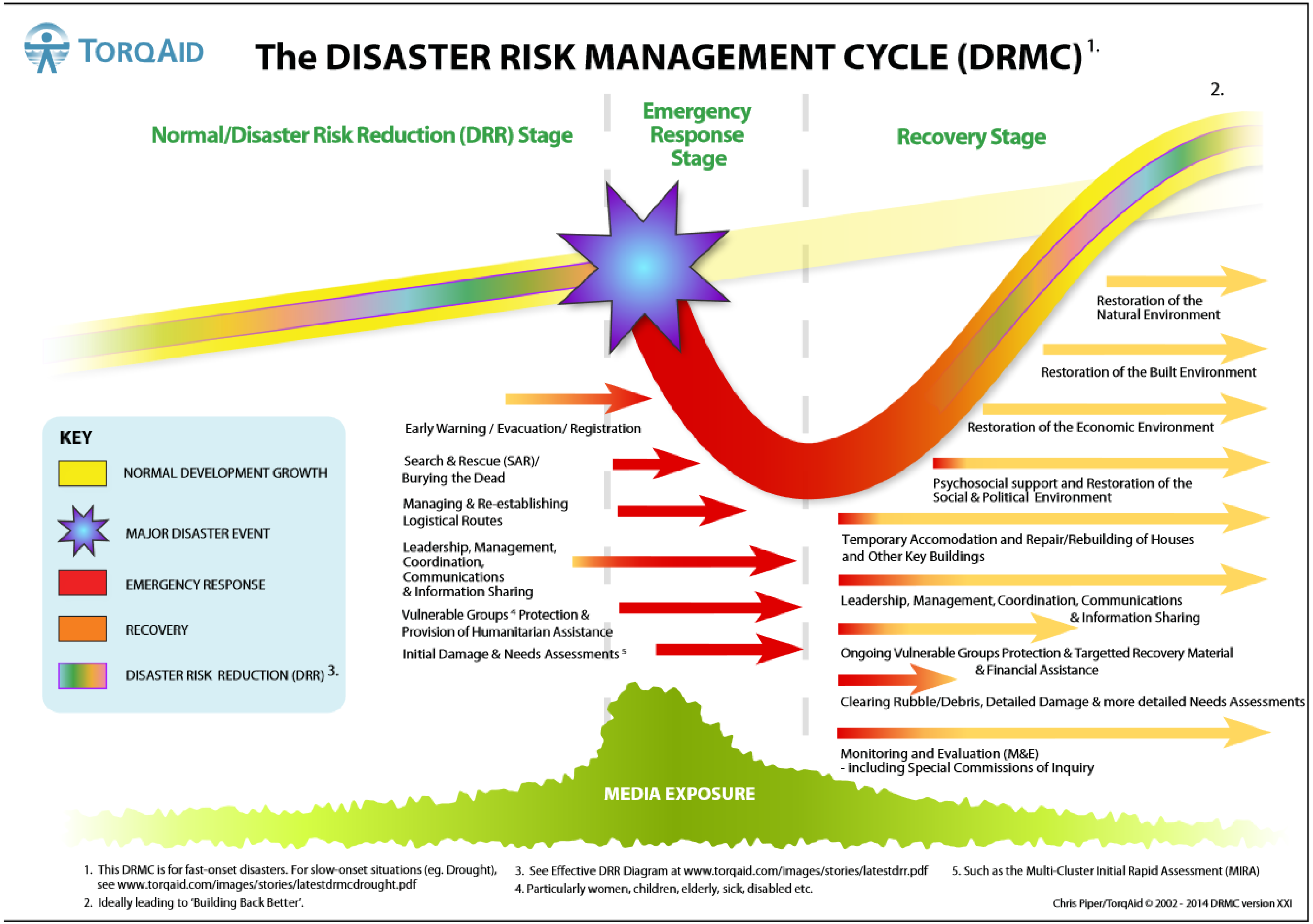

Torqaid 2014

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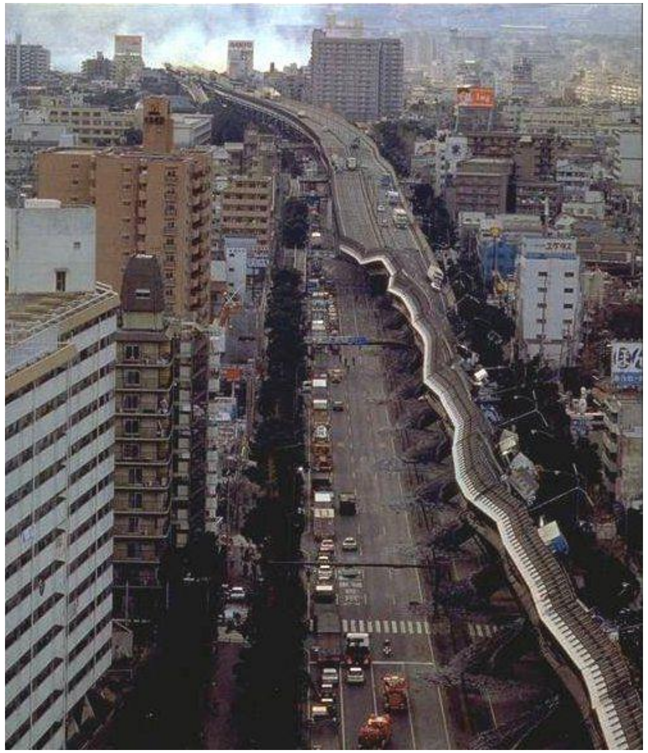
Some Practical Examples



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Rail

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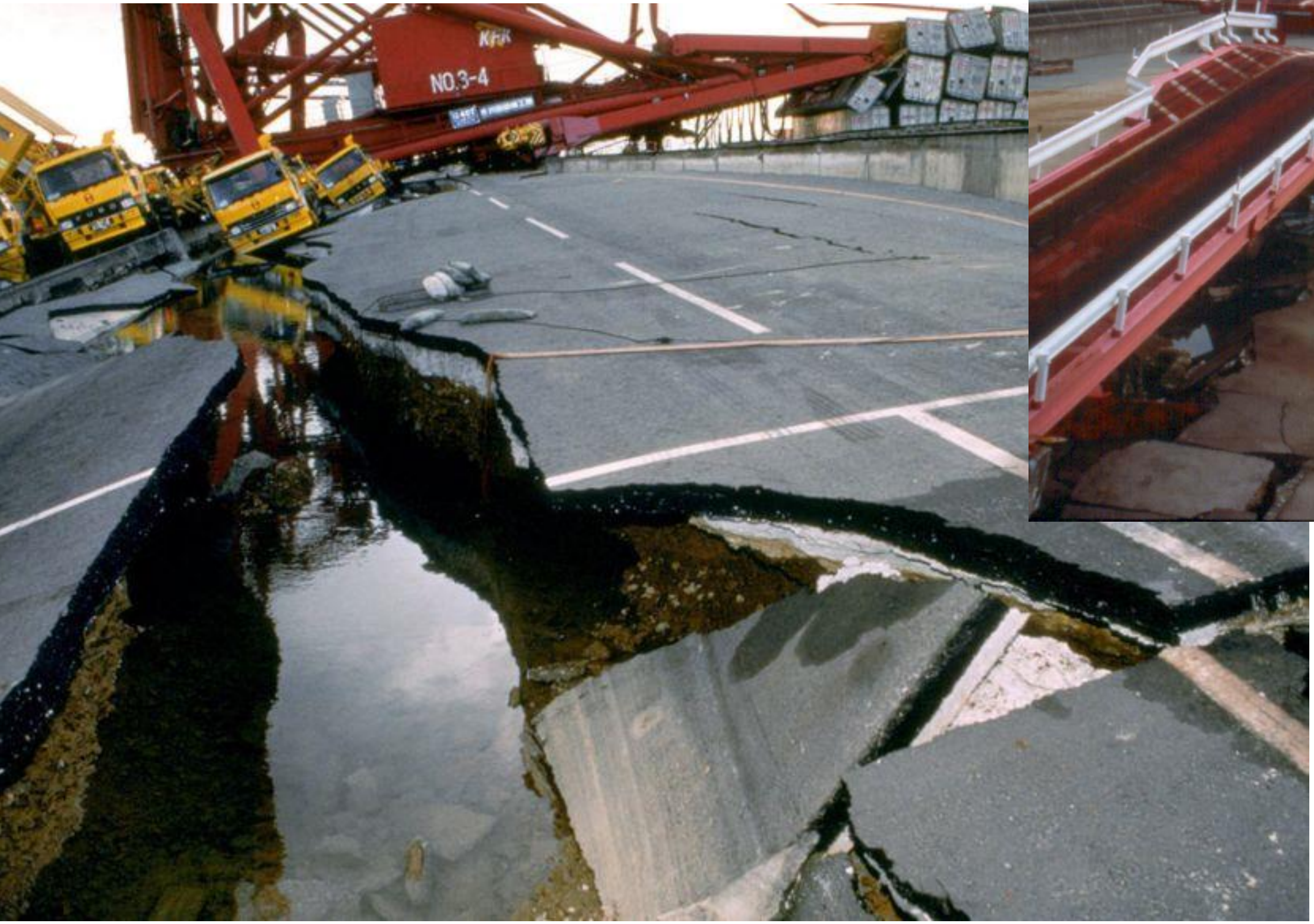
Harbor



Kobe 1995
(picture: national Geographic)

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Example: Kobe earthquake 1995

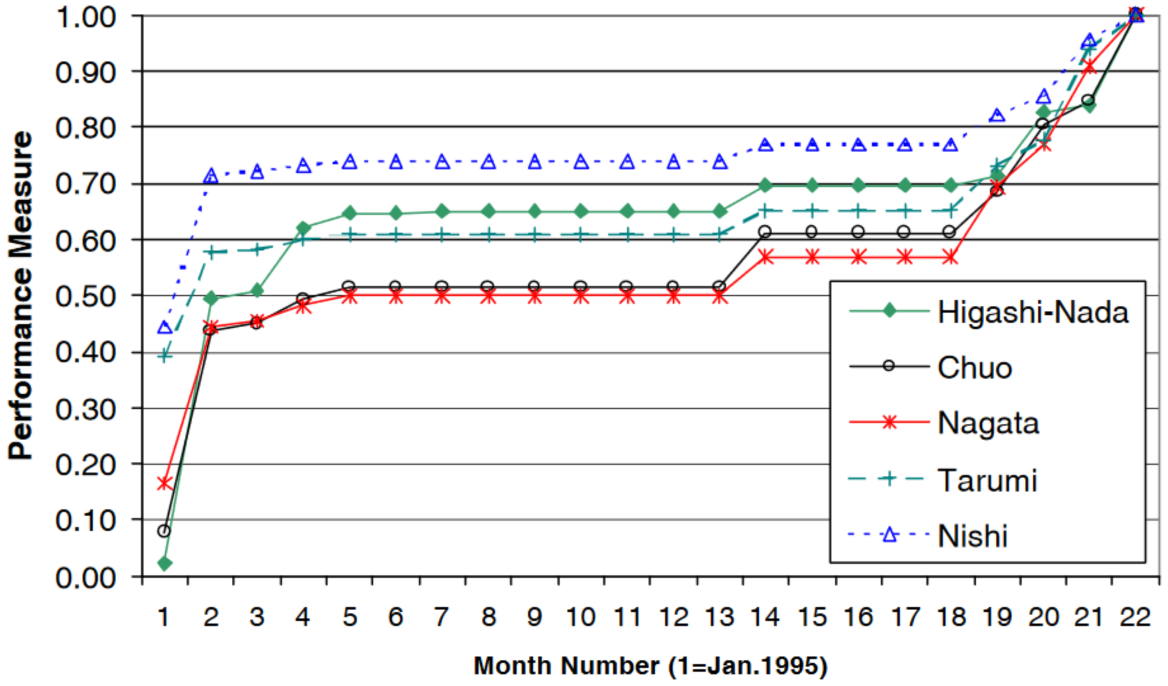

Figure 7. Highway Performance Restoration, Selected Kobe City Wards

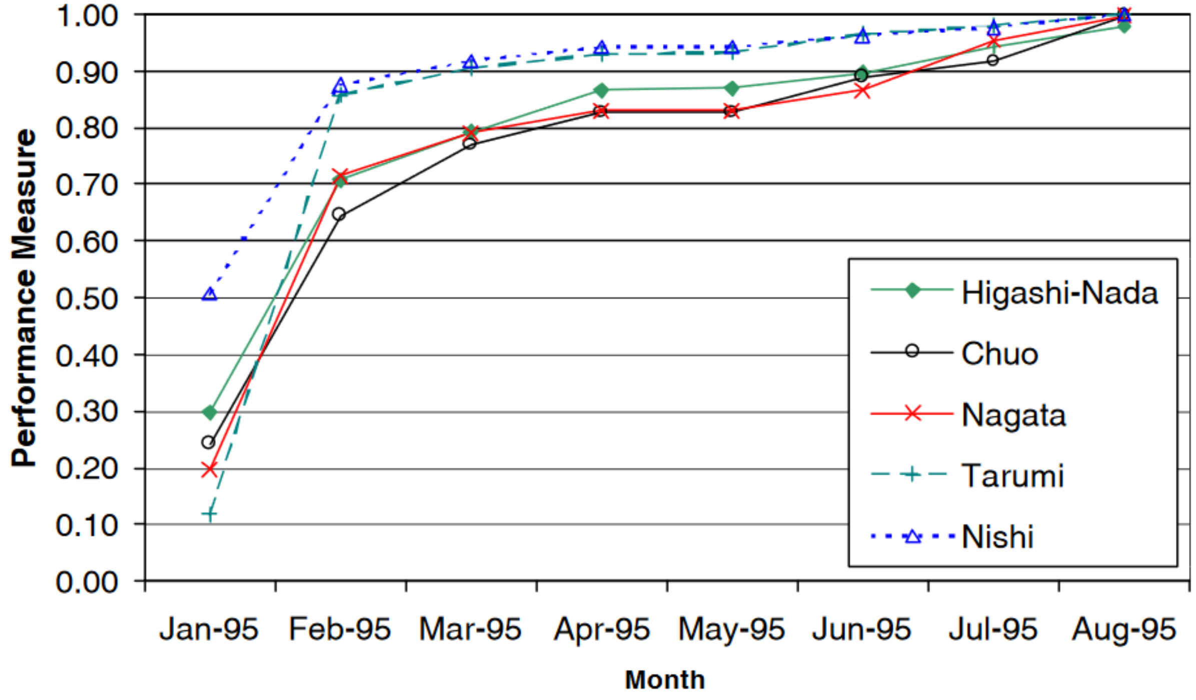

Figure 8. Rail Performance Restoration, Selected Kobe City Wards

Chang, Nojima 1999

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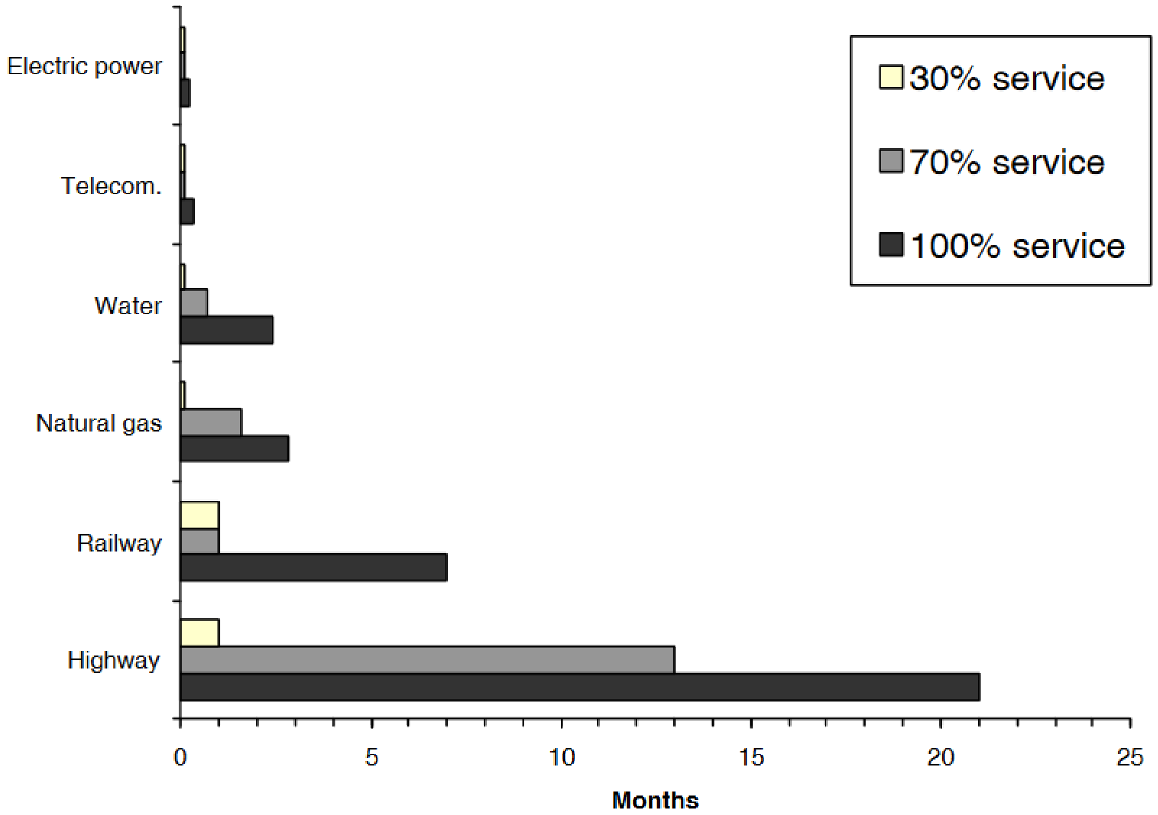
Response



Note: except for railway and highway, data are based on Takada and Ueno (1995) and represent percent of customers with service restored.

Chang, Nojima 1999

Figure 4. Lifeline Restoration Timeframes, Hyogoken-Nanbu Earthquake

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Bringing it together

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Response and Recovery

Response

- Bringing people out
- Bring helpers in
- Bring food etc. in

→Use available infrastructure

→Repair/improvise necessary links

Recovery

- Reestablish functioning
- Bring out debree

→Focus on high impact links first

→Build back better ☺

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Response

Monitoring and assessment

- Provision of situational information.
- Actors can implement their own solutions.
- Confidence in crisis management.

Support impacted actors

- Provision of short-term transport alternatives.
- Teleworking, postponement and alternative locations.
- Help for those stranded.

Removal of discretionary demand

- Removal of discretionary demand to support essential demand.
- Creating a capacity-swapping market.

Modal shift

- Alternative modes not able to cope with demand surges.
- Satellite facilities.

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Respo Response Options to a Transport Disruption | The Geography of Transport Systems

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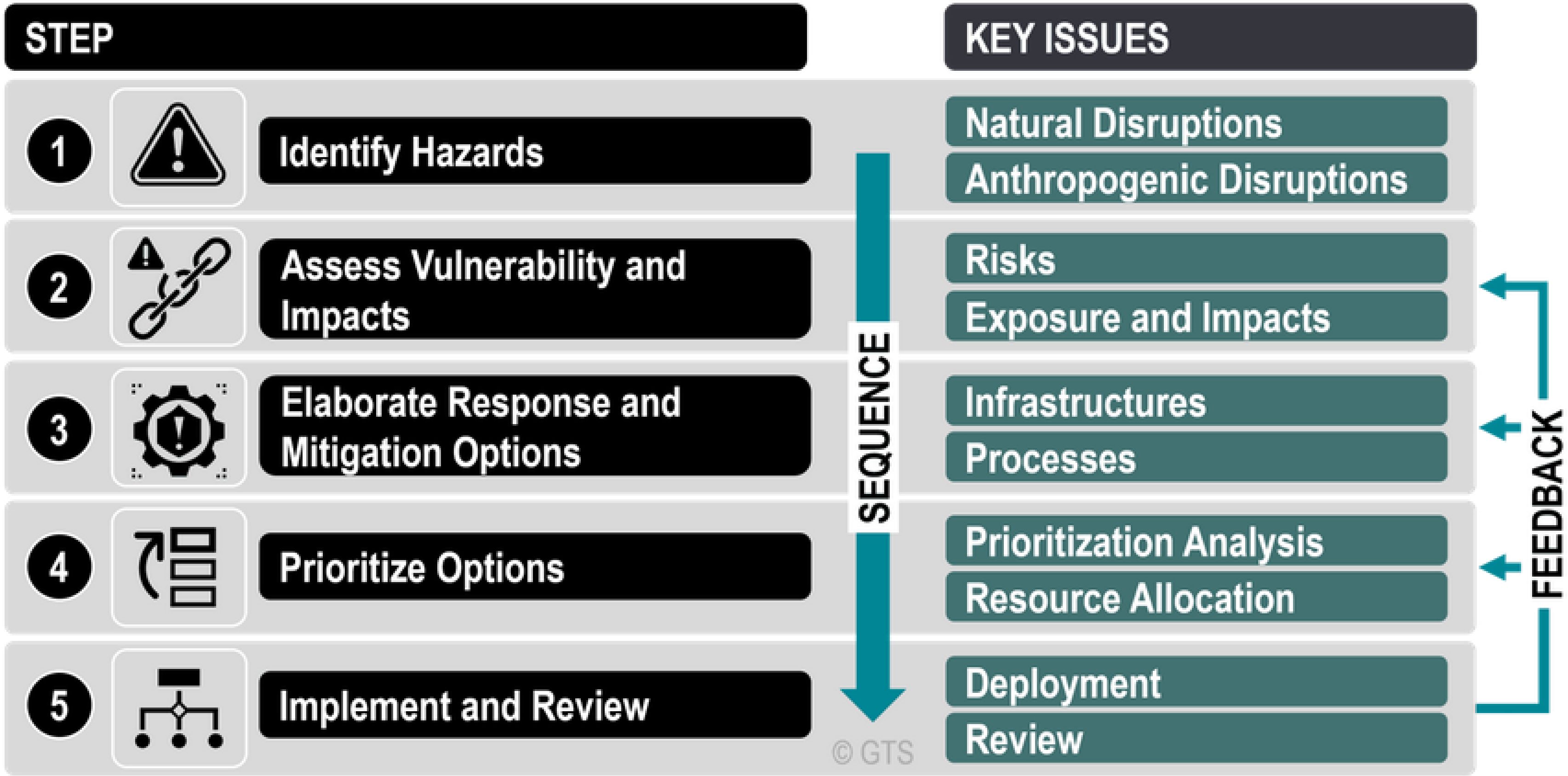
Preparedness and Resilience



Transport Resilience Building Process

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Measures

TABLE VIII
LITERATURE REVIEW FOR ENHANCEMENT STRATEGIES OF TRANSPORTATION RESILIENCE

Reference	Phase(s)	Strategies
Liu et al.[17]	Mitigation	Optimizing allocation of retrofit resources to highway bridges
Chang et al.[22]	Mitigation	Selecting bridges to be retrofitted and specific schemes for them
Zhang and Wang[38]	Mitigation	Optimizing bridge retrofitting and new construction
Fotuhi and Huynh[63]	Mitigation	Optimizing retrofitting of rail links, location of new terminals, and expansion of existing terminals
Asadabadi and Miller-Hooks[40]	Mitigation	Building seawalls, raising the height of roadways, and improve drainage systems
Soltani-Sobh et al.[36]	Preparedness	Optimizing pre-positioning of recovery centers for bridges restoration
Abadi and Ioannou[58]	Response	Reconfiguring to include normally ineffective resources and routes
Jin et al.[97]	Response	Integrating disrupted metro network with localized bus services
Dunn and Wilkinson[92]	Response	Redirecting air routes from disrupted airports to closest operational ones
Wang et al.[19, 24]	Response	Conducting contraflow and reconstruction of selected roads
Bocchini and Frangopol[18]	Recovery	Optimizing intervention schedule for highway bridges
Nair et al.[55]	Recovery	Optimizing recovery activities on links between terminal processes
Chen and Miller-Hooks[56]	Recovery	Optimizing recovery activities on modal or transfer arcs
Baroud et al.[85]	Recovery	Optimizing recovery schedule for water way links
Vugrin et al.[80]	Recovery	Optimizing recovery modes and sequences for disrupted links
Zhang and Miller-Hooks[59]	Recovery	Optimizing recovery schedule for rail links
Zhang et al.[48]	Recovery	Optimizing restoration schedule for road-bridge network links
Miller-Hooks et al.[57]	Preparedness and recovery	Optimizing preparedness activities and recovery activities on each link
Faturechi et al.[25]	Preparedness and response	Optimizing pre-prepared teams and equipment and repair actions on links
Faturechi and Miller-Hooks[26]	Mitigation, preparedness, and response	Optimizing link retrofit, capacity expansion, resources preparedness, and link response actions

Zhou, Wang, Yang 2019

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Example: Deutsche Bahn and Climate Change

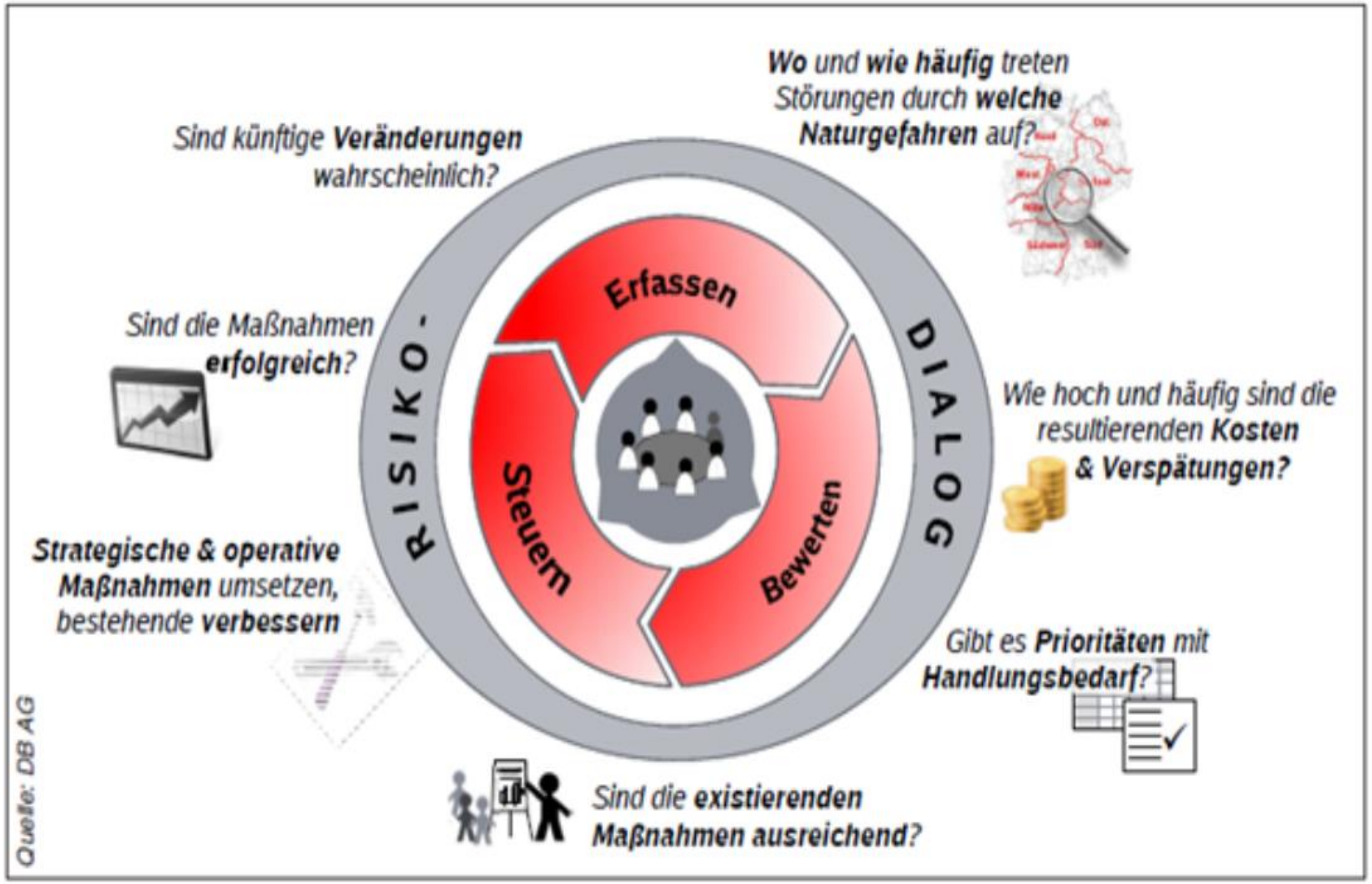

Abb. 1: Konzept der ganzheitlichen Naturgefahrenstrategie der Deutschen Bahn [Mess19, S. 19]

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Example: Deutsche Bahn and Climate Change

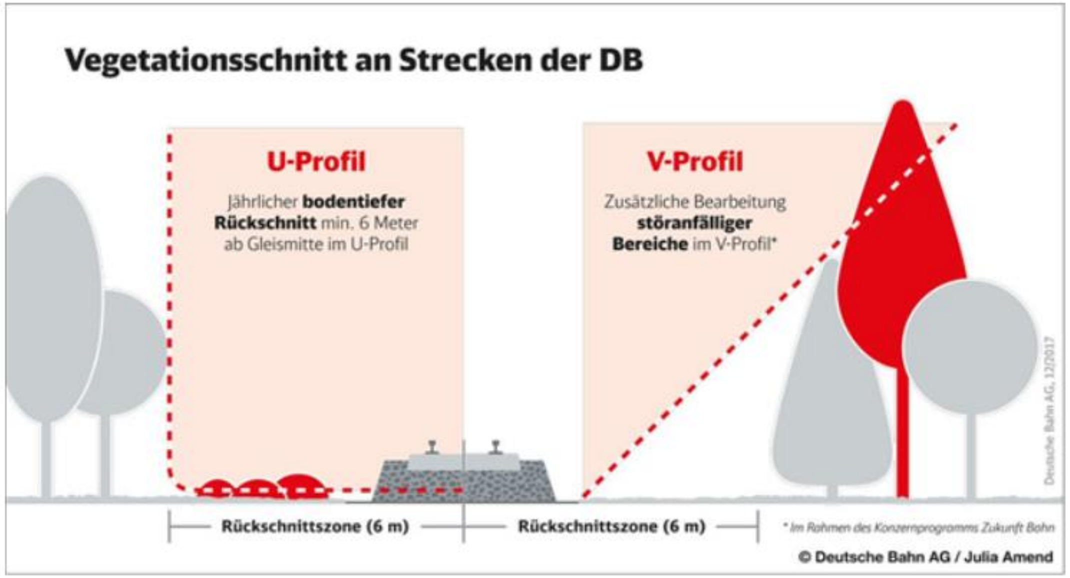

Abb. 2: Vegetationsschnitt an Strecken der DB. [DBAG18f]

Example: storm damage to railroad infrastructure

- More (extreme) storm events

➔ Better vegetation Management

- Generally 6m kept vegetation free
- In storm hotspots V- Cut

Example: Track deformation due to extreme heat

- Local warming in Germany, more extreme heat days
- Tracks deform due to heat
- → Paint tracks white

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Cited Literature

Lei, Y., Wang, J., Yue, Y. *et al.* Rethinking the relationships of vulnerability, resilience, and adaptation from a disaster risk perspective. *Nat Hazards* **70**, 609–627 (2014). https://doi.org/10.1007/s11069-013-0831-7

Mitusch (2021): Best-Practice-Beispiele im Personenverkehr, Forschungsinformationssystem (https://www.forschungsinformationssystem.de/servlet/is/543793/)

Rodrigue, J-P et al. (2020) The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, https://transportgeography.org.

Torqaid 2014: Disaster Risk Management Cycle (DRMC) (https://reliefweb.int/report/world/disaster-risk-management-cycle-drmc)

Y. Zhou, J. Wang and H. Yang, "Resilience of Transportation Systems: Concepts and Comprehensive Review," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 20, no. 12, pp. 4262-4276, Dec. 2019, doi: 10.1109/TITS.2018.2883766

Weilant, Sarah & Strong, Aaron & Miller, Benjamin. (2019). Incorporating Resilience into Transportation Planning and Assessment. 10.7249/RR3038.

Wisner, Blaikie, Cannon and Davis: At Risk: natural hazards, people's vulnerability and disasters. Second edition. 2003.

Stephanie E Chang, Nobuoto Nojima, Measuring post-disaster transportation system performance: the 1995 Kobe earthquake in comparative perspective, working paper 1999.

Stephanie E Chang, Nobuoto Nojima, Measuring post-disaster transportation system performance: the 1995 Kobe earthquake in comparative perspective,Transportation Research Part A: Policy and Practice, Volume 35, Issue 6, 2001, Pages 475-494, ISSN 0965-8564, https://doi.org/10.1016/S0965-8564(00)00003-3.

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- Thanks!
- Questions?

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