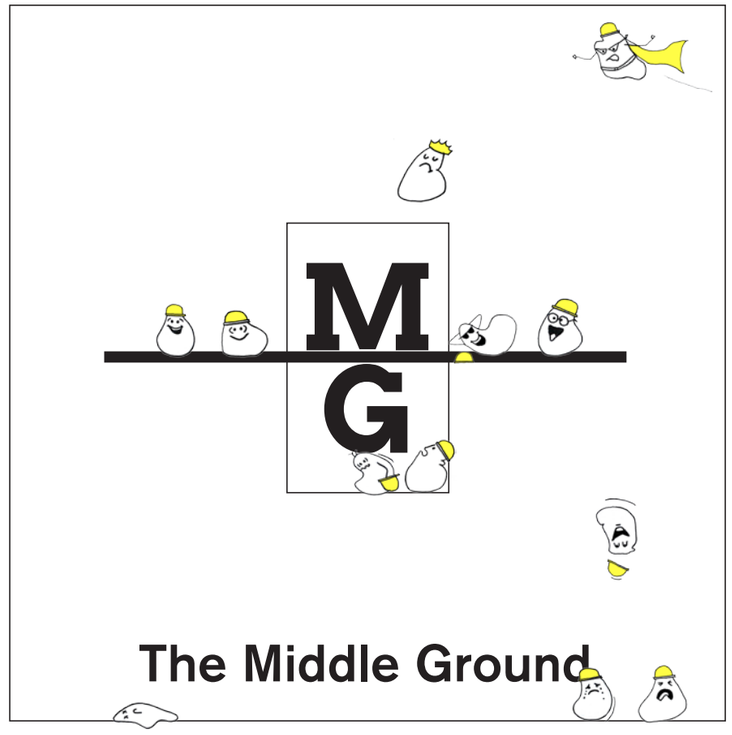
The Middle Ground

Supriya Krishnan



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Graduation Report
AR3U100 Graduation Lab: Urban Transformations and Sustainability (2016-2017)

July 2017
Graduation Studio Delta Urbanism / Department of Urbanism
TU Delft - Faculty of Architecture and the Built Environment

“The phoenix must burn to emerge.” - Janet Fitch

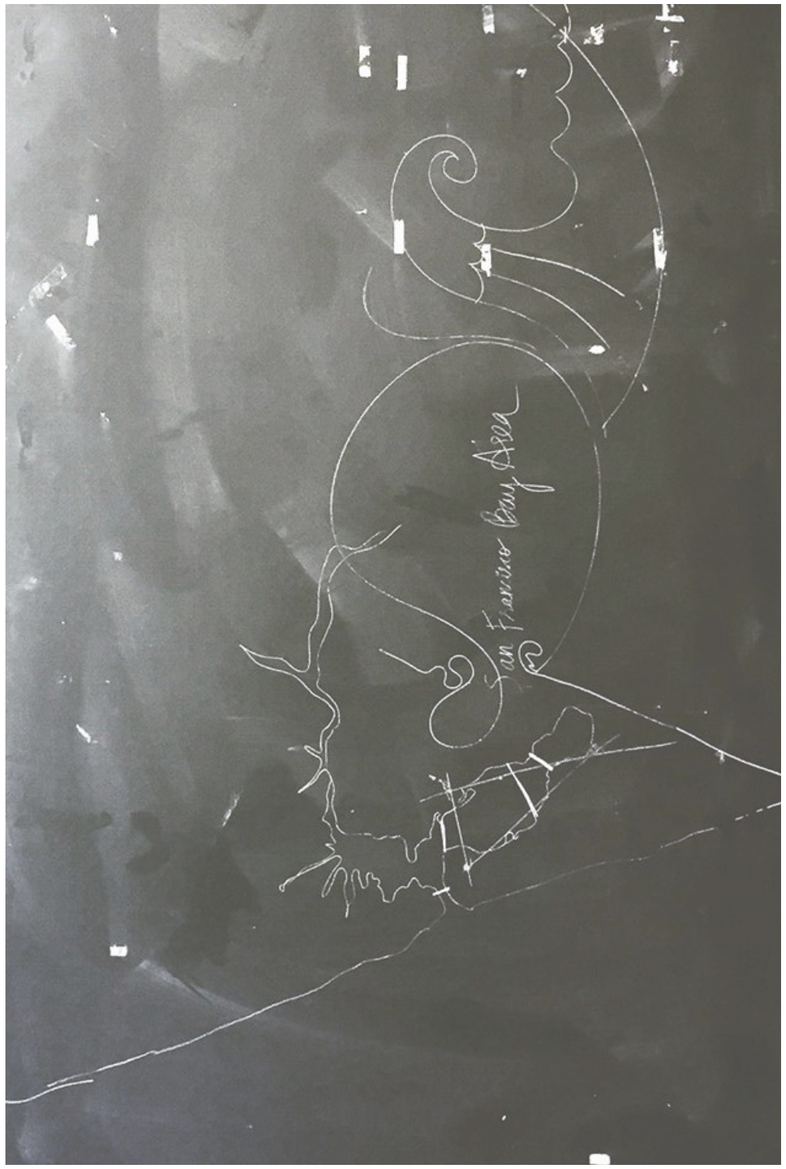

fig 1 *Sythesis of D-i studio (Drawn by S Krishnan)*

The Middle Ground

Spatial Planning under Uncertainty

(Evaluating the effects of natural hazards on critical urban infrastructure networks towards a spatial strategy for risk reduction)

July 2017
Graduation Thesis Report
AR3U100 Graduation LAB: Urban Transformations & Sustainability
San Francisco Bay - Resilience by Design
TU Delft / Faculty of Architecture/ Department of Urbanism / Delta Urbanism / https://deltaurbanismtudelft.org/

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Keywords
planning uncertainty, risk reduction, cascading effects, incremental planning, long range planning, spatial planning, damage chain

fig 2 *Looking towards the San Franciso Oakland Bridge (Photo: Sumanth Rao)*

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While this thesis may be an official culmination of a challenging Masters programme at TU Delft, it brings along with it the opportunity to take a moment to thank the people who enriched the journey.

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…and to my amazing family in India for not only for their infinite belief and love, but for also setting the most inspiring examples for life.

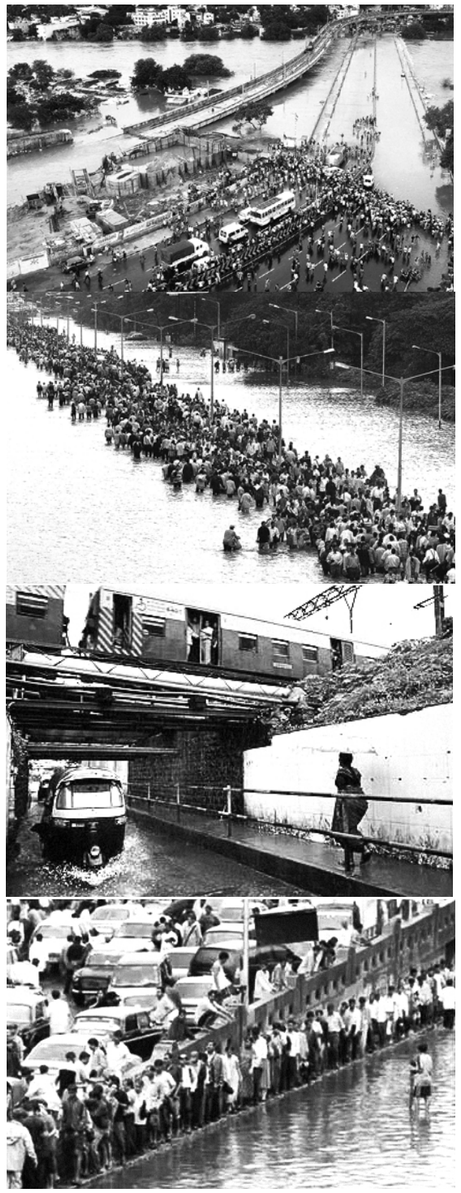

fig 3 *Snapshots of flooding events in the city of Mumbai*

CONTENTS

fig 5 *World development Report*

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fig 6 *Cyclone Warning in Bangladesh (World Bank, Amir Jina UNISDR))*

GLOSSARY

Bay water

Open ponds, lakes, streams

1.5 meter sea level rise /1 in 100 years flooding

Parcels at high risk of flooding
Parcels to high risk of liquefaction from earthquakes

P1 – INCREMENTAL patches
(1 in 20 year inundation): Relocate housing, reinforce levees around light industrial plots, elevates critical infrastructure facilities (substations, waste water treatment plant, FEDx shipping), recreational baylands

P2 –TRANSITIONAL patches
(1 in 50 year inundation) Improve permeability of surface, retrofitting existing buildings, introduce amphibious buildings/water neighbourhoods and evacuate ground level development, flexible medium non-hazardous industries

P3- TRANSFORMATIONAL RESILIENT
patches (outside 1 in 100 year inundation): Currently out of the projected risk areas. To imbibe greater densities of development

Plots to function as emergency evacuation centres during a crisis / Plots with global infrastructure (airports, seaports)

2 mile radius around disaster base

PRIORITY DEVELOPMENT CORRIDOR (PDC)
high concentration of critical infrastructure networks

HIGH RESILIENCE PATCHES:
Currently at least damages from flooding and earthquake liquefaction

FEMA high Risk Insurance Zones (V, VE)

Station Area Development : 500m radius

AMTRAK / BART Train Station

Critical Infrastructure Utility (Waste water treatment plant, Electric Substation, Power Plant) Highway network (National/ State)

Critical transit route (rail or road, to be retrofitted, to act as second line of defence)

Enhanced natural buffer (water channels, green streets)

City Boundary

The glossary is a broad palette of terms and visual language utilized for the maps developed throughout the report. A few maps do not adhere to this scheme, but relevant explanations have been provided where necessary.

SF: San Francisco
CI: Critical Infrastructure
MG: Middle Ground
RPM: Resilient Patch Matrix
CT: Complexity Theory
Agencies:
GOV: California Office of the Governor
COES: California Office of Emergency Services
FHA: Federal Highway Administration
DOT: Department of Transportation
FEMA: Federal Emergency Management Agency
EPA: Environmental Protection Agency
SFEI: San Francisco Estuary Institute
MTC: Metropolitan Transportation Commission
BCDC : San Francisco Bay Conservation and Development Commission
SGC: Strategic Growth Council
BART: Bay Area Rapid Transit
ABAG: Association of Bay Area Governments
SGC: Strategic Growth Council
SFES: San Francisco Estuary Institute
CDWR: California Department of Water Resources
California Natural Resources Agency
Metropolitan Transport Commission (Metropolitan planning Organisation
SPFC: State Plan of Flood Control
AMTRAK: The National Railroad Passenger Corporation
SFBWTA: San Francisco Bay Water Transit Authority
LIC: Lifeline Interdependencies Council
PG&E: Pacific Gas and Electric Company
SFPUC: San Francisco Public Utilities Commission
CALTRANS: California Department of Transportation

Reading analysis maps:

A7	*Map code*
MACRO/ MESO/ MICRO	*Scale of analysis*
Finding the ‹Critical Web› of the Transport Network that will survive in the face of multiple projected hazards.	*Objective*
The existing and proposed public spaces/amenities that can act as ‹safe› points during a crisis are marked on the transport network. A first simulation is run to map the road segments connecting the public spaces The two hazards in consideration (flooding and earthquake liquefaction) are projected separately. A simulation is made keeping the hazards as barriers to connect the same ‹safe› points. This removes the ‹impacted› segments from the network.	*Process*
ArcGIS/ArcMap Network Analyst	*Instruments*

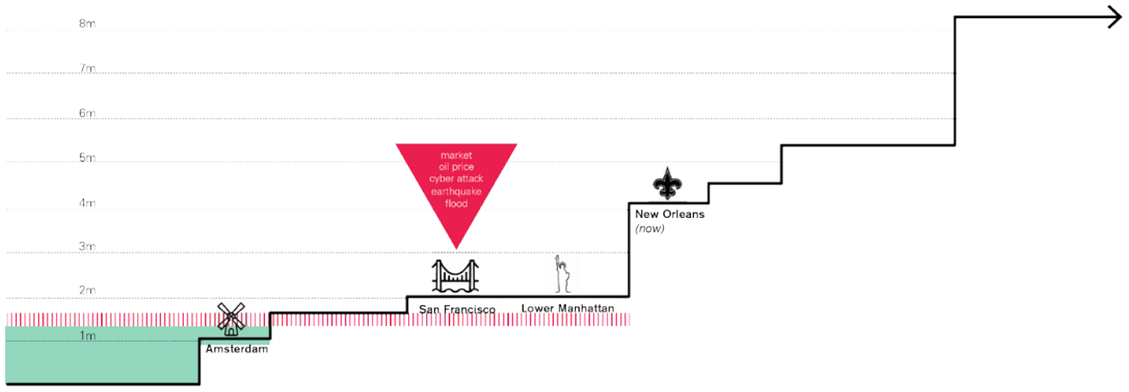


fig 9 *Graph comparing the projected flood inundation of the San Francisco Bay Area for the year 2100 with other major cities. Also indicated are the top five risks that will cause most damage by GDP to the Bay Area .Data source: 'When sea levels attack', (informationisbeautiful.net), Damage by GDP data from Llyod's City Risk Index 2015 (graphics: Author)*

MOTIVATION

What is the chance of you experiencing a flood event in your lifetime?

As a native of Mumbai- one of the world's most vulnerable but economically important deltas, an annual spate of flooding during monsoons was part of our existence. An academic year in the Netherlands along with the parallel Honours (DIMI Infrastructure+Environment) project that studies water risk and infrastructure systems in Sao Paulo and Tokyo; is aiding an understanding of the variations in the way society and the terrain interact with water.

The socio-economic complexities that impact physical responses to water (or the lack of them) is crucial. This is reflected in the priorities and perception to the problem of water related risks in these regions. Planning these relationships needs a balance among different claims and interests of design, engineering, science and governance. Delta Interventions Graduation Studio led by Delta Urbanism research group at TU Delft's Department of Urbanism reflects on these critical interdependencies between natural processes and societal practices, offering an opportunity for intensive research in this domain. The developed context of San Francisco with moderate but dynamic risks offers an important testing site for experimental research.

A United Nations prediction states that if current trends of development continue, the entire planet will be urbanized by the end of the 21st century. This prediction implies that effects of extreme events such as blackouts, floods, tsunamis or terrorist attacks will have increasingly dramatic and intimate effects on the specific structure and dynamics of cities and urbanism (Juval Portugali 2012). Climate change is real and the manifestations are enhancing each year in the form of extreme events (Hurricane Katrina in New Orleans, the tsunami leading to an earthquake leading to nuclear meltdown in Fukushima, Hurricane Sandy, Indian Ocean Tsunami) and gradually rising phenomenon (sea level rise and global temperature rise). Understanding the interface of climate change and human development have become crucial considering the increasing economic stakes and toll of disasters.

A previous study of three global landscapes that face water risks continually - Sao Paulo, Tokyo and Amsterdam, illustrate very different ideologies adopted to combat climate related risks.

«...these statements involve known and unknown risks, uncertainties and other factors which are not exhaustive. The companies contributing to this report operate in a continually changing environment and new risks emerge continually. Readers are cautioned not to place undue reliance on these statements...»

(Extract from World Economic Forum›s Global Risk Report 2016)

About Plan Bay Area

PDAs and PCAs in Alameda County

Plan BayArea 2040

Extract from 'Plan Bay Area 2040' highlighting the Priority Development Area for Alameda County in East Bay (http://www.planbayarea.org/). Priority Development Areas (PDAs) are places planned by jurisdictions for future investment, housing and jobs. Each PDA includes numerous development sites for housing at a variety of income levels, commercial development, and community facilities. These sites are all close to transit and existing or planned services and amenities and are crucial for overall revitalisation

fig 10 *Extract from 'Plan Bay Area 2040' highlighting the Priority Development Area for Alameda County in East Bay (http://www.planbayarea.org/)*

About Plan Bay Area

New PDAs ,PCAs, PRAs,PDCs in Alameda County

Plan BayArea 2040

Proposed revision to 'Plan Bay Area 2040' highlighting the Priority Development Corridors (PDC) and Resilient Patch Matrix for Alameda County in East Bay

fig 11 *Proposed revision to 'Plan Bay Area 2040' highlighting the Priority Development and Resilience Area for Alameda County in East Bay (Mapping by Author)*

Introduction

Looking towards Hunter's Point :Scenes from the field visit to San Francisco (Photo: Sumanth Rao)

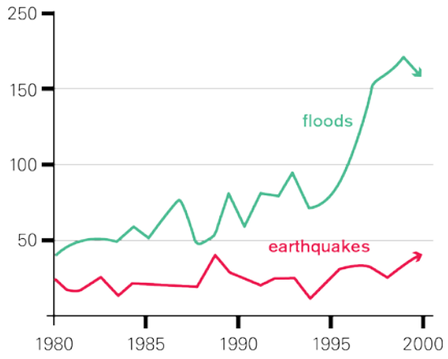


fig 14 *Graph comparing the global occurrence of earthquakes with the occurrence of flooding events over the past 20 years (data source: CRED Annual Disaster Statistical review 2006-07, graphics by author)*

Fact Sources;
Hallegatte, S., et al. (2013). "Future flood losses in major coastal cities." Nature Climate Change 3: 802-806
Kates, R. W., Colten, C.E., Laska, S. and Leatherman, S.P. (2006). "Reconstruction of New Orleans after Hurricane Katrina: a research perspective." http://www.un.org/sustainabledevelopment/development-agenda/ Proceedings of the national Academy of Sciences, 103(40), pp.14653-14660.

INTRODUCTION

Destruction and Displacement represents the face of natural disasters. Disasters have the power to wash away cities (Lisbon 1755, Antigua) and civilizations (Harappa). In the post modern civilization, the risk of disaster comes with higher stakes due to high concentration of population, wealth and the interconnected global economy. The layout of our metropolises also brings with it high interdependencies between urban infrastructure networks (transport, water, power) where the failure of one network cascades to cause secondary disasters (earthquake leading to a flood leading to fire outbreaks) that disrupt other networks and essential functions like the stock exchange, mortgage rates, trade networks to something as simple as ATMs that magnify losses dramatically. A study from the World Bank (Hallegatte, Green et al. 2013) highlights that ,' the risks from sea-level rise and sinking land, and global flood damage for large coastal cities could cost $1 trillion a year if cities don't take steps to adapt.' There are two aspects to this problem:

Cities continue to densify towards the mouth of the risk because of market forces and lack of awareness of the magnitude of danger. Increasing urbanisation and regeneration present an unparalleled opportunity to form policies and strategies for resilient growth.

"Growing concentrations of people and economic activity in most cities are seen to overlap with areas of high risk exposure while exposure to major earthquake risks will increase from 370 million to 870 millionxix. Urban development investment is also set to increase from US$7.2 trillion in 2011 to US$12 trillion by 2020xx. The exposure of urban assets to sea level rise and flooding could reach US$35,000 billion by the 2070s which is ten times more than the current levels.'
UN Sustainable Development Agenda

Current measures to combat disaster focus on 'protective built infrastructure' (dikes, levees, dams) or 'adaptive overlaid infrastructure' (soft landscape edges, parks) ,both of which have their strength thresholds and are known to fail in case of extreme events (Hurricane Katrina) (Kates 2006)

The increasing intensity of climate change related hazards highlights the need to shift perspectives from 'planning for fear' to 'planning to embrace the uncertainty' brought by natural hazards. This is the guiding principle of the thesis adopts a systems approach to understand how an urban elements (networks and space) will respond to risk exposure in the absence of or minimal defense infrastructure . It attempts to draw the recovery pattern of an urban system during a crisis to understand if it can inform a resilience pattern for the future. In doing so, the project looks at the role of existing urban infrastructure and space in the event of both short term (2-10 years) and long term (100 years) planning and how re-attributing roles can generate a new 'Middle Ground' that acts as the backbone for resilient regional growth over the next century.

The research highlights lack of cohesion in planning practice to pursue long term implementation strategies such as resilience in land use management, looking beyond building back' and investing in incremental gain models that grow with risk .It aims to address this vital knowledge gap between engineering simulations and planning in the real world and how we can build a framework to sync them for long range risk reduction.

Publications
The course of the thesis lead to an exploratory research involving analysisng multiple papers from the domains of computer science, seismic studies, water management that evaluate the impact of risk of urban components. The process of analysis led to the development of the following publication:

— Understanding and improving Critical Infrastructure Resilience: Essential to achieving global agreements (Murdock H., Krishnan S. 2017) - Youth Science Policy Interface Publication coordinated by the UN Major Group for Children & Youth (www.irdrinternational.org)
— The Anatomy of a Disaster: Analysing interdependencies of critical urban infrastructure networks in choreographing modern disasters (unpublished)
— The Middle Ground: Spatial Planning under Uncertainty by learning from recovery for resilience (Krishnan S. Bacchin TK ,Stolk E.H) (selected for a poster presentation for the 'Decision Making under Deep Uncertainty ' Workshop to be hosted at Oxford Martin School, University of Oxford)

Keywords: spatial planning, risk reduction, cascading effects, long range planning, damage chain

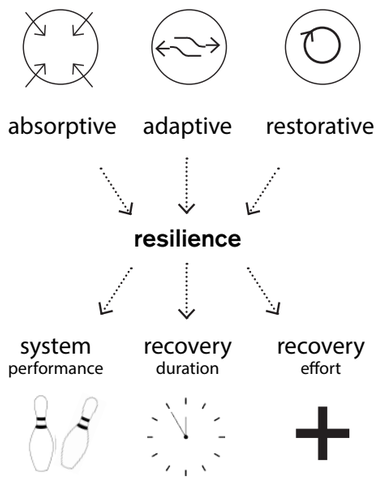


fig 15 *Conceptual illustration of a resilience assessment framework (content from: Climate Change and Infrastructure (Wilbanks))*

EXECUTIVE SUMMARY

The graduation project 'The Middle Ground'- Planning Landscapes of Uncertainty' was undertaken under the 'Delta Interventions' graduation studio at the Department of Urbanism. The main theme is transforming dense urban regions towards resilience by embracing risk in the physical landscape. As a project that was conducted with the backdrop of prior academic (urban design+water management) studies in the context of Mumbai, Tokyo and Sao Paulo ,a broad overview of flood management strategies was a wonderful insight as a head start for the thesis. This report elaborates on the key milestones in the process, product, planning of the thesis along with reflections on its relevance to the research group and the domain of urbanism.

The report is structured in six parts – each part attempts to answer one of the sub research questions posed for the thesis.

Aspect 1: the relationship between the theme of the graduation lab and the subject/case study chosen by the student within this framework (location/object)

Graduation studio Delta Interventions focuses on novel approaches in 'integrating' flood risk management and spatial planning to envision the transformation of coastal urban landscapes.

Global studies indicate that the vulnerability from flooding for the world's largest cities will increase manifold towards the next century.This implies that because flood defences have been designed for past conditions, even a moderate rise in sea level would lead to soaring losses in the absence of adaptation. Accepting the limits of 'hard', 'object oriented' protective measures, the thesis critically analyses the conventional paradigms on protecting and adapting urban landscapes.

As systems ingrained in space, the thesis looks at the impact of risk on urban components (space and networks) to identify ways a system may breaks down. In essence it draws from the meaning of 'resilience' as the ability to 'recover' and 'sustain growth'. It draws from understanding system and human behavior during a crisis to derive patterns of failure/damage to inform a robust urban structure.

This philosophy forms the backbone of them methofdology and theoritical framework. 'Integrating' the spatial logic of socio-technical systems in their responses to risks while balancing competing urban growth trajectories forms the essence of the urban design framework. Hence, transforming attitudes from growth that 'resists' risk to growth that 'responds' to risk is the main message of the project.

fig 16 The position of Urbanism in planning for uncertainty

Aspect 2: the relationship between the methodical line of approach of the graduation lab and the method chosen by the student in this framework

The Urbanism track at TU Delft investigates the relationships between urban patterns, society and design and planning for sustainable and fair urban environment. With the added context of risk, 'balancing' competing claims requires new relationships to be forged between design, engineering, science and governance . History has demonstrated that risks have the power to substantially restructure the urban space.

The thesis questions the conventional approach to spatial adaptation that is derived from a range of fixed state variables to deliver a static strategy (protection dikes, widening channels etc) to 'protect' the urban structure from risk. It advocates for adopting a 'systemic' approach to understand variations in behavior of the system under stress and the flexibility of components to adapt in order to 'grow with risk'. It draws from the logic of understanding risk and failure to develop a 'generative' framework that feeds modifications in urban components. .

Hence this calls for a paradigm shift in thinking: systemic instabilities can be understood by a change in perspective from a component-oriented to an interaction- and network-oriented view (Helbing 2013)[1]

Effectively the place where recovery happens is never discussed and spatial planners, urban designers and landscape architects are rarely involved in recovery planning (ALLAN 2010)[2].

This forms the inspiration for the research by design process. Understanding systemic approaches, failures in urban components, risk management, land programming involves drawing from a diverse range of conclusions from pure engineering studies, policy papers, analyzing design projects and allied reports. The challenge was to synthesise several layers of information to distill into in a tangible framework to transfer the results on space. Here it mingles with the socio-economic space and proposes future trajectories of growth.

Design is utilized as the palette for spatial organization of complex processes to determine an inventory of possible outcomes as opposed to a single master plan. The thesis attempts to produce a transformative strategy for risk management through editing the spatial morphology. Preliminary concepts that informed actions:

1. Focuses on mainstreaming 'risk reduction' in 'urban planning' by understanding 'recovery' patterns
2. Several levels of analysis (see chapter x) have been undertaken to draw partial feedbacks for further insights.
3. Focuses on breaking down the logic of risk in space by defining variables that will be relevant for space.
4. Utilizes design thinking abstraction and design of complex systems
5. Advocates for a systemic approach to take priority over component approach for ingraining resilient growth in the system
6. Draws synthesis from data and tools available in open institutional or academic domains for decision making. This offers a more realistic approach for decision making especially in a crisis where sensitive information may be inaccessible.
7. Modifies the Dutch Layer Method[3] of analysing the urban fabric by adding a layer of urban infrastructure networks (power, energy, water) to understand urban network vulnerabilities ,flexibility and accessibility during crisis
8. Produce a transferable '**spatial risk assessment guideline'** to gauge the level of spatial resilience that can be used in the context of the San Francisco Bay Area and to other geographies with relevant modification of variables.

The above systems are utilized to establish a backbone for resilient growth on the regional /metropolitan scale. This backbone can then form the basis for trial and error in urban development with the hope of directing growth towards adaptation.

[1]Helbing, D. (2013). "Globally networked risks and how to respond." Nature
[2]Allan, P., Bryant, M., Wirsching, C., Garcia, D. and Teresa Rodriguez, M. (2013). "The influence of urban morphology on the resilience of cities following an earthquake." Journal of Urban Design, 18(2)..
[3]Dutch layer approach: Hoog, M.D., Sijmons, D. and Verschuren, S., 1998. Heront-werp van het Laagland. Het Metropolitane Debat. Thoth, Bussum.

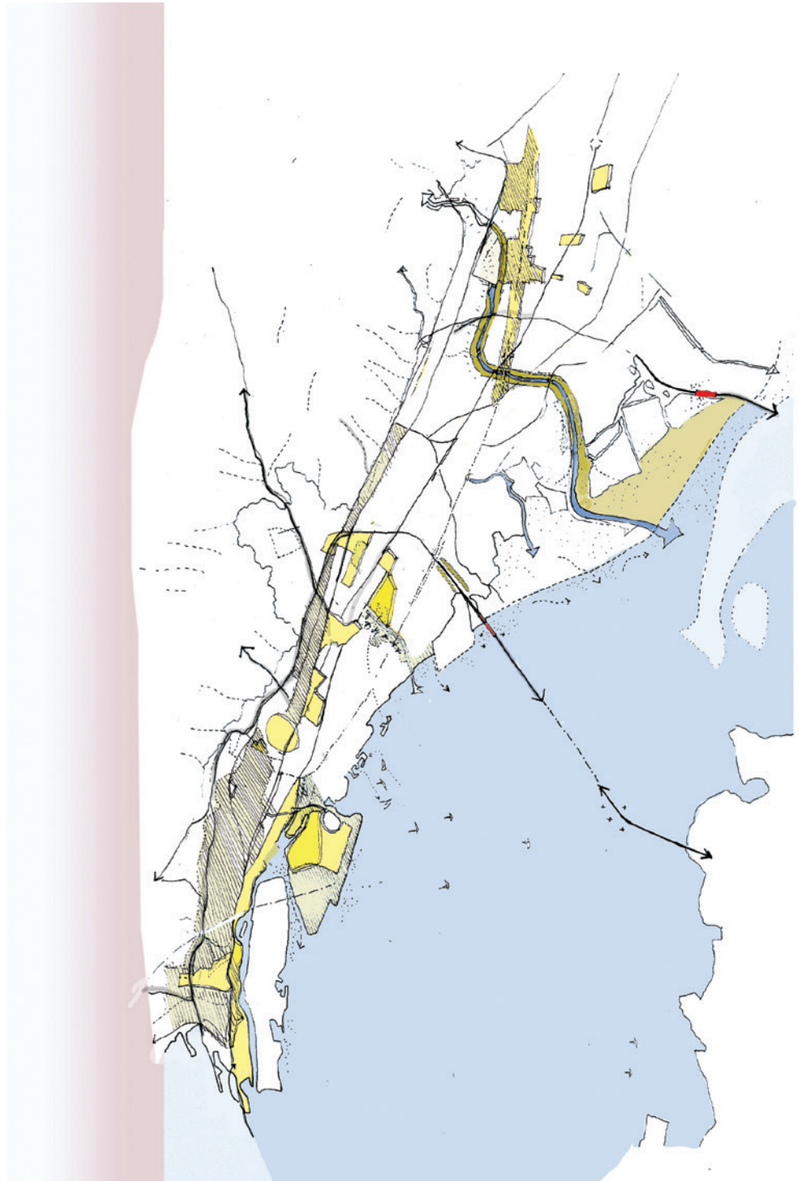


fig 17 *Transforming the Bay: Current urban centralities of East Bay - San Francisco (Drawing by S Krishnan)*

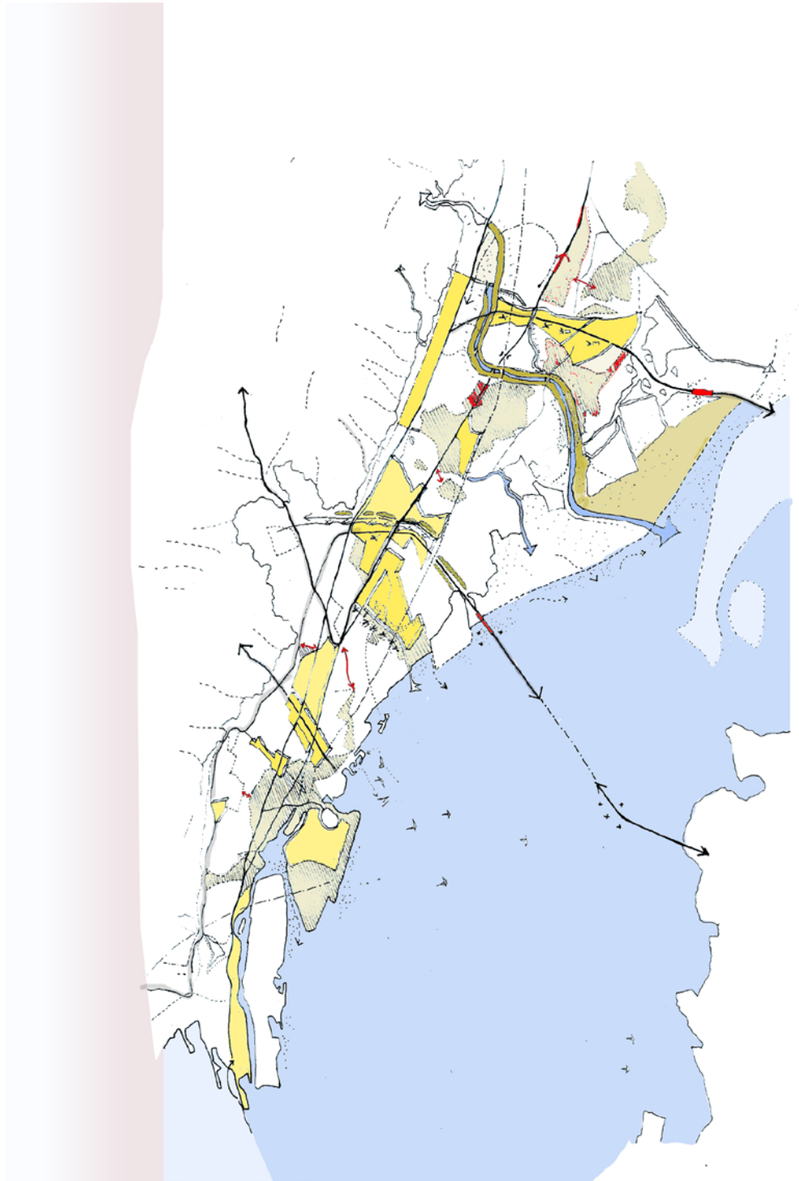


fig 18 *Transforming the Bay: Proposed urban centralities of the East Bay - San Francisco (Drawing by S Krishnan)*

“The severe risk of climate change and rising sea levels on urban areas has not been addressed in the UN’s proposed New Urban Agenda, so flood-risk cities will have to learn from each another and share solutions”

The Guardian

Risk

The objective of this section is to explore the premise of ‘risk’ in the urban landscape and the characteristics of modern disasters. It utilizes a systems approach tries to understand the flow of a disaster and its implications in physical space. It discusses current global trends and reports in establishing goals and implementation agendas to tackle climate change related hazards and overall mood of investment for disasters. In doing so .the chapter concludes with the focus area of the project (disaster risk reduction in by modulating spatial planning with a focus on building resilience of critical infrastructure networks) within the scope of the graduation research group that works on ‘Designing for uncertainties’.

fig 19 *A rainy day on the San Franciso oakland Bay bridge (Courtesy: Sumanth Rao) (Quote from: https://www.theguardian.com/cities/2016/oct/14/global-sea-levels-rising-fast-cities-most-at-risk-flooding-un-habitat)*

Risk

—Areas of exploration

—How the concept of ‘risk’ and ‘resilience’ is perceived in global development reports (World Bank, Tyndall Center)?

—What is the current attitude to managing risks from natural hazards in the urban environment?

—What is the characteristic of and damage chain in modern urban disasters?

OMA plans rebuild by design defense strategy for jersey coastline

fig 20 *One of the proposals for 'Rebuild by Design' post Hurricane Sandy: Dealing with urban edges for protection (http://www.designboom.com/wp-content/uploads/2013/08/rebuild-by-design-HUD-proposals-designboom-02.jpg)*

RESILIENCE IN SPACE

Resilience
the capacity to recover quickly from difficulties; toughness.

100 resilient cities
Resilience describes 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.

UN Habitat
Resilience refers to the ability of human settlements to withstand and to recover quickly from any plausible hazards. Resilience against crises not only refers to reducing risks and damage from disasters (i.e. loss of lives and assets), but also the ability to quickly bounce back to a stable state.

OECD
Resilient cities are cities that have the ability to absorb, recover and prepare for future shocks (economic, environmental, social & institutional). Resilient cities promote sustainable development, well-being and inclusive growth.

Harvard Business Review
Resilience was defined by most as the ability to recover from setbacks, adapt well to change, and keep going in the face of adversity.

Civil Engineering
Resilience in the context of civil and industrial engineering systems is usually expressed mechanistically as the ability to "bounce back" after a major disturbance.

Government Agency
Resilience is defined as the capacity to anticipate, prepare for, respond to, and recover from significant disruptions (Wilbanks, 2012).

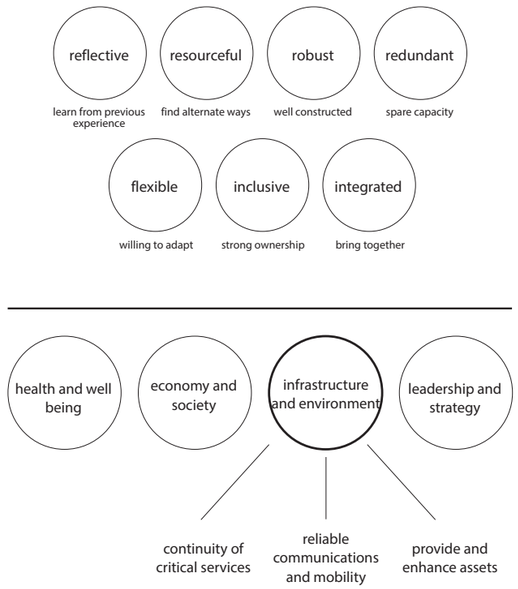
Resilience today, has many interpretations ,as a domain that is inviting interest among premier intergovernmental , non-profit, academic and independent organisations along with the design and development agencies , in the age of climate change. Resilience is an important goal for two reasons. First, because the vulnerability of technological and social systems cannot be predicted completely, resilience—the ability to accommodate change gracefully and without catastrophic failure—is critical in times of disaster (Foster 1997).

While an overview of the definitions of resilience brings forth an array of words, the underlying 'objective' implies that a system must be able to bounce back to equilibrium. It is the 'processes' of arriving to the 'objective' that sees ambiguity. In the mostly qualitative descriptions of arriving towards resilient systems, it is worth noting that several terms have contradictory meaning in the literal sense. As an intervention within the system of space, where each term has a spatial implication, contradictions only convolute decisions. In addition, Geis (2000) argued that the term disaster 'resistant' is both more fitting and more marketable than disaster 'resilient'. This is one of the primary issues with planning for resilience, specifically urban resilience. The lack of a cohesive institutional grammar often put a haze across the concept ,making it appear to be a highly 'qualitative', home grown exercise.

An observation of the current inventory of practices for resilience will illustrate the two approaches to build resilience
—Building protective infrastructure as a compound to the territory
—Adapting the edges of the territory to facilitate buffers to reduce the impact of a risk

Both approaches involve 'building and additional layer' to the fabric which is individually vulnerable to damage. This vulnerability leads to massive damages during a hazard of high intensities causing cascading damages. This is the problem with planning for resilience today and also one of the drivers for the thesis.

Definition sources:
http://www.100resilientcities.org/resilience#/
http://unhabitat.org/urban-themes/resilience/
https://www.oecd.org/gov/regional-policy/resilient-cities.htm
https://hbr.org/2015/01/what-resilience-means-and-why-it-matters



Sendai Framework
One of the most prominent, recently adopted global reports to address the importance of reducing the consequences of a disaster is the Sendai Framework 2015-2030 .It aims for substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries

It aims to guide the multi-hazard management of disaster risk and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience. Its primary targets include:

1. Reduce global disaster mortality
2. Reduce the number of affected people globally by 2030
3. Reduce direct disaster economic loss
4. **Reduce disaster damage to critical infrastructure and disruption of basic services**
5. Increase the number of countries with national and local disaster risk
6. Reduction strategies enhance international cooperation to developing countries
7. Increase the availability of and access to multihazard early warning systems

Target 4 forms the main focus of this project. As the essence of the functioning on an urban system, as it is directly connected to most other agendas

fig 21 City Resilience framework (www.100resilientcities.org)

RESILIENCE IN GLOBAL REPORTS

Global reports addressing the issue of disaster risk include amongst others:

1. COP21
2. UN Guidelines for Reducing Flood Losses
3. The World Bank GFDRR : Building Resilience: Integrating Climate and Disaster Risk into Development
4. World Economic Forum: The Global Risk Report
5. UN Framework on Climate Change (UNFCCC)
6. Global Risk Report
7. UN Agenda for Sustainable Development
8. 100 Resilient Cities
9. WORLD BANK : Risk and Opportunity : Managing Risk for Development
10. Arup City Resilience Index
11. Sendai Framework for Disaster Risk Reduction

The following are the highlights some of the chief agendas from these reports with a focus of building system resilience through and disaster risk reduction in development through investment in critical infrastructure

THE GLOBAL RISKS REPORT has expanded its scope from analyzing the interconnected and rapidly evolving nature of global risks to also putting forward actionable solutions and calling for public-private collaboration in strengthening resilience.

UN AGENDA FOR SUSTAINABLE DEVELOPMENT
Goal 8: Reduce exposure of economic assets and people to hazards such as earthquakes, floods, hurricanes and drought, which magnifies disaster risk.
Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (flood control systems, protective embankments, seawall rehabilitation, building codes, retrofitting of buildings, risk-sensitive planning, hazard mapping and disaster risk financing)
Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with focus on affordable and equitable access for
Goal 13: Take urgent action to combat climate change and its impacts. Target actions under this goal, focusing on strengthening resilience and adaptive capacity, capacity building and integrating climate change measures into policies and plans, awareness raising on climate adaptation and early warning

Sources; Zimmerman (2001), Bell (2002), Tierney (2002), https://www.unisdr.org/who-we-are/what-is-drr , www.preventionweb.net/go/sfdrr

Provision of long-term financing for addressing disaster and climate risk, needed to optimize implementation and bring about transformative change.

100RC
1. Transportation and land use planning, our disaster and recovery planning, our climate readiness and critical neighborhood programs
2. Accommodate growth, long range resilience and secure future
3. A new Office of Resilience and Recovery
4. Plan and Prepare for Tomorrow: land use planning and recovery planning, as well as earthquake planning and preparedness.
5. Mitigate, Adapt and Retrofit confront the pressing realities of an imminent large earthquake, a changing climate and rising seas

WORLD BANK
Risk and Opportunity: Managing Risk for Development
This report calls for individuals and institutions to move from being “crisis fighters” to becoming “proactive and systematic risk managers

ARUP CITY RESILIENCE INDEX
Infrastructure and environment: The man-made and natural systems that provide critical services, protect, and connect urban assets enabling the flow of goods, services, and knowledge
- Provide and Enhances Protective Natural and Man-Made Assets
- Ensure Continuity of Critical Services
- Provide Reliable Communication and Mobility

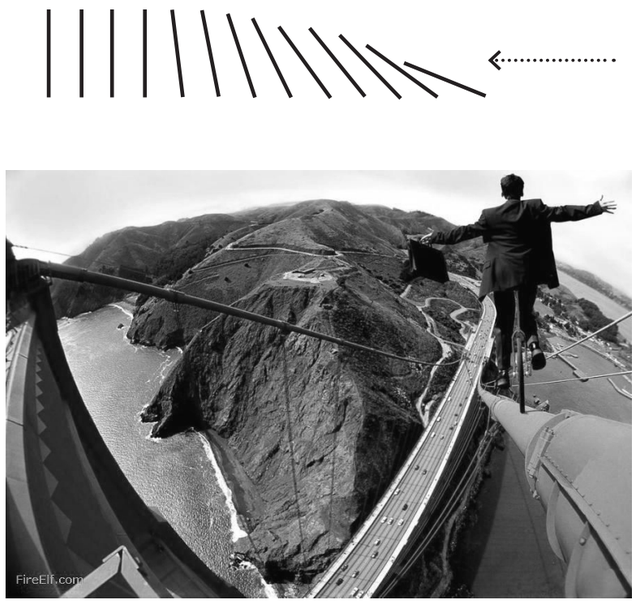


fig 22 *the domino effect (Source: http://cdn.fireelf.com/pics/28/Golden-Gate-Bridge--San-Francisco-Amazing-Trick--Illusion-Or-Photoshop.jpg)*

«In a world where future forecasting seems futile, where predictions are unreliable, and where even the most absurd scenarios are plausible, many urban planning decisions seem to be governed not by vision, but by fear: fear of disaster, fear of change, fear of the unknown…»

-City Shock Planning the Unexpected, The WHY Factory

The world today sustains in an ecosystem of risk, that is the danger of being exposed to multiple hazards. There is the underlying risk of the occurrence of an extreme event ("event risk") and the risk of damage that occurs as a result of an unforeseen consequence of the event ("outcome risk"). Simply defined, risk is the product of the "event risk" and the outcome risk".

Risk = Probability (of an event occurring) x Consequence (of the event)

Disasters are seen as the consequence of inappropriately managed risk. Natural hazards become disasters as a result of human and societal vulnerability and exposure (Chengdu Declaration of Action, August 2011). The combination of hazards, vulnerability and inability to reduce the potential negative consequences of risk results in disaster (IFRC). Vulnerability is the amount of potential damage caused to a system by a particular hazard (Jones and Boer, 2003).

While the probability of a risk occurring cannot be controlled, the consequences are a result of the vulnerability of exposed resources which is why hazards that strike in areas with low vulnerability will never become disasters.

The greater the vulnerability, worse are the consequences. Hence, the starting point of the research is understanding the possible consequences of risk for the region to determine the probable intensity of uncertain impacts.Catastrophes in modern society illustrate the following characters:

Less localised, with a significant impact on a larger hazard zone. In the case of Hurricane Katrina, the storm's entry point at the Gulf coast is significant because of the fact that nearly half of the gasoline consumed in the U.S. passes through refineries that were affected by the storm. The international impact was especially felt throughout the energy sector as oil prices escalated (Elmerraji 2016)

Highly interconnected

The effects of the Tohoku Tsunami and Indian Ocean Tsunami were felt across several countries. At the largest scale so far, floods in Thailand in 2010 led to a worldwide shortage of computer components due to impact on production units (Chongvilaivan, 2012).

Scale Effects

The power outage in Italy (2003) illustrates scale effects in cascading disasters. A short circuit due to a branch of a tree on one transmission line lead to a series of blackouts on the Swiss–Italian border affecting 56 million people through disrupted trains, civil aviation and food networks.

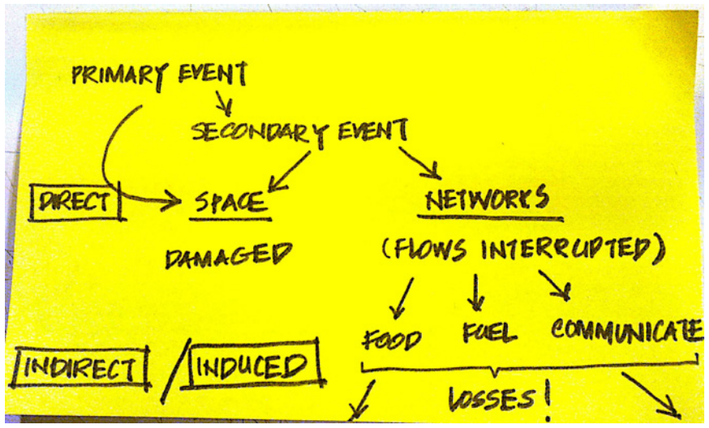
In order to assess what makes a system resilient, it is essential to know 'what the system is made of'. Apart from the physical components, the process involves a study of drivers of growth, characteristics of the system, long term change and vulnerabilities. It involves a study of the direct and indirect impacts of a disturbance. Back casting projected growth by overlaying projected risk is one way to understand what causes a system to paralyse and logically determine what must be restored to be able to achieve equilibrium again. In a dynamic landscape, the parameters for restoration are also in a state of continuum. The objective of the study is to identify the weak links in the system that will collapse in the event of a disaster.

The current state-of-the-art involves processing massive volumes of urban data to generate vulnerability assessments. The problem lies in contextualisation. An important aspect of urban resilience is that it deals with real systems in physical space. Initiatives like 100 Resilient Cities are gaining momentum after catastrophes like Hurricane Sandy. It also mentions the objective to be 'resilient'. The applications levels differ vastly. While, qualitative and quantitative models can inform better probabilistic models, the 'performative' value can be determined only by intervening in the urban environment. This is the attempt of the thesis. The project draws upon selected literature on resilience and risk reduction focusing of 'flood risks' and 'infrastructure systems' to analyse both engineering, development and design approaches to tackle risks.

“When the San Andreas earthquake happens in Southern California—and that’s the most-likely big earthquake in the United States—we know that all of the transportation life lines, the electric systems, the water systems, the gas lines, that cross the San Andreas fault, exactly where they’ll break and what will happen when they break. That hasn’t gotten anybody to do anything about them. So here in Los Angeles, we get 85 percent of our water from outside the region—that means across the San Andreas fault—in aqueducts that willbreak, [and] we could tell you how many times they’re going to break and that it’s going to take 18 months to get them fixed again and we have six-months’ supply of water on this side of the fault—when we’re not in a drought and the reservoirs are full.”

Citylab

https://www.citylab.com/environment/2014/09/a-most-terrifying-risk-assessment-of-californias-next-big-earthquake/380934/ (Image: http://www.ibtimes.co.uk/hurricane-katrina-powerful-photos-storm-that-devastated-new-orleans-9-years-ago-1463168



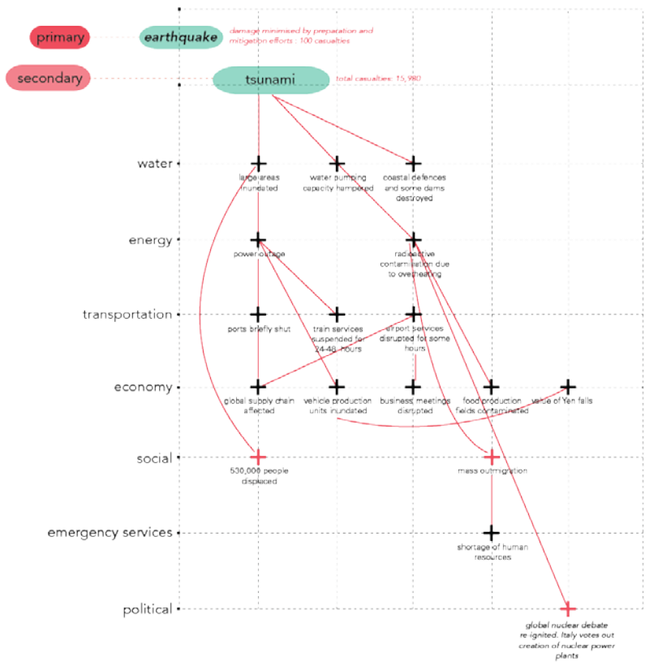


fig 24 *The flow of a disaster (drawn by author)*

ANATOMY OF A DISASTER

Backcasting is a tool of analysis utilized to understand the "cause and effect" of an event such that it disturbs equilibrium. Imagining scenarios for repercussions of a disaster can perhaps help foresee the inventory of changes in the system that orchestrates a disaster. Hypothetically, if we want to plan a successful natural hazard culminating to a disaster, the risk must be exposed in a way that it targets the most vulnerable areas in a way that makes coping with the impact difficult. Based on a general literature study related to calamities, the impact of a disaster must successfully achieve two objectives to cause maximum damage and lengthy recovery period:

— Paralyse accessibility (to food, fuel, information) by hampering mobility and communication infrastructure that moves essential goods, services, power and people
— Damage essential facilities such as hospitals and schools and business districts

The disasters were curated based on the differences in geography, cause of the disaster, relevance of 'cascade' effect in larger disruptions. The source of damages and the point of amplification of damages have been assessed through the documentation referred to for the analysis. **In all three examples transportation, water and communications, in addition to fuel supplies played a crucial role in amplifying damage and recovery efforts (money, time and human resources)**

Inspired by 'causal loop diagrams' , the following is a series of studies in analysing three modern disasters and their paths of cascades. The primary, secondary and tertiary (if applicable) disasters are analysed for their implications on human life and economy .The focus is on the behaviour of critical infrastructure networks (transportation, water, energy) and have been plotted to visualise the pattern of a disaster flow.

Storm> heavy precipitation> storm surge
Earthquake> soil liquefaction > fire
Flood> surface runoff> groundwater intrusion

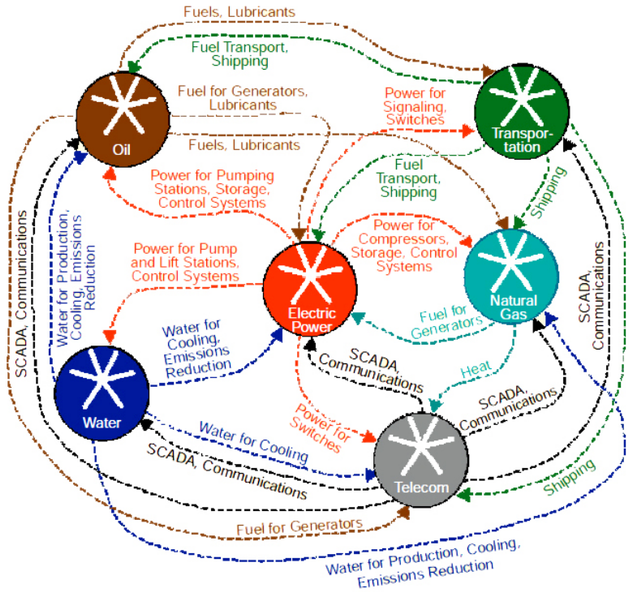
A general study of the impact of extreme climate events (based on the ongoing research for the Theory of Urbanism paper described in Appendix II) will indicate these two objectives achieved at varying levels in modern disasters making recovery to normalcy that much more difficult . In the event of a water related calamity, a prominent projection illustrates that 140,000 people who will work in the 100 year flood inundation area of San Francisco will be out of work and hamper economic opportunities (out of work, crime) .This is an example of the dependency between physical and social networks (Institute 2012)

Risk Reduction is a marginalized terrain and still has staunch competition from the concept of 'emergency relief'. The lag in cohesive planning for disaster risk reduction can be attributed to two aspects that dictate development –Institutions and Investment.
A causal damage chain of a disaster plotted as a schematic cascade to identify the following points:

- **Direct ,indirect and induced damages to the system**
- **Short term and Long term changes in the urban system**
- **Failure of Services**
- **Communication: People, Data and Energy (Services, Supplies)**
- **Tipping points/ Points of transformation**
- **Primary, Secondary, Tertiary disasters**

The objective of his exercise is to break down the flow of a hazard to its essentials, map its impact in space to understand the aspects that must be reinforced.

Hurricane Katrina
Hurricane Katrina illustrates the case of a primary hazard (hurricane) cascading to several secondary and tertiary hazard that are diffused through a larger span of time. These include power outages, damages to oil grids and petroleum hubs, fires, loss of production, damaged houses, displaced population that conclude into severe disruption of human life and damages to physical and economic infrastructure. Rising global oil prices and shut down of the New York stock exchange are the crucial economic terminal nodes of the cascade.



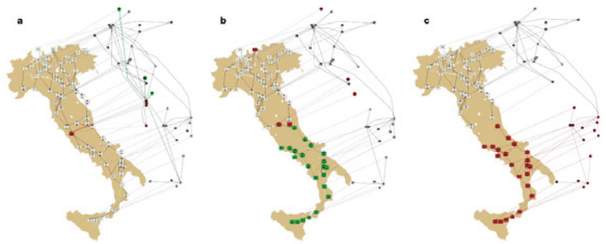


fig 25 *Modeling interdependent urban sectors as each is impacted by climate drivers (Rinaldi, Peerenboom 2001)*

fig 26 *Modelling a blackout in Italy. Illustration of an iterative process of a cascade of failures using real-world data from a power network (located on the map of Italy) and an Internet network (shifted above the map) that were implicated in an electrical blackout that occurred in Italy in September 2003 (Source: Catastrophic cascade of failures in interdependent networks, Buldyrev, Havlin 2010)*

— Hurricane Katrina (2005)
Hurricane Katrina illustrates the case of a primary hazard (hurricane) cascading to several secondary and tertiary hazard that are diffused through a larger span of time. These include power outages, damages to oil grids and petroleum hubs, fires, loss of production, damaged houses, displaced population that conclude into severe disruption of human life and damages to physical and economic infrastructure. Rising global oil prices and shut down of the New York stock exchange are the crucial economic terminal nodes of the cascade.

— The Tohoku Earthquake of 2011
The Tohoku Earthquake of 2011 shows how impacts of a secondary and tertiary disasters are each more complex to respond to than the previous. The primary trigger ,the earthquake, was an 'expected' disaster which the populations and authorities were equipped to deal with through planned long term mitigation and evacuation measures. Th ensuing tsunami took 1500 times of the lives claimed by the earthquake in addition to severe damages to critical infrastructure and the economy. The terminal node 'radioactive contamination' caused the largest disaster based mass migration and stirred a raging global debate against nuclear power.

— Volcanic eruption in Iceland (2010)
The eruption of the Icelandic volcano Eyjafjallajokull is the case in which the primary trigger affected a functioning global network. Paralysing critical civial aviation even for a week cascaded to disrupted logistics, fuel supply and disrupted social/ business events that cascaded to irreversible economic losses.

(Diagrams built with inputs from (Wilbanks, 2012, Marvin Phaup 2010, Chatterjee, 2011) , D'Ercole and Metzger (2009, (Dirk Helbing, 2012) (Helbing, 2013a), D'Ercole and Metzger, (2009,CBS News articles, CNN,OECD, The Guardian, Japan Times 2011 ,wikipedia, FEMA's Facilitator Guide 2011, http://www.slideshare.net/Ruth1618/tohoku-earthquake-case-study, http://exploregeography.net/case-study-the-tohoku-tsunami-japan-2011/, http://joeblakey.com/geography/case-study-japan-earthquake-tsunami-110311/)

“In the case of San Francisco, while sea level rise is gradually occurring, its combination with high tides and storm surges mean that 100 year floods will be 20 year events by 2033, and 2 year events by 2060. If this risk were to be solved in a hard engineered way the cost of new levees would be $ 9,500,000,000 and the upgrading of existing levees would cost $ 3,400,000,000.”

Introductory presentation, Delta Interventions,T Bacchin, 2016

Space

This section focuses of the role of planning, in specific, spatial planning in mitigating risks from natural hazards and designing for uncertainties. A ‘plotting’ of three modern disasters are made to derive the critical points of vulnerability of a spatial system . In doing so, it discusses the concept of ‘interconnectedness’ that leads to cascading failures of infrastructure and how reading the damage chain can help identify point of control. It highlights the clear disjunction between ‘disaster’ and ‘development’ which leads to higher investment in post disaster rehabilitation as opposed to pre disaster long range planning.

fig 27 (Introductory presentation, Delta Interventions, 2016)

Space

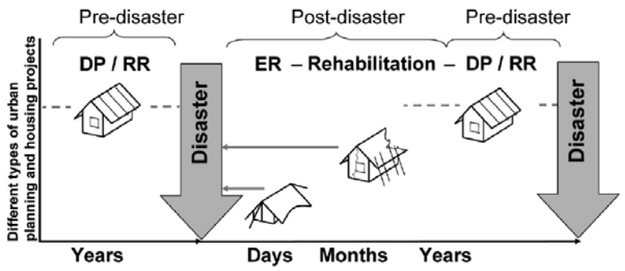
—Areas of exploration

—What is current the role of urban planning in disaster management and risk reduction?

—What is the role of existing urban elements (networks, space) during a crisis?

—What is pattern of movement of people and supplies in a normal and crisis situation? What is the inherent self-organization that exists in city systems to combat unforeseen

Figure 1 Research focus: pre-disaster projects in the field of urban planning—one subset of development planning—and risk reduction



Note: DP = development planning; RR = risk reduction; and ER = emergency relief.
Source: Wamsler, 2002.

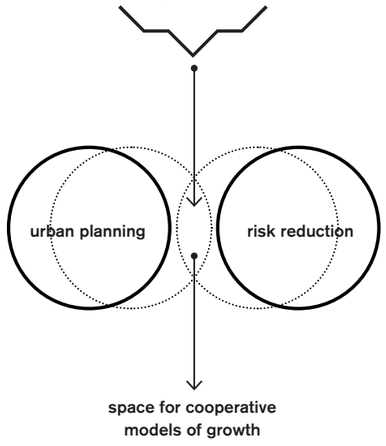


fig 28 *An extrapolation of foci in disaster planning, current and required consensus between the domains of urban planing and risk reduction. Ideas from (Wamsler, 2001)*

INVESTMENT : BEFORE V/S AFTER

Any political decision to deal with climate change inevitably involves balance and the tension amongst a range of choices: the balance of effort to adapt "now versus later" to a range of uncertain climate changes and tension between different types of effort, such as to "mitigate and/or adapt" in any particular regional setting (Corfee-Morlot, 2009).

Given the diverse network of stakeholders in an organism as complex as a city, it can be difficult to frame the opportunity of resilience in a way that allows all actors to align it to their current mission and goals (UNISDR 2012). For a long time urban planning was dismissed within organizations, since it was associated with centralized, social planning (Chavez, World Bank). According to Maskrey (UNDP-BCPR), 'somehow we still have not got this idea that it is better to reduce risks than to have disasters, and it is still not on the political agenda in any big way.'

In addition, the tenure of the ruling government is not long enough to adapt to an almost invisible hundred year risk with only long term impact as a priority agenda. Hence, while the mainstreaming of risk reduction is becoming increasingly recognized as a key challenge for development, very little work has been undertaken to identify how this could be done (Wamsler 2006).

Conclusions like these that run common across development reports compel the consideration of more beneficial growth models that can incorporate this environmental dynamic. Even if the will and resources become available, the timeline of climate change and the time for development of protection infrastructure required to combat it may not necessarily sync in time to avert damages in time.

Responses to a disaster can be categorised as 'structural 'and 'non-structural'. The current trend of focusing on preventing flooding using structural means catches us in a spiral of risk,. The response to a dynamic risk is very often a static with no capacity for absorption. Deltas in developed countries definitely have lower levels of risk at the moment, largely because of higher investment in flood defence infrastructure (Mcsweeney 2015). Japan, which has faced catastrophic flood events over the past century for instance, has adopted continual system upgrades for intense calamities (De Graaf, R. and Hooimeijer, F. eds., 2008).

Closer home, Netherlands that is also better endowed financially practices the same. But history has proven that no dike is too high, no dam too strong to guarantee damage mitigation in the event of a calamity. In the case of San Francisco, while sea level rise is gradually occurring, its combination with high tides and storm surges mean that 100 year floods will be 20 year events by 2033, and 2 year events by 2060. If this risk were to be solved in a hard engineered way the cost of new levees would be $ 9,500,000,000 and the upgrading of existing levees would cost $ 3,400,000,000 (Introductory presentation, Delta Interventions, 2016).

With rising costs of flood defences and several uncertainties, how much really is too much?

Governments, donors and development agencies have acknowledged the need to shift gears in disaster management planning and finance from relief and response towards prevention (UNISDR, 2005). Its long-term focus and proactive nature distinguish hazard mitigation from the more immediate and reactive activities taken during disaster preparedness, response, and recovery (Godschalk, 2003).

Yet, their interventions aimed at reducing social and economic vulnerability and investing in long-term mitigation activities are often believed to be few, poorly funded…in comparison with money spent on humanitarian assistance and relief and post-disaster reconstruction (Fuente World Bank). The same study concludes that total post-disaster expenditures exceed pre-disaster expenditures on average (and almost year by year). In the case of San Francisco as also with most other cities, the budget for disaster management is part of the 'general funds' or 'rainy day fund'. Inclusion of the overriding factor of climate risk needs room in the larger allowances made for physical infrastructure. For this, prioritization and involving stakeholders in beneficial partnerships will be key.

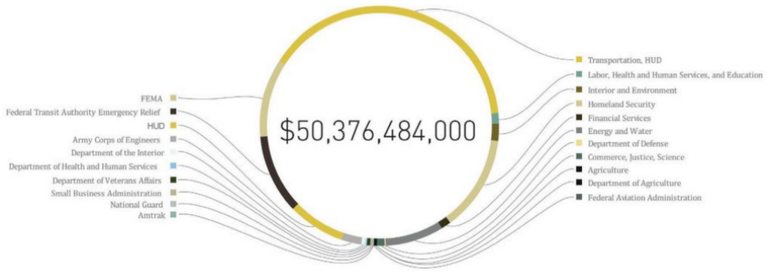


fig 29 *Online articles reflecting on the investments made in protection infrastructure against flood risk (Guardian, Carbonbrief)*
fig 30 *A graph illustrating the expenditure of rebuilding infrastructure post Hurricane Katrina (Source: Harvard GSD)*

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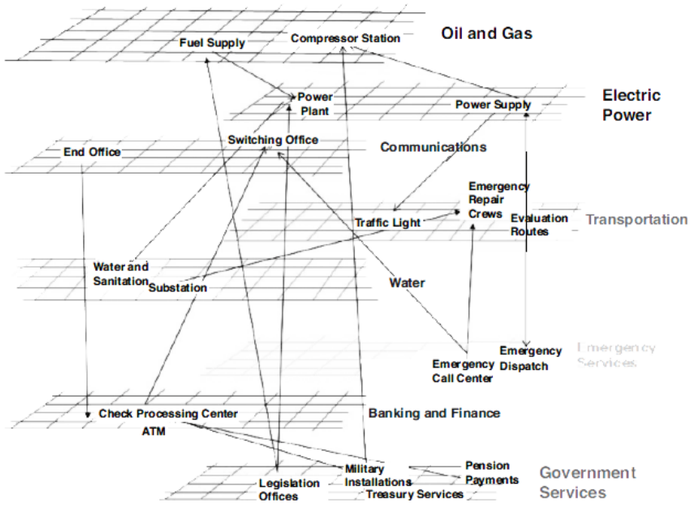
Identifying Critical Infrastructure

In order to design for a dynamic process such as climate, (KM de Bruijn 2006) recommends 'adopting a storyline that constructs the event for an understanding of the sequence of events from the rise of the threat to its recovery' (including the action and reaction of actors). In the case of this thesis, the objectives are minimizing both direct and indirect damage caused due to failure of critical infrastructure systems.

Based on the initial exercise to formulate how to 'design a disaster', the drivers that needed to be hampered included: Infrastructure, Economy and Services. Hence, the methodology spans across three scales, where each scale plays a role in identifying variables that inform better decisions for the three scale giving rise to an almost cyclic iterative process of design decisions.

While a comprehensive study would utilize a comprehensive study of all the above components, the purpose of this exercise is to device a tangible urban strategy by identifying the most important spatial entities or network components that play a role to mitigate risks and damages. While, critical Infrastructure involves several flows, the thesis focuses more on the 'built infrastructure' which includes urban buildings and spaces, energy systems, transportation systems, water systems, wastewater and drainage systems, communication systems, health-care systems, industrial structures, and other products of human design and construction that are intended to deliver services in support of human quality of life (Wilbanks, 2012). Relevant literature were analysed for characteristics and importance of the most important networks for better disaster recovery. It emerged that cascades are fairly common and there are clear pathways of spreading. In their paper, Luiijf et al. (2009), found that the energy (power) sector accounts for 60% of all cascades followed by telecommunication (28%), transportation (5%) and water (3%).

Hence, the scope of the thesis will be assessment of impacts of flooding and earthquakes on the interdependencies of three infrastructure networks – transport, water and energy on the urban landscape



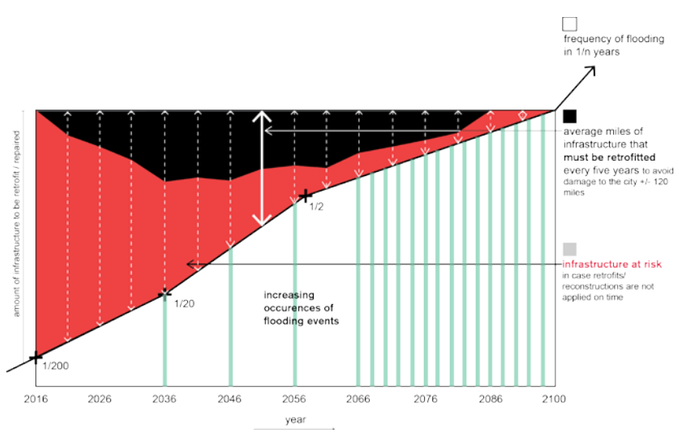


fig 31 *Infrastructure systems can be modeled as interconnected infrastructure layers (Wilbanks 2014)*
fig 32 *An ideological graph showing the timeline of rising flood frequency with the speed of constructing/ retrofitting protective infrastructure. The gap grey area highlights potential damage if the protection development doesn't keep pace with the pace of climate change for the San Francisco Bay Area (Source: Author)*

INFRASTRUCTURE AND RISK: CONNECTIVITY AND IMPACT

The term 'infrastructure', as defined by the President's Commission on Critical Infrastructure Protection (www.ciao.gov) is "a network of independent, mostly privately-owned, man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services". Recovering from a disaster event is closely associated with the resilience of the physical infrastructure of the terrain. The outcome of a risk is most manifested in the event of the failure of these fundamental networks and in its ability to hamper movement – of people, vehicles, supplies and water.

Besides loss of life, infrastructure destruction is by far the most obvious type of damage that comes to mind when we think about natural disasters. But the economic consequences are rarely considered beyond what the cost will be to rebuild, since a lot of current infrastructure are not designed to withstand hydrostatic load (aka external loading)- leading to buckling/ cracking/ corrosion (Elmerraji 2016). Also, in an event of a major climate catastrophe, the resources for rebuilding get scarce due to loss of critical infrastructure networks, inactive working population and general downgrading of its market value making recovery that much more difficulty. The San Francisco–Oakland Bay Bridge that partly collapsed during the 1989 Loma Preita earthequake took 24 years to be rebuilt completely. Hence, infrastructure resilience is imperative.

The mere movement of people inside a city depends on the integration of the electricity grid, the railway network, roads, communication of traffic lights and many more. These interdependencies yield significant vulnerabilities due to the cascading failure of these networks in an event of a risk (Juval Portugali 2012). SPUR's 'After the Disaster' report believes that San Francisco's resiliency relies on the redundancy of our transportation network (SPUR 2010).

Contextualizing these interdependencies is one solution towards planning for resilience and could perhaps inform living patterns in the built fabric.

Modern infrastructure systems are coupled together and therefore should be modeled as interdependent networks (Buldyrev 2010).

If networks that cover the urban realm are connected at one or more points, disturbances in one network can affect the networks connected to it. The evolution of a flood risk to due to higher sea levels can also worsen flooding in nearby rivers leading to upstream flooding. Flooding of crucial infrastructure nodes can lead to blackouts, hampering business. The interdependence related disruptions can be classified as follows (Steven M. Rinaldi 2001):

— **A cascading failure** occurs when a disruption in one infrastructure causes the failure of a component in a second infrastructure, (a natural event can led to failure of an electric utility which can hamper commercial activities)

— **An escalating failure** occurs when an existing disruption in one infrastructure exacerbates an independent disruption of a second infrastructure (Disruption of a telecommunication network, disrupting road transport, disrupting arrival of critical medical services)

— **A common cause failure** occurs when two or more infrastructure networks are disrupted at the same time (possibly due to same geographical location)

Hence, a single risk can also spawn several larger or smaller risks along with it leading to a complex disaster. Rising seas pose a threat to many different types of resources such as:
—Transport: Lines, nodes
—Power: Electric utility systems, power plants
—Water: Storm water systems and waste water treatment plants and outfalls, Groundwater aquifers
—Nature and human: Wetlands and fisheries, Human systems.

Understanding the robustness and redundancy of networks subject to an attack are essential to identify critical nodes. A dramatic real-world example of a cascade of failures ('concurrent malfunction') is the electrical blackout that affected much of Italy on 28 September 2003. The shutdown of power stations directly led to the failure of nodes in the Internet communication network, which in turn caused further breakdown of power stations (Rosato 2008)

In California, electric power disruptions in early 2001 affected oil and natural gas production, refinery operations, pipeline transport of gasoline and jet fuel within California and to its neighboring states, and the movement of water from northern to central and southern regions of the state for crop irrigation. The disruptions also idled key industries, led to billions of dollars of lost productivity, and stressed the entire Western power grid, causing far-reaching security and reliability concerns (Steven M. Rinaldi 2001)

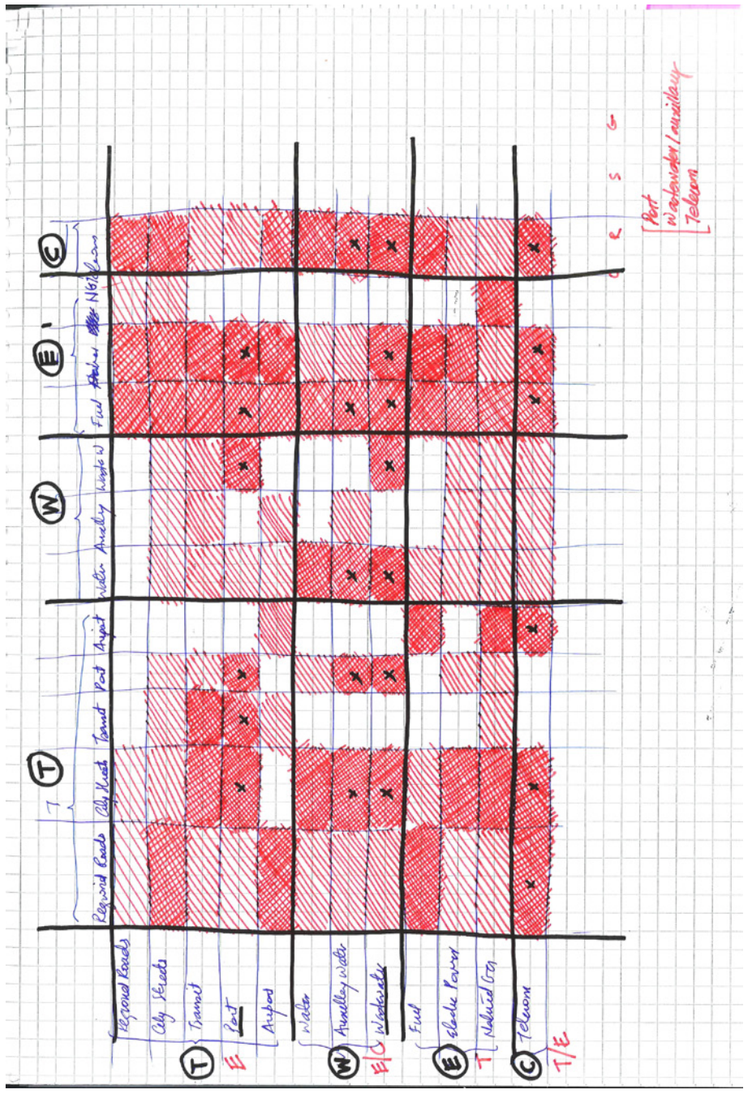


fig 33 *Studying impact and interdependencies between critical infrasrructure (Based on Analysis in FRANCISCO, T. C. A. C. O. S. 2014. Lifelines Interdependency Study. SPUR 2010. After the disaster: Rebuilding our transportation Infrastructure. San Francisco Planning + Urban Research*

fig 34 *Studying impact and interdependencies between critical infrasrructure (Based on Analysis in FRANCISCO, T. C. A. C. O. S. 2014. Lifelines Interdependency Study. SPUR 2013)*

“People are generally averse to uncertainty and vagueness and are accordingly reluctant to take action in response. However, when uncertainty is framed positively, people have stronger intentions to act”

[Morton et al., 2011].

Risk+Space

This section advocates for mainstreaming the role of spatial planning in disaster risk reduction. It focuses on studying ‘recovery patterns’ to arrive at a framework to plan for long term resilience to reduce negative consequences. Based on previous studies, it refines the problem further to highlight chief areas of research and the inter-scalar nature of the project. It provides an analysis of the test case- the San Francisco Bay through existing vulnerabilities of critical infrastructure networks (transport, water, power) to the two hazards in consideration. In doing so, it establishes spatial risk taxonomy and the ‘critical web’ that will survive in the East Bay.

fig 37 *Exploratory model of flood levels of East Palo Alto (Studio Delta Interventions, TU Delft , Team; R Dewan, S Rao, F Ahuis, S Krishnan)*

What causes a disaster? (graphics: Author) Source: Network model is derived from the eleven-system interdependent infrastructure as postulated by Chang et al. [7] and based upon the structure derived by Rinaldi et al. [8] (Reed, 2009)

Risk+Space

—Areas of exploration

—What is the role of the ‘physical space’ in planning for uncertain growth?

—What are the urban growth variables that can determines the impact or risk on the system?

—How can conclusions from engineering assessments (seismic studies, computer science) on urban systems be synthesised using ‘design thinking’ to formulate a spatial planning framework?

—Which other variables (biophysical, hydrological and social) can aid in establishing better spatial resilience improvement exercise?

—How can understanding the system of recovery to extreme calamities provide feedback to bounce forward in space for long term resilience?

—How can the incremental progress of risk in the urban landscape (rising sea levels) inform incremental urban growth strategies for a region? How can transformational spatial development be phased for the far future?

fig 40 Proposed theoritical framework and research domains

THEORITICAL FRAMEWORK

The thesis is an exercise in finding synergies between behaviour of man made critical inrastructure using fundamentals of landscape ecology for design. Hence, the theoretical framework is an evolving but non-linear backbone of this project. While it provides the strong rationale for the problem field and argumentation for the line of thought, the concepts of theories that will be infused throughout the journey of the planning process helps interpret the complex nature of the topic from different perspectives and raise important critiques. Each theory support a set of analyses, evaluation and design process that build on to the next step in the project. For a systematic analysis model, it is necessary to establish objectives of the study to curate the study material for a global topic. The literature review focuses on the following areas:

1 Understanding the fundamental of the topic of global climate risk (CC)

— The concept of risk
— A study of global concept and impact of climate change, risks and disasters
— Current practices in institutional design of disaster management with focus on flood risk
— The work of prominent risk research labs: MIT Risk Centre, TNO, ETH Risk Lab and global development agencies to draw upon existing implementation frameworks to tackle climate related risks.

2 Understanding theories of analyzing interdependencies in networks and application to the urban fabric

— The interdependencies of networks are being studies through two concepts – The Complexity Theory of Cities and Cascade Effects of networks, Perrow's Infrastructure Taxonomy, Critical Dependencies by Rinaldi.
— — Landscape measurement techniques such as cell systems, surface coverage ,patch matrix techniques, landscape ecology patterns, performative urban systems, the American Landscape will be utilized based on Andre Botequilho's 'Measuring Landscapes' and Forman's ' Landscape Mosaic
— Complexity Theory of Cities: The major achievement of CTC is thus not so much in identifying new urban phenomena but in giving a single and sound theoretical basis to a variety of urban phenomena and its interdependencies (Portugali 2009).

3 Understanding the context of the San Francisco Bay area

Reports that study, analyse, evaluate and propose projections for future risks will be utilized to understanding on a regional level the existing loops, loose ends and redundancies in the networks. (Brooks, 2003, Wilbanks, 2012) (Gianluca Pescaroli, 2016) (SPUR, 2011) (IPCC, 2014) (Bank, 2013) (Perrow, 1984) (Meyer, 2013) (Helbing, 2013, K. Peters, 2008) (Gersonius, 2012)(SPUR, 2010, Institute, 2012) (ABAG, 2014) (SPUR, 2011) (Francisco, 2011) (Francisco, 2014)

(refer Appendix V for complete theme based list of references)

fig 41 *Snapshots of the highway network and power stations in the San Francisco Bay Area (Courtesy: Sumanth Rao)*

PROBLEM STATEMENT / HYPOTHESIS /RESEARCH QUESTION

Problem Statement

"Climate change, the greatest threat to mankind, is resistant to reliable methodological quantification. In many cases it is not possible to "ascertain the probability of outcomes and their consequences through well-established theories with reliable and complete data. Both the risk and uncertainty of climate change require a very large degree of subjective judgment, erring on the side of precaution". People are generally averse to uncertainty and vagueness and are accordingly reluctant to take action in response. However, when uncertainty is framed positively, people have stronger intentions to act [Morton et al., 2011]. The process of climate change induced slow onset risks (sea level rise) or fast onset risk (earthquakes) are too gradual or too sudden, which is why the urgency to invest and act in an integrated, incremental manner with coherent physical goals has often been missing.

For examples, the current process of planning for flood risk in urban areas focuses on simulating the intensity of hazardous scenarios on the landscape and making strategies to 'protect' the terrain from water. Studies to analyze the interdependencies that lead to delayed recovery and damages see a roadblock due to the uncertainty of the event occurrence in one lifetime or one political term.

Hence, resource allocation (both planning and investment) focuses on repairing post disaster damage as opposed to preparing to reduce the damage at the source through better urban development strategies. A fundamental issue is the lack of integration between the domains of urban planning and risk reduction.

Hypothesis

The recovery period after a crisis is inversely proportional to the redundancy of critical infrastructure networks that keep accessibility alive after a calamity in order to resume system equilibrium. Planning to prevent the negative consequences of a hazard event can be tackled better if we understand the response ecosystem of critical infrastructure networks in the urban fabric that can guide the resilient network of the region. This can help prioritize development and investment models.

How can understanding the effects of flooding and earthquake risk on critical urban systems (networks and space) inform incremental spatial strategies towards risk reduction?

fig 42 *Post disaster scenes , cascading failure impact of recovery operations (Source: National Geographic)*

SUB RESEARCH AREAS

Each section of the report answers a set of the sub research questions posed or explored during the course of the project

STAGE 1: Risk

— How the concept of 'risk' and 'resilience' is perceived in global development reports (World Bank, Tyndall Center)?

— What is the current attitude to managing risks from natural hazards in the urban environment?

— What is the characteristic of and damage chain in modern urban disasters?

STAGE 2: Space

— What is current the role of urban planning in disaster management and risk reduction?

What is the role of existing urban elements (networks, space) during a crisis?

— What is pattern of movement of people and supplies in a normal and crisis situation? What is the inherent self-organization that exists in city systems to combat unforeseen disruptions?

— How can a 'systems approach' help map the multifunctionality of urban elements to deal with short term and long term impact from natural hazards?

— What is the role of critical urban infrastructure systems in combatting disasters?

— What are the current ways in which urban morphology can be adapted for resilience towards flooding and earthquake liquefaction across scales?

STAGE 3: Risk+Space

— What is the role of the 'physical space' in planning for uncertain growth?

— What are the urban growth variables that can determines the impact or risk on the system?

— How can conclusions from engineering assessments (seismic studies, computer science) on urban systems be synthesised using 'design thinking' to formulate a spatial planning framework?

— Which other variables (biophysical, hydrological and social) can aid in establishing better spatial resilience improvement exercise?

— How can understanding the system of recovery to extreme calamities provide feedback to bounce forward in space for long term resilience?

— How can the incremental progress of risk in the urban landscape (rising sea levels) inform incremental urban growth strategies for a region? How can transformational spatial development be phased for the far future?

STAGE 4: Evaluation

— What tangible parameters can be considered to devise transferable 'spatial risk assessment framework' systematically evaluate spatial resilience

— What plans and systems of governance does San Francisco Bay need to modify to effectively position long range spatial planning strategies for risk reduction?

— What kinds of cooperative growth models are available/ can be devised for fruitful partnerships?

— What is the role of the 'urbanist' in the domain of planning for risks and disasters?

— What main urban trends/disruptions can contribute to transformation growth towards the year 2100?

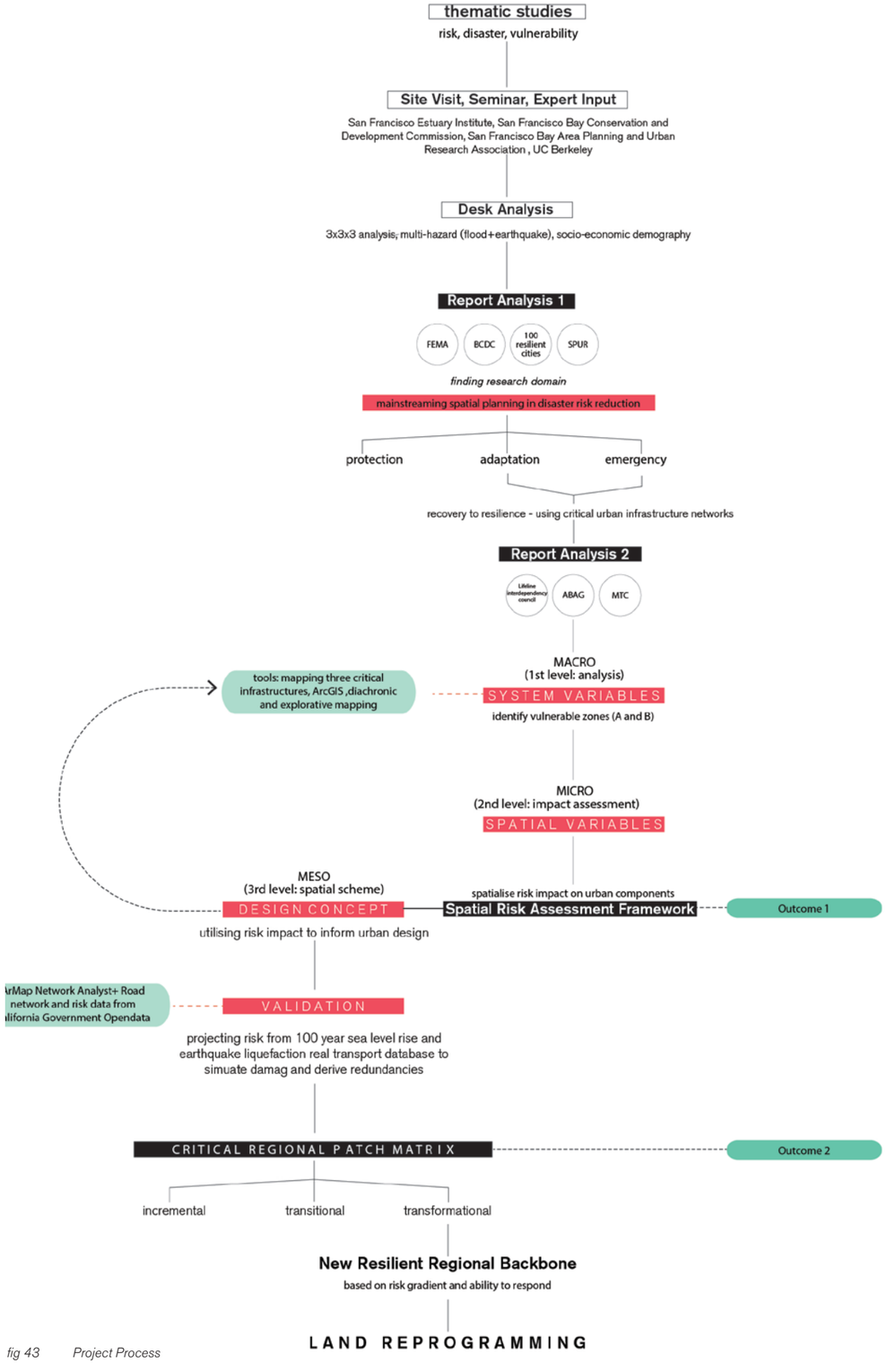


fig 43 *Project Process*

PROCESS

The thesis project involves the following steps:

Thematic studies: Broad thematic studies relevant to the 'graduation studio' were conducted covering the following domains:

- Urban Landscape Dynamics, Narratives & Values
- Performative Design/ Process-Based Design
- Dynamic Adaptation (Designing with Uncertainty)/ Climate Adaptation
- Landscape Urbanism/ Sustainability & Liveability
- Landscape Infrastructure (Green-Blue Infrastructure Design/ Water Sensitive Design/ Building with Nature)
- Integrated Spatial Planning & Flood Risk Management
- Territorialism/ Infrastructure Spaces

Desk Analysis: A desk analysis of the San Francisco Bay Area was conducted for the first level understanding of the scale and demography of the region. Historical maps were studied to understand the urban development pattern, growth of infrastructure networks and the events leading to it.
This was followed by a visit to the San Francsico Bay area with the students of the Masters in Urban Design programme at University of California- Berkeley. The field work involved visiting a selection of 24 sites across the bay (Appenix III- Site Visit Log). A seminar with decision makers of the Bay Area (San Francisco Bay Conservation and Development Commission, San Francisco Bay Water Transit Authority, San Francisco Estuary Institute) was conducted for preliminary insights and interactions. Additional visits to the South Bay and municipality of East Palo Alto were conducted.

Report Analysis 1: Prominent reports on the resilience of the Bay Area were conducted to identify current objectives, timelines to plan for resilience. The reports include:

- East Bay Corridors Initiative Priorities 2015-16 (Association of Bay Area Governments)
- Adapting to Rising Tides Transportation Vulnerability and Risk Assessment Pilot Project (BCDC+CALTRANS+MTC)
- San Francisco Bay Plan (BCDC)
- Adapting to Rising Tides
- Climate Change and Extreme Weather Adaptation Options for Transportation Assets in the Bay Area Pilot Project (BCDC+MTC+BART+CALTRANS)
- Plan Bay Area (MTC+ABAG)
- Seamless Transit - How to make Bay Area public transit function like one rational, easy-to-use system (SPUR)
- 100 Resilient Cities

fig 44 *[1]Meyer, Han, Steffen Nijhuis, 2016: Designing for Different Dynamics: The search for a new practice of planning and design in the Dutch delta, in Juval Portugali, Egbert Stolk eds., Complexity, Cognition, Urban Planning and Design, Berlin: Springer*

The research domain was identifies –mainstreaming risk reduction in urban planning with a focus on critical infrastructure systems that aid recovery

Report Analysis 2: A second round of report assessments were conducted with a focus on infrastructure and risk. This includes:

- Cascading Failures- Earthquake threats to Transport and Utilities (ABAG)
- Lifeline Interdependency Council Report (The Lifeline Council, City and County of San Francisco)
- Long term Disaster Recovery Plan prepared for the City of Oakland as a Model Plan for Local Governments in the San Francisco Bay Area

The reports provided the current state of analysis made for vulnerability of critical infrastructure systems and expected losses.

Spatial Analysis:
D-i has a strong emphasis on the agency of spatial interventions in the production of territories, on traces that are drawn in the landscape forming a narrative of space occupancy over time. In this context, infrastructure space is analysed and designed as a medium – manifesting the programmatic dimensions and the multiscalar nature of the territorial project. Hence, the mapping process also involves analysis at three main scales with a specific objective.

MACRO
The South Bay of San Francisco is the boundary condition for the 'macro scale' and in the case of this project the 'system scale'. A 3X3X3[1] analysis of the entire bay was carried out to evaluate the natural, artificial and human occupation networks on the site.

Objective: To understand the layout of critical infrastructure networks that defines the system structure and overall vulnerable zones due to flood risk and earthquake impact. The projected risks for earthquakes and sea level rise were mapped utilizing information from 'US National Topo Maps' and FEMA. The impacts of the risks were overlaid on the each network individually to identify which were critical and safe. All the critical network risk maps were overlaid to find zones that have higher densities of networks at risk which will be further referred to a 'high impact risk zone'.

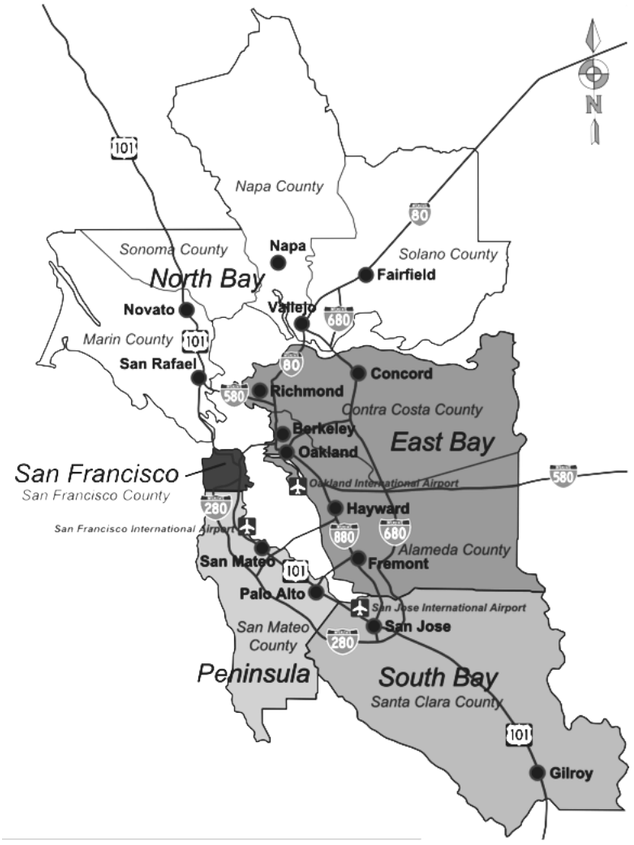


fig 45 *The San Francisco Bay and its counties (Source: http://www.bayareacensus.ca.gov/counties/counties.htm)*

MICRO

The urban district within a city forms the MICRO scale of the project. This helps in demonstrating how land use patterns can be modulated at the level of the 'city', which is the fundamental unit of the local planning process in California. The critical infrastructures were then mapped in better coherence on the urban district scale. Important transit routes, connector routes to larger roads / economic centers, important functions such as hospitals, fire stations, schools, city centre were located.
The vulnerability of the lines were assessed to derive the 'most critical' and 'safest' zones which did not necessarily overlap.
As an example ,in the San Leandro site, the end of the Bay Bridge, which is the only crucial connector to the rest of the bay is at high risk, both from seal lever rise related inundation and disruption due to an earthquake.

Objective

To assess the direct physical impact of risk on an urban network on each parcel to assess potential for adaptation. The unit is the right scale to assess physical characteristics of the landscape such as porosity, permeability, important axial nodes, business districts, sufficiency of public spaces, connectivity, critical amenities and socio-economic demography. Assessment at the MICRO scale offers a direct feedback loop of physical changes that must be extrapolated at the MACRO territorial level.
The MICRO scale is also utilized to establish the 'Spatial Risk Assessment Guidelines' that sets parameters to assess the level of resilience of a site.

MESO

The MESO scale in this case is the 'County' which is the scale of larger spatial decision that can make the strategy a part of the climate mitigation plan of the county. The feedback from the MICRO scale helps refine the strategy at the Macro Level . Extrapolate physical impact on subsystems on the city scale with the intent to assess the magnifications of damages that can be possible due to cascade phenomenon. The meso scale or county scale is also, in most cases the 'administrative' boundary condition. Hence, it has been adopted as the 'regional design' scale for the project.

Objective

The MESO scale acts as the mediating unit for governing larger spatial structural changes to include robustness and reduce damages. As part of a larger resilience guideline, the scale helps identify fundamental 'gaps' (spatial, functional, administrative) in reaching desired resilience goals.

Validation

A projection of risks is made on a real dataset of transport of the San Francisco Bay Area to understand vulnerabilities accurately. In correlation with the mapping process, it helps derive the 'critical web' or the 'middle ground' of the region whose security must be assured to avoid large scale damages. This will act as the spine to guide growth .This also brings with it the 'Design Concept' of the thesis.
The Critical Regional Patch Matrix is then classified based on the gradient of risk to establish spatial parameters to aid resilience. Land can then be reprogrammed based on the level of risk. The gradient/probability of risk can be utilized to phase the interventions into 'incremental', 'transitional' and 'transformational' growth.

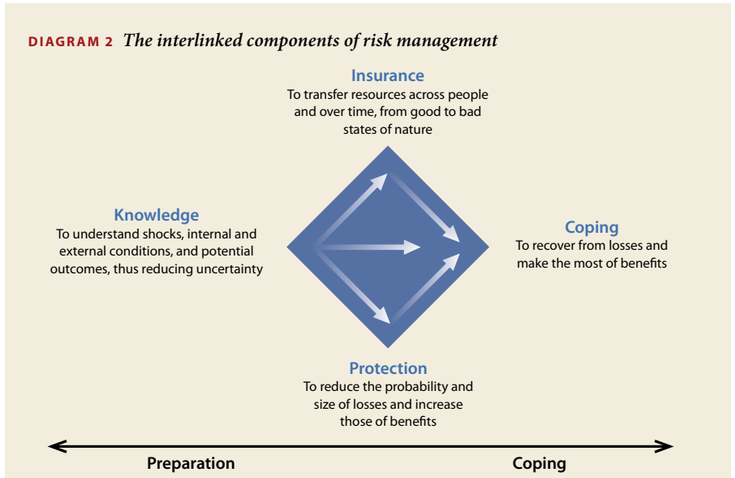


fig 47 *Interscalar parameterisation framework for analysis and evaluation (Source:Bank, I. B. f. R. a. D. T. W. (2013). Risk and Opportunity :Managing Risk for Development. World Development Report)*

RISKS IN SPACE

The thesis deals with 'large systemic risks' due to climate change (earthquake, flooding) that involves decision making at the level of the national, regional and sometimes international agencies. The effects trickle down to the level to local municipalities and communities that can implement changes based on the impacts they face due to 'idiosyncratic risk'.

It elaborates on understanding connecting the 'logic of risk' with the 'logic of urban spatial planning'. This involved assessing existing approaches to managing risk and how it connects to the dynamic urban growth. Integrating the changing intensities of combined risks (earthquake, flooding) with the behavior of urban elements in space is a major challenge. 'Risk management is the process of confronting risks, preparing for them, and coping with their effects. Resilience is characterized by the ability of people, societies, and countries to recover from negative shocks, while retaining or improving their ability to function.'(Bank 2013) Hence, it is a method to modulate the impact of the 'consequences' of the risk. In the event of a calamity, the impact due to a risk is directly related to the time and effort needed for recovery. Hence, risk management is an important tool to determine the 'risk chain' of events to backcast the failure chain for stronger recovery framework. Hence, the main objective of a risk management process is to arrive at good decisions based on available information. The rational decisions making process involves, assessing the variables that are important with the aim to 'optimize' utility of available resources to cope with the risk.

Mainstreaming risk reduction in the domain of 'urban planning' calls for a 'granular' understanding to risks and what may be the long term dividends to be gained /lost. Understanding the causal chain of events, hidden chain of failures and their impact on space and livelihoods plays an essential role in determining critical areas for intervening. Visualizing failure chains can make non-critical infrastructure critical. Landscape vegetation management, which by no means is seen as critical infrastructure, was the main cause of the series of blackouts on the Swiss–Italian border affecting 56 million people (K. Peters 2008, Helbing 2013).

A broad overview of global risk and resilience assessment frameworks was conducted to assess the attitudes to managing risks in the urban environment. According to the World Development Report on Risk and Opportunities, the following main obstacles are highlighted in the patch of managing risk (Bank 2013):

— Lack of resources. Even when a risk management strategy is cost-effective, individuals and groups may find it difficult to undertake because of large upfront costs and limited access to credit.

— Lack of information and cognitive failures: Relevant information may not exist or be available to decision makers.

— Behavioral failures. Even if information exists, decision makers may be unable to turn knowledge into actions and behaviors that prepare them for risk.

— Obstacles beyond the control of individuals hamper their risk management

— Government failures. Risk management can also be impaired by government failures stemming from capture by interest groups, corruption of government officials, and distortionary policies

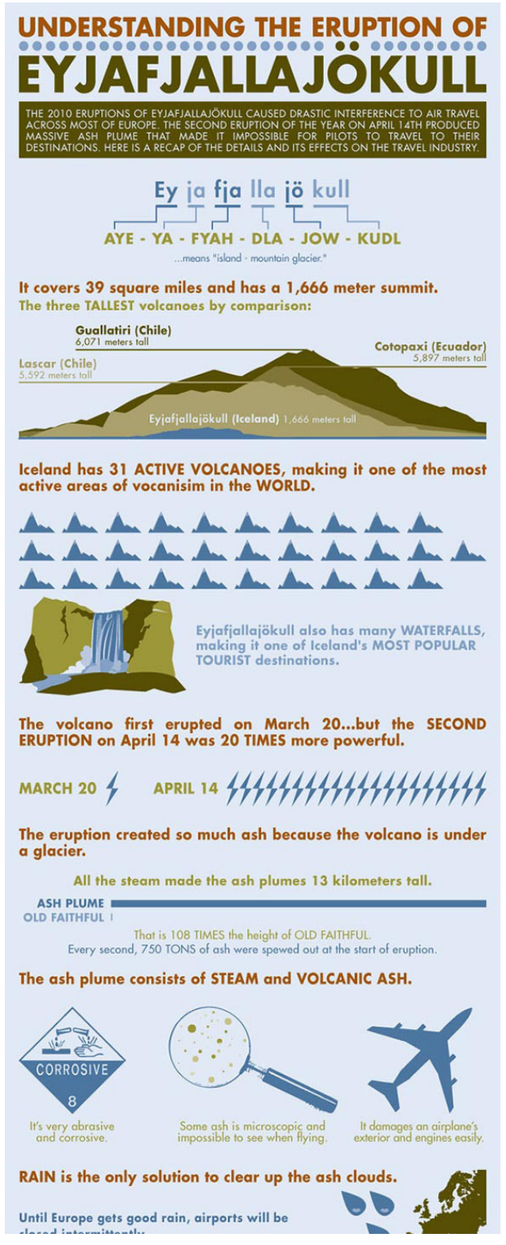
— Social and economic externalities: Risk management actions undertaken by some people or countries may impose losses on others.

The case of unknown unknowns

In addition, planning for uncertain risks due to natural hazards adheres to the concept of 'deep uncertainty'. Also known as Knightian uncertainty in economic circles, deep uncertainty refers to a situation for which even experts cannot agree on appropriate models to understand it, on the potential outcomes and probabilities of its occurrence, and on how much importance should be given to it. Building knowledge helps to reduce the degree of uncertainty. The history of science is full of cases where deep uncertainty gradually became ordinary uncertainty, amenable to management and control.
Reasons for skepticism towards risk assessment models:

1. Misuse of model and incorrect applications
2. Too much model use dedicated to people who don't understand models
3. Insufficient basic scientific research for credible environmental and societal aggregations
4. Inefficient planning and resources for model maintenance and management
5. Lack of incentives to document models
6. Over emphasis on optimal use of computers; under emphasis on efficient use of human resources
7. Proliferation of models, lack of systematic inventory of models
8. Lack of communication

Hence, utilizing 'robust' planning principles that can adapt to change is the common understanding for planning for risks. These must be evaluated over a range of scenarios to test the flexibility of the variables involved.



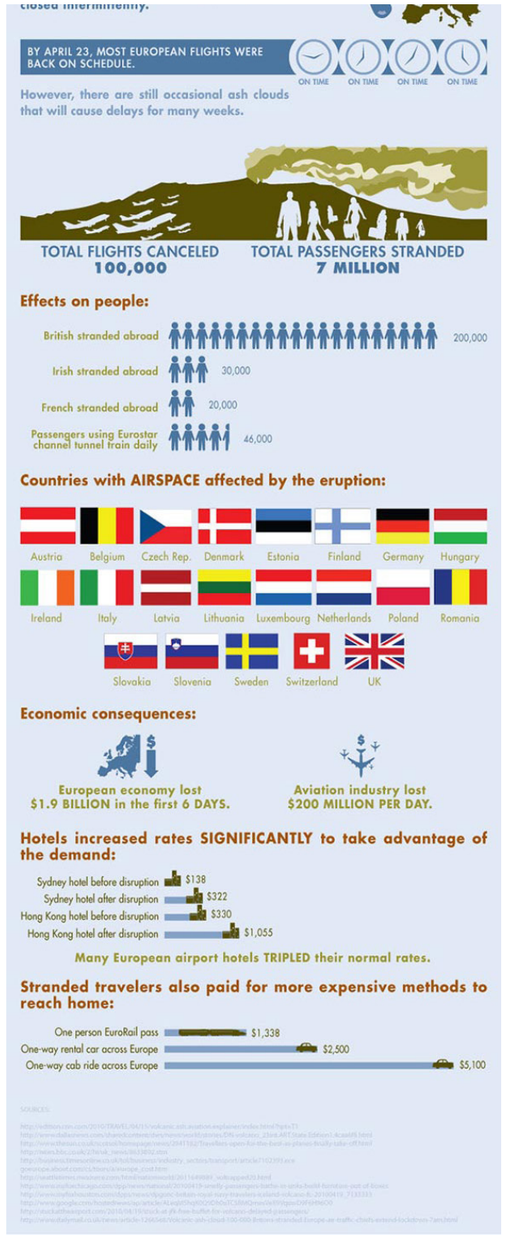


fig 48 *The flow of events during the week of the Volcanic Eruption at Iceland is a relevant example of a cascading impact of a risk leading to unexpected outcomes (Source: http://gadling.com/2010/04/27/eyjafjallajokull-icelands-volcanos-explosion-cost/)*

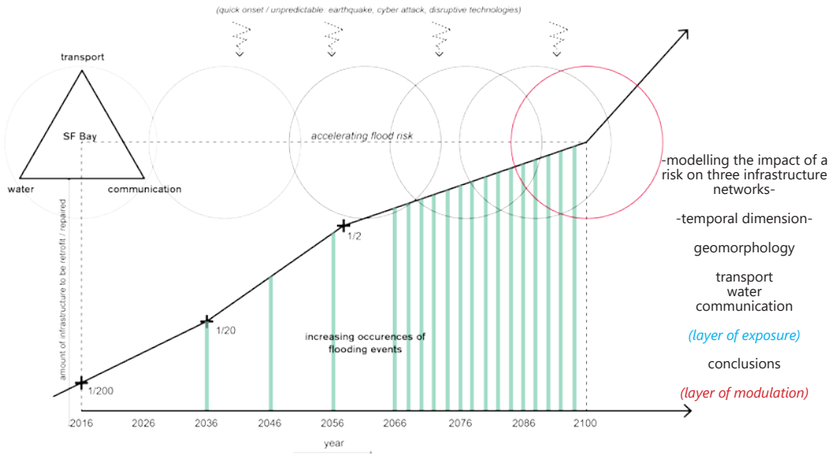


fig 49 *Recurrence of intense climate related events versus the available timeline to plan and implement resiliency strategies. Three critical infrastructure networks -transport, water and energy will be considered*

SPATIAL PARAMETERS FOR RESILIENCE

In a project that deals with massive interconnected infrastructure, not all of which have spatial implications, it becomes necessary to filter essential and specific information that the project can deal with. Hence, Multi Criteria Analysis (MCA) is adopted through parameterisation.

Parameterization, the process of deciding and defining the parameters necessary for a relevant specification of a model or geometric object, was employed with the following objectives:

—The intended 'spatial outcome' of the thesis.
— Better defining the scope of interventions across scales
Composite parameters will be adopted to find aggregate of vulnerabilities over three scales as opposed to an overall aggregate. The objectives for parameterization, in addition to a coherent spatial planning framework include
—describe the state of the system and underlying processes
—determine vulnerability of critical infrastructure to sea level rise and earthquakes
—What are the baselines, benchmarks, indicators?
—determine the objective of the resiliency plan
—measure the factors contributing to adverse impacts and the diminished capacity
—track progress towards or away from the goal (Milman, 2008)
—ability to adapt and endure

The necessity to formulate parameters was driven by the specific expectations in the scope of a project that deals with massive urban infrastructure. The process of defining parameters Formulation of spatial parameters to evaluate and model a climate-risk related impacts at three different scales was done by enumerating the causes, dependencies and potentials related to that specific elements (under consideration for this project) at that specific scale. The process involved understanding direct and indirect impacts of the flood and earthquake on three critical infrastructure lines – transport, water and communication.

The networks were look as objects in space that can behave differently at the three scales. While studying characteristics of nay network it is essential to understand it is essential to list a possible inventory of behavior of that object in normal circumstances, under stress, failure and its impact on connected networks.

Based on the conceptual framework described by (Adger, 2004) in the report titled ‹ New indicators of vulnerability and adaptive capacity›, Indicators can be classified as:

Diagnostic
Indicators based on outcomes of previous disasters
— Study of National Assessment reports for disaster management (FEMA, National Security Agency)
—Utilizing 'Causal Loop Diagrams' (CLD) to manually model the cascade impact of disruption to one system to another
—Independent agency report for disaster resilience (100 Resilient cities)

Predictive
Indicators based on the social, economic, political and environmental conditions
— Site Observations
— Presentations from development agencies working on the site (BCDC, SPUR, BART, Stanford) with future projections for development that enumerated scopes and challenges of development in the region
—Papers on modelling behaviour of critical infrastructure and 'complexity theory'
—Papers on formulating 'indicators' of infrastructure performance and correlation studies.

Thus, parameterization for analysis, evaluation and concept has been generated by coalescing and critiquing the indicators in the above studies at the macro, meso and micro scales. The observations were categorized by a series of questions .The answered were then categorized to 'cause', 'dependencies' and 'potential'. The figure indicates a sample evaluation set of one loop –transport' .The same exercise has been repeated for the three networks at all three scales. While preliminary analysis is schematic, the final indicators will be considered for their real spatial implications of the three chosen infrastructure. This has then been summarized to generate an analysis, impact and concept matrix which will determine the framework for the regional structure.

While indicators will play an increasingly important policy role, they capture only synoptic aspects of vulnerability at the scale at which they are applied. It is, therefore, important to develop our understanding of vulnerability by examining how it arises in a variety of contexts, paying attention to the relative importance of various social, economic, political, geographic and environmental factors in different countries, and also to the hazard specific nature of vulnerability.

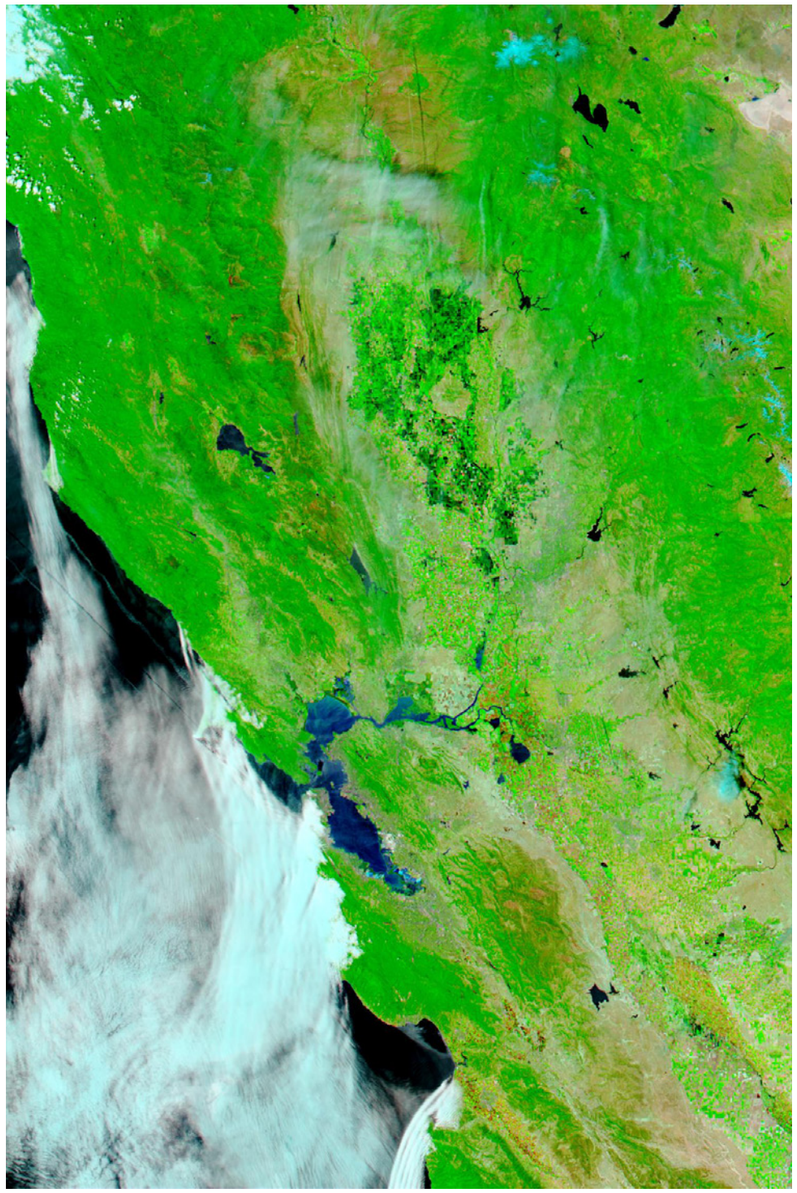


fig 52 *Flooding after levee break in san Joaquin-Sacramento river delta, San Francisco Bay Area (false color) in context to the state of California. Credit: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC*

CONTEXT / HAZARD IN FOCUS

The central hazard that will be utilised for analysis in this project is flood risk associated with sea level rise due to climate change and ocean warming compounded by pluvial and fluvial flooding (which includes light rains+rain pack+snow pack effect). This will be analysed against the backdrop of high earthquake risk that the San Francisco Bay Area is constantly threatened by. The hazard can be classified as a combination of a Discrete Recurrent Hazard (transient phenomena such as storms, extreme rainfall, earthquakes) and Continuous Hazards (gradual rise in sea level over many years) (Hulme, 1996; Adger and Brooks, 2003) (Brooks 2003).

In the case of a global risk like sea level rise, a context is essential to illustrate how logical flow of events applies to the urban system. Delta Interventions graduation studio has adopted the study of the San Francisco Bay Area for the academic year 2016-17.

The San Francisco Bay Area (referred to locally as the Bay Area) is a populous region surrounding the Francisco and San Pablo estuaries in Northern California in the United States of America. Among other cities, it is home to San Francisco, is a prominent global city, ranked as one of the most liveable cities in the USA characterised as a hilly city on the tip of a peninsula surrounded by the Pacific Ocean and San Francisco Bay. The area is well known worldwide for the complexity of its landforms, the region being composed of at least six terrains with considerable relief in the landscape. It has two kinds of coastlines – the inner bay and the ocean edge.

The Association of Bay Area Governments (ABAG), the regional planning agency for San Francisco, projects that the population of San Francisco will grow to 1 million, and the Bay Area will grow to 7.2 million residents by 2040 (Cities 2015). The Inner Bay which has over a 1000 miles shoreline which is home to a bustling urban fabric, especially along the inner bay. The same shoreline is vulnerable to a range to natural hazards. Including storms, extreme high tides and rising sea levels. Over the past century, sea level has risen nearly eight inches along the California coast (Institute 2012). Although sea level rise is an overarching problem, another large contributor is fluvial water sources from light rains, snowpack effect and rain-snow effect.

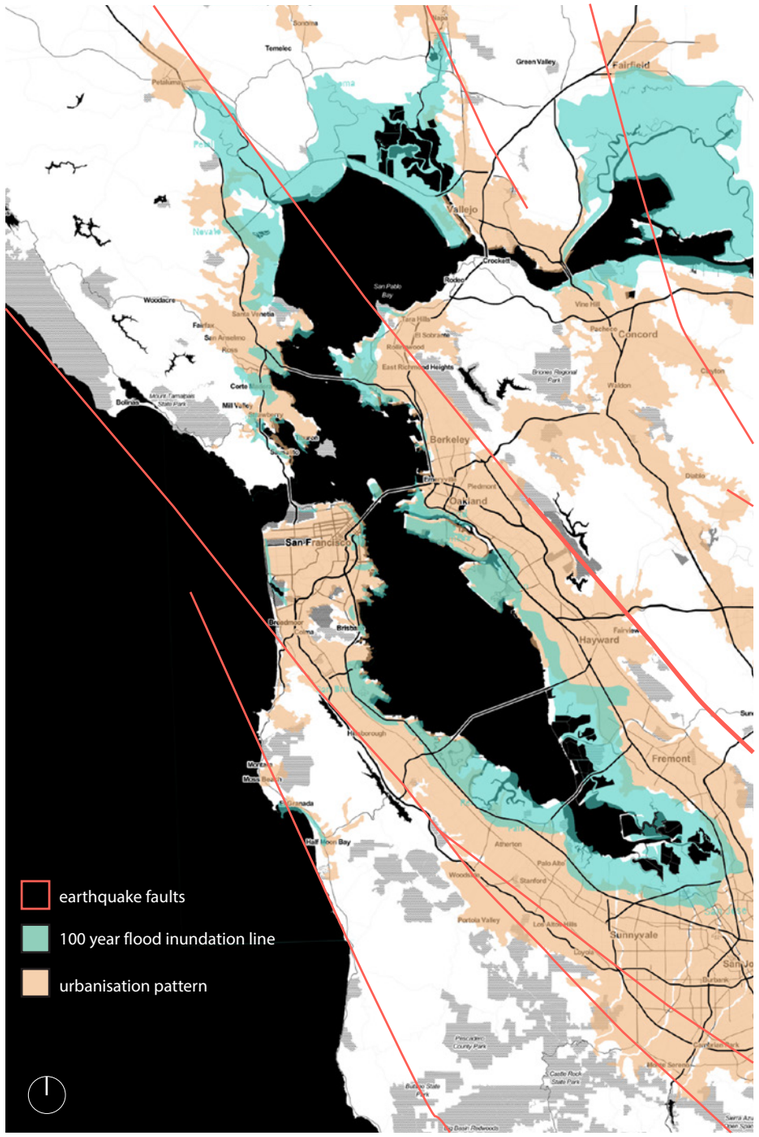
The dominance of gradual change over an adhoc event is a crucial fact that enables urgency for implementation. While it is a known fact that San Francisco is sitting on a massive earthquake hotbed, a slow, hard to comprehend outcome of sea level rise does not command immediate attention. There are over 52,000 hectares of vulnerable low-lying lands; in many areas the ageing levee systems do not meet federal standards. A visual analysis of the 50 year flood inundation map illustrates that at least 40% of the urbanised land is under threat. A cost of replacing property at risk of coastal flooding of 1.0 m rise is approximated to be $49 billion. This is perhaps the starting point of the bargain between investing before the flood to minimise damages or after the flood to cope with the damage (BCDC ,2008).

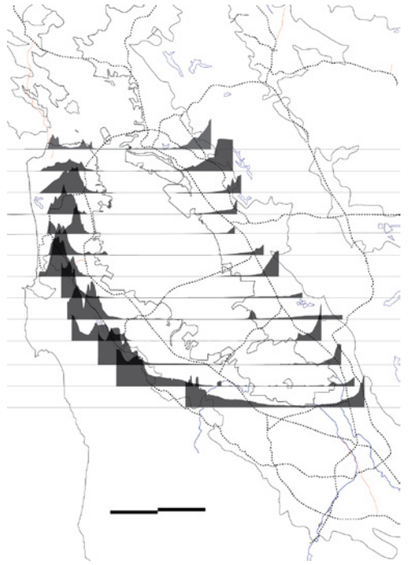
Several agencies in the San Francisco Bay Area such as Bay Conservation and Development Commission, Association of Bay Area Governments, Bay Area Regional Collaborative, San Francisco Estuary Institute, SPUR, the Climate Readiness Institute, and the California Coastal Conservancy are working towards the common objective of mitigating the effect of flood. Several predictable obstacles plague the path of planning including:

—Underserved communities
—Immovable infrastructure
—Too many stakeholders (public utilities such as railways are privatized)
—Power with the 'local' Not the state
—Long recovery periods
—'When no one has seen it, How do you address it'?
—Coordination agency for networked assets do not exist

Scales
The thesis for a large portion will work in an interscalar fashion, moving back and forth between regional, county and city scales. Reports from government agencies, independent research and site observation will be utilised to identify potential areas of intervention. A multi-scalar approach will be adopted which will include the following stages:

—MACRO (Metropolitan Scale): Bay Area: Analysis of terrain, major infrastructure interdependencies (water, transport, communication) against the backdrop of flood risk (East Bay, North Bay, South Bay or the Peninsula)
—MESO (County scale): understanding larger urban growth patterns, land use (San Mateo, Santa Clara, Alameda- counties most at risk based on the report by Pacific Institute)
—MICRO (City scale): living environment (Palo Alto, Oakland)





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S
— Developed context with several active development agencies
— Hub of cutting edge technology
— Development led by infrastructure
— Strong community structures and diversity in population
— Rich natural assets and abundance of potable water

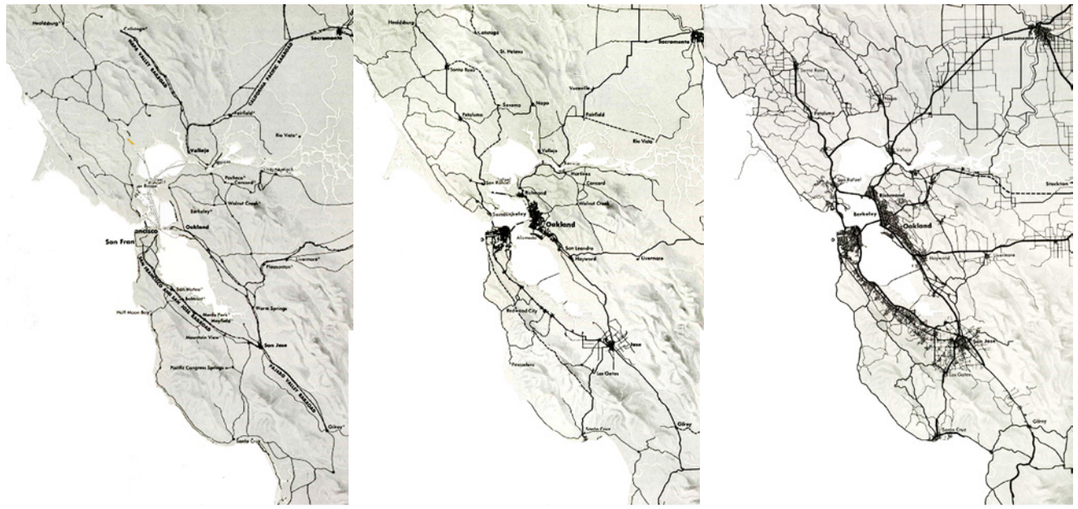
T
— 200 sq miles >> 250,000 people at risk from sea level rise of 1.4 m by 2100
— Active earthquake fault runs under the territory
— Economic Centre: Silicon Valley at threat of inundation
— Further development in high risk zones
— Lack of coordination between agencies
— Urban decay

W
— Most urban development on geologically weak alluvium soil – unstable.
— Fragmented institutional frameworks
— Power with the 'local' Not the State
— Large scale damming cut off sediment supply to the Bay. Many streams don't have natural outflow
— Too many stakeholders but only few with decision making power
— Non engineered levees
— Unwilling stakeholders (public utilities privatized)
— Concentrated job centres
— long commute times
— Weak public transport system
— Underserved communities

O
— Urban infrastructure in centers of North America show signs of ageing and deterioration. Will need to be rehabilitated and improved
— Water navigation potential
— Maximum investment in the transport sector

fig 53 *Mapping the San Francisco Bay Area (Urbanisation+ Inundation+ Earthquake fault lines)(Mapped by author)*
fig 54 *Geomorphological sections through the inner Bay (Information from Google Maps) (graphis: Author)*

0 10 20 50 kms



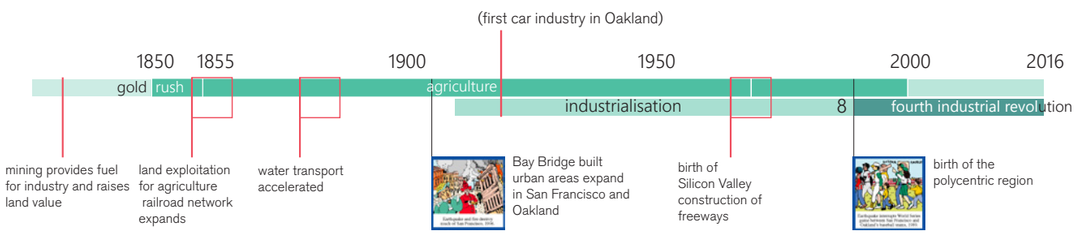


fig 55 *Growth timeline of the Bay Area highlighting major events and points of transformation (As explained in SCOTT, M. 1985. The San Francisco Bay area: A metropolis in perspective, Univ of California Press.: graphics by author)*

PLANNING TRADITION

The urban growth of San Francisco is closely interlinked with the growth of its technological networks. Evolution in transport was responsible for guiding urban form and land use patterns. This evolution can be explained through the transition two ways. US land use regulations are fragmented. California's benign climate was marketed as an asset for growth leading to migration of thousands of people. Fast growing urban population that responded to phenomenon like the gold rush, Silicon valley boom was quick to adopt to changing economy[1]. The nature of living and enterprises that led to points of transformation:

— Changing trade conditions (Agriculture > manufacturing> services)
— Demand for new forms of production (large scale >small scale> technological services)
— Political choices: State vs. city, welfare capitalism

The physical transformation of the urban system:

Expansion of the Railroad and water navigation:
The expansion of the railroad from the 1800s and the acceleration of water for navigation from the 1870 provided access to energy, oil and electricity power grid over larger distances. This encouraged growth of heavy industries across the eastern shoreline of San Francisco Bay and the Carquinez Strait.

In a single decade, then, combination rail and ferry services united the metropolis near the Golden Gate with almost the whole surrounding region and with an important section of the Central Valley as well, making towns from fifty to seventy-five or a hundred miles away fairly accessible.(Scott, 1985)

The years preceding completion of the Pacific railroad were characterized by a 'railroad fever' in the San Francisco Bay Area. There was as much talk of stock subscriptions, county railroad bonds, public and private donations of land for depots, and of new subdivisions and new towns along railroad rights of way.

Industrial Expansion
Several industries that were based in San Francisco started expanding along the East Bay with larger facilities

Development of new towns
The ease of access also led to the development of towns along with the industries. The race to absorb fast immigrating population saw large 'tract like communities' sprout along the freeways, some of which look identical.

Enterprise System
Commercial enterprises that were so far based within the city limits also gauged the potential of the expanded metropolitan limits to set concentrated bases. In the decade following the Second World War, new shopping centers developed in remote sites across the Bay. This new type of landmark in the outlying areas served by the sweeping freeways is the "regional," or district, shopping center, with its landscaped mall, its department store, specialty shops, and branch bank.

Birth of the Polycentric region
The birth of Silicon Valley and the subsequent technology boom in the nineties exploded job opportunities in the South Bay making inter county transit that much more important.

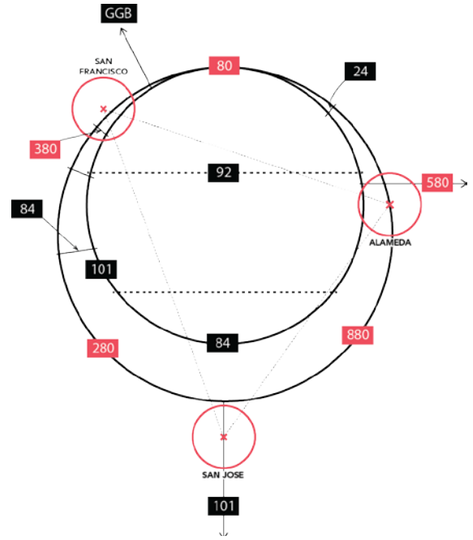


fig 56 *System Structure of the San Francisco Bay Area (By Author)*

[1]Knaap, G., Nedovi -Budi , Z. and Carbonell, A. eds., 2015. Planning for States and Nation-states in the US and Europe. Lincoln Institute of Land Policy. / Land use Regulation in the United States – Patricia Salkin

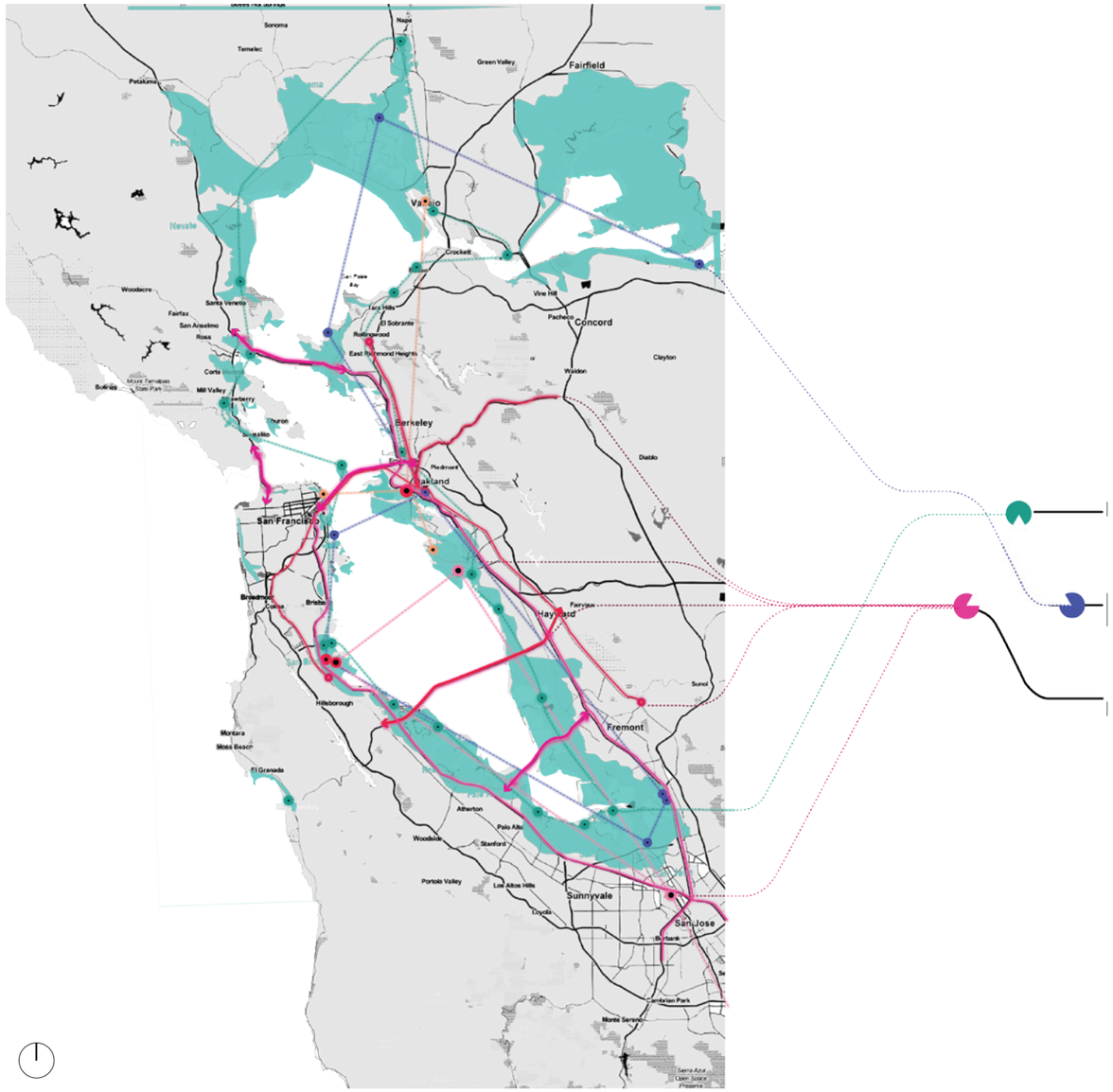


fig 59 *Infrastructure Lifelines of the San Francisco Bay Area as evaluated by SPUR (San Francisco Bay Area Planning and Urban Research Association). The map also indicates in red the lines that were disrupted in the Loma Preita earthquake of 1989 (Mapping: Author)*

CRITICAL LIFELINES OF THE SAN FRANCISCO BAY AREA

	SF earthquake 1989
water and waste water	
supply and collection: Hetchy Hetchy System under San Francisco Public Utilities Commissions	7000 ft sewer pipes damaged 1200 breaks in water mains 36,000 ft pipes needed replacement
electric power / telecommunication	
generation: Potero Plant distribution: PG&E hydropower for public utilities: Hetchy Hetchy	two power plant damaged (Hunter's point, Moss Landing) 150,000 customers w/o gas
transport	
Roadways: interstate and state highwas (101, I 80, 580), city streets	80 bridges closed $2 bn damage to bridges/ roads
Bridges: San Francisco Oakland Bay Bridge Golden Gate Bridge	Bay Bridge upper section collapse Cypress Street viaduct collapse
Ferry: Golden Gate Ferry, Alameda Harbour Ferry, Alameda Oakland Ferry, Vallejo Baylink	BART, MUNI disrupted due to power outage
Mass Transit: Municipal Railway (MUNI) Bay Area Rapid Transit (BART) Peninsula Corridor Caltrain	Port of Oakland suffered mino damages
Bus system Alameda-Contra Costa, San Mateo County Transit, Golden Gate Transit	3000 ft of Oakland Airport Runway damaged San Francisco Airport shut for 12 hours
Airport San Francisco International Airpo	

The importance of reducing the risk to lifelines cannot be understated. Imagine what would happen if even one of our lifelines seriously failed in an earthquake. How would people be able to shelter in place without drinking water? How will emergency workers get to our city if the bridges fail?

How will our economy recover if we can't move people or goods around the region? However, the seismic performance standards for lifelines vary widely and are not tied to public policies for reducing risk or ensuring community resilience in the face of a major earthquake. As things now stand, it may take months or even years for some systems to be restored to full operation.

The current structure of the city can be envisioned as a reduction of its critical physical communication networks that keep a system functional.

San Francisco City to the west and Santa Clara county (home to Silicon Valley) to the south continue to be generators of employment dominated by the service and technology sector. Alameda county to the east is the county with the largest outflow of daily work migrants to San Francisco and Santa Clara.

The double peripheral ring structure connected to each other by a series of bridges is the access structure of the region. The importance of bridge as an element of communication can be seen over a longer period of time.

Extract from the report LIFELINES: Upgrading Infrastructure To Enhance San Francisco's Earthquake Resilience by SPUR (www.spur.org)

A1

MACRO

Understanding urban structure and a broad overview of socio-economic vulnerability of the region in the face of projected hazards

A 3X3X3 analysis approach is adopted to map three urban layers (nature, occupation, infrastructure) across three time scales in the past. An additional layer under consideration is socio economic vulnerability

Open Data from ArcGIS and Bay Area Census

road network

1 in 50 year inundation line due to sea level rise

nature

urbanisation footprint

population density

income levels

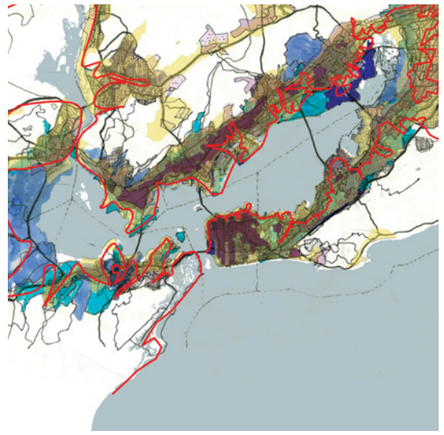
vulnerable nodes along the Bay

_occupation

_transport infrastructure

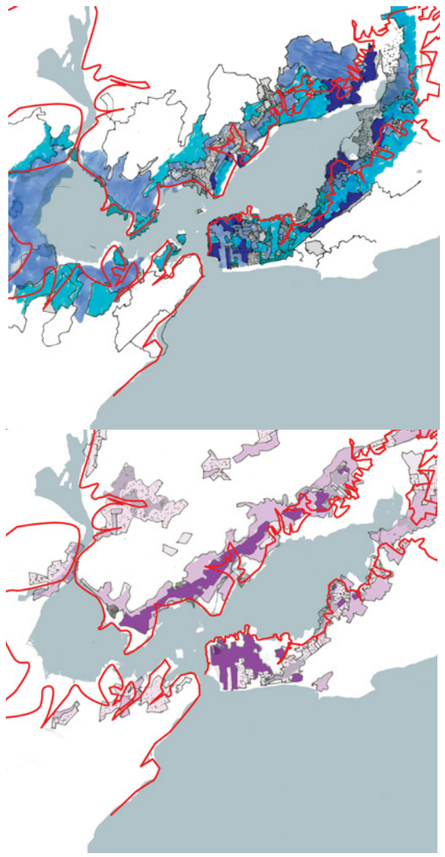
the San Francisco Bay

_50 year inundation line _natural stream
_green cover
_tidal marsh/ mud flat



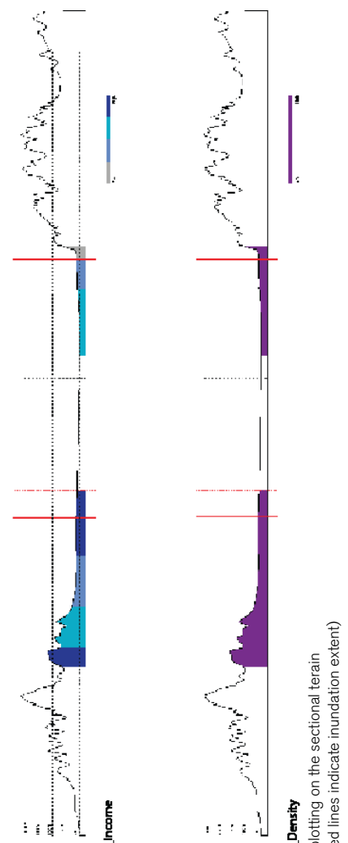
_overlay

_critical nodes



_income levels

_population density



_Income

_Density
_plotting on the sectional terain
(red lines indicate inundation extent)

fig 60 *3X3X3 analysis of the San Francisco Bay Area to arrive at critical nodes primary layer: nature, infrastructure, occupation; secondary: density, income levels (Meyer, Han, Steffen Nijhuis, 2016: Designing for Different Dynamics: The search for a new practice of planning and design in the Dutch delta, in Juval Portugali, Egbert Stolk eds., Complexity, Cognition, Urban Planning and Design, Berlin: Springer)*

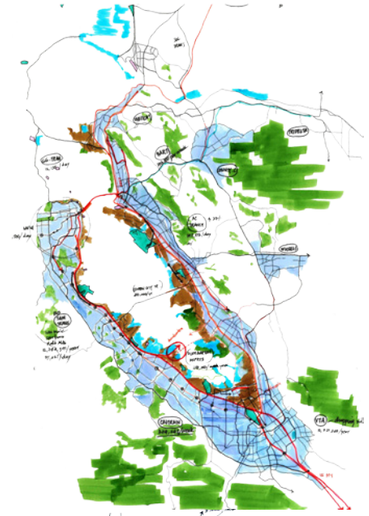
A2

MACRO

Identifying zones with a high density of critical infrastructure networks at risk of direct damage from the two hazards in consideration (flooding and earthquake liquefaction)

Three Critical Infrastructure Networks are mapping in space
1. Transport - roads, railways with proposed expansion plans
2. Energy - Overhead power grid, underground fuel lines
3. Water - Underground supply line and drainage channels (engineered, natural)

Data from California Department of Transportation, Pacific Gas and Electric Company, Open Street Map, California Energy Commission, Creek Mapping Project- Oakland Museum of California



I1: Transit lines

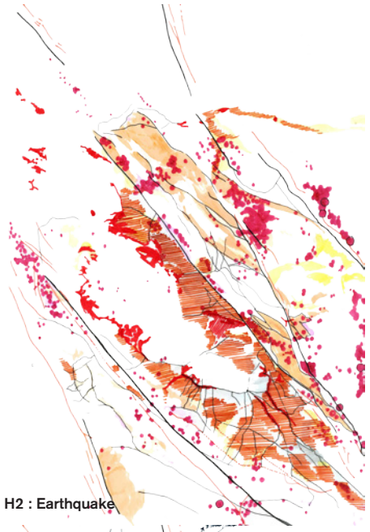
I2: Gas and hazardous fuel supply lines

I2: Power lines

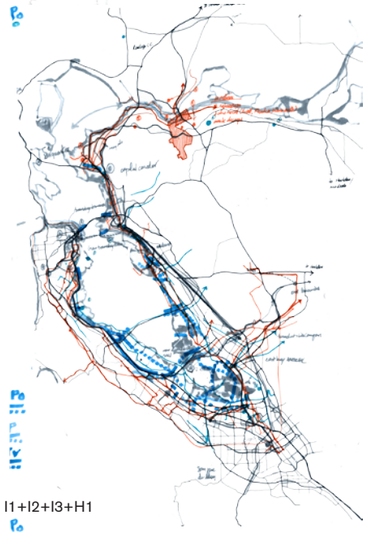
- previous occurences of earthquakes
- risk zone: liquefaction due to earthquake
- risk zone: flooding
- road network
- gas and hazardous fuel supply
- power lines
- networks affected by flooding
- networks affected by earthquake liquefaction

fig 86 *Mapping the Bay Area and its Critical Infrastructure Networks (Graphics: Author)*

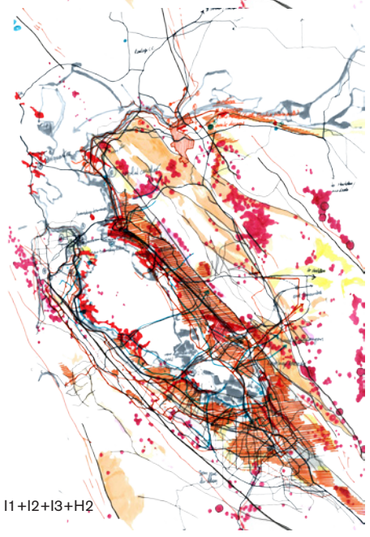
H1 : 1.4m Sea Level Rise



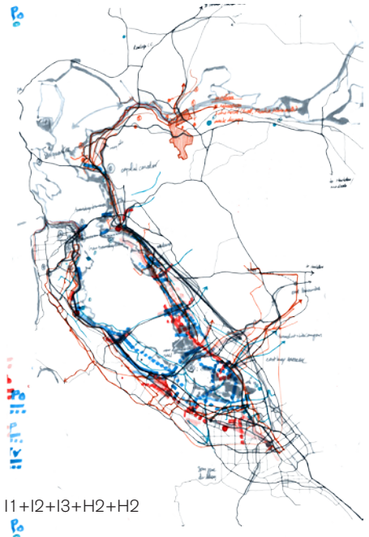
H2 : Earthquake



I1+I2+I3+H1

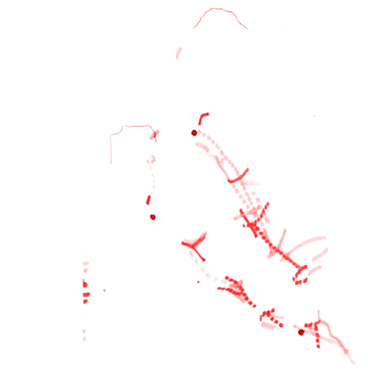


I1+I2+I3+H2

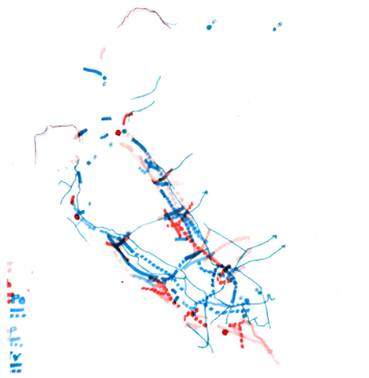


I1+I2+I3+H2+H2

H1 affected lines



H2 affected lines



H1+H2

NETWORK VULNERABILITIES

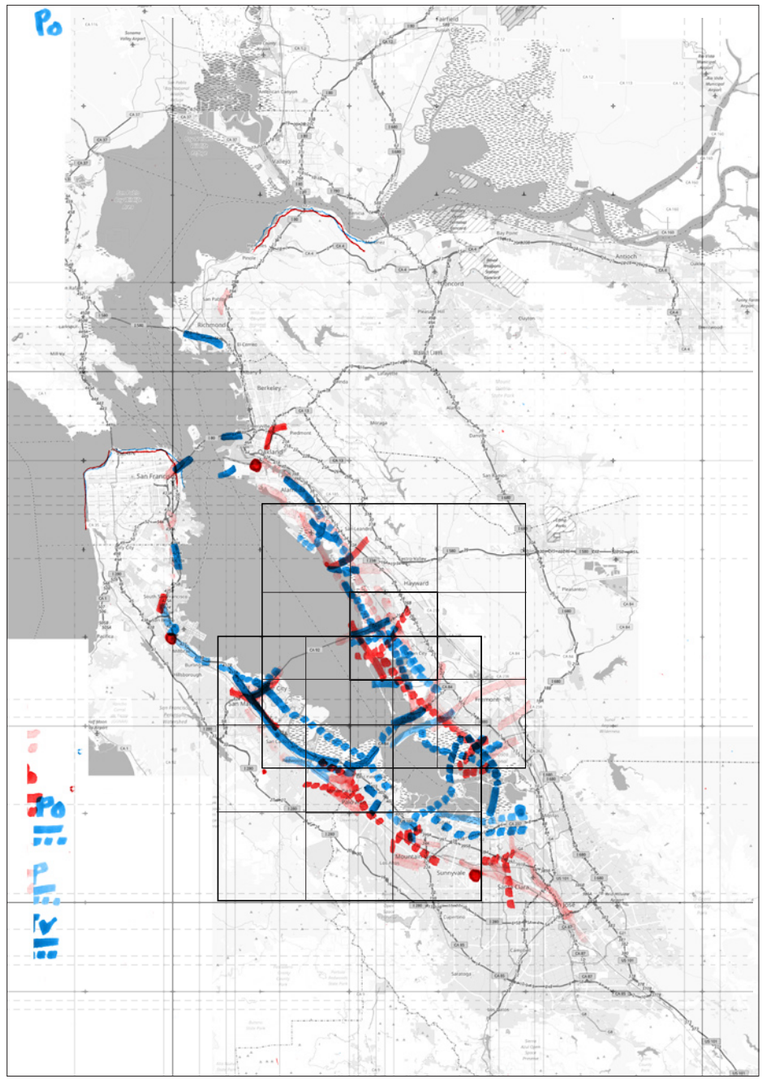
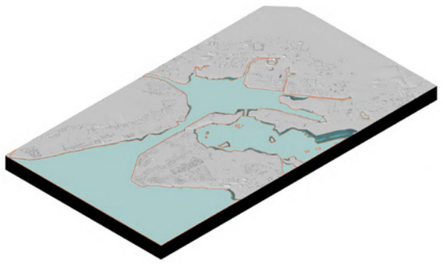


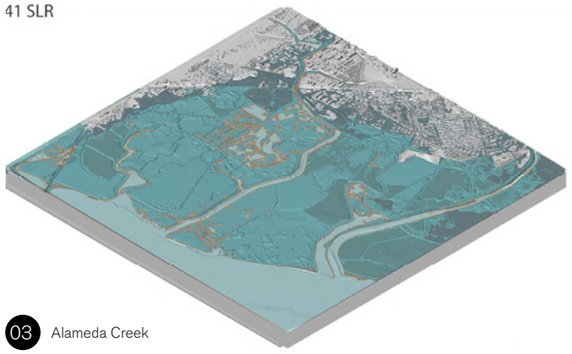
fig 87 *Zones of high risk critical network concentration*

.41 m SLR



01 Oakland

41 SLR

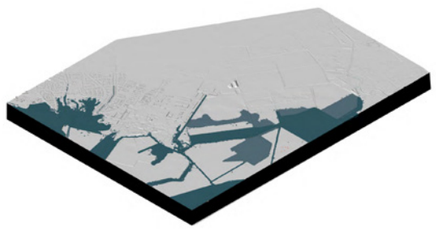


03 Alameda Creek

1.4m SLR

02 Hayward

1.4m SLR



04 Newark

fig 88 *Terrain of selected sites in the East Bay (UC Berkeley College of Environmental Design)*

SITE IN FOCUS

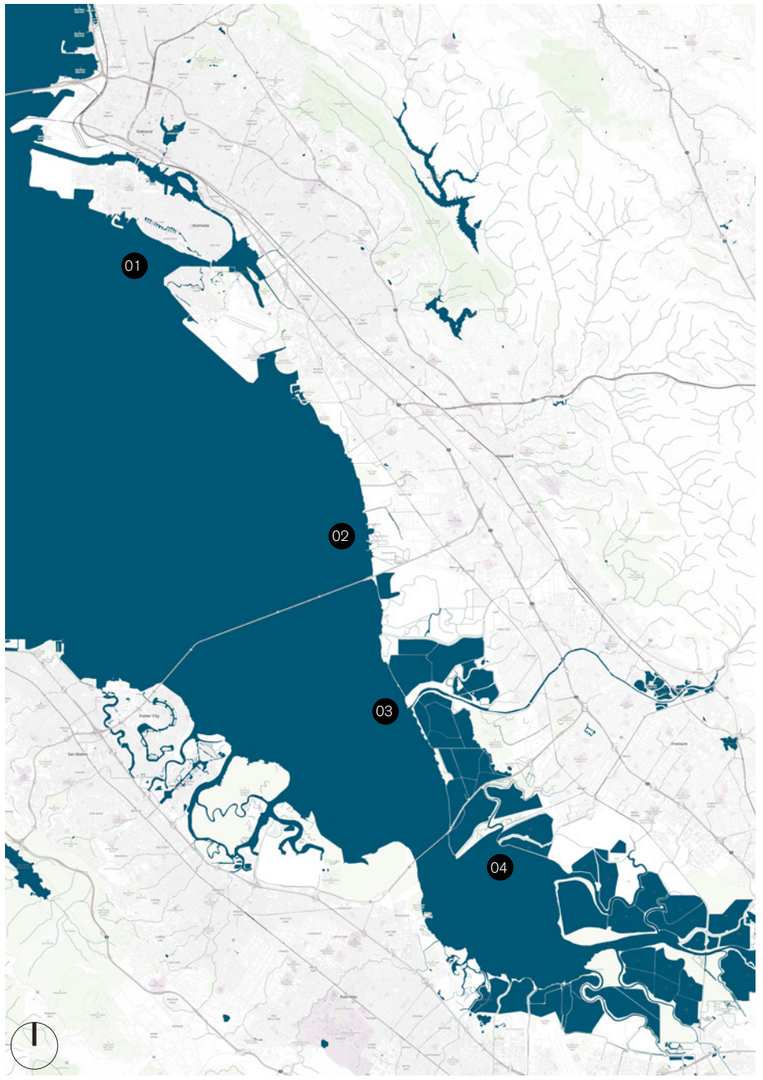


fig 89 *Proposed site: East Bay (Mapping tool: Mapbox)*

0 2 5 10 20 km

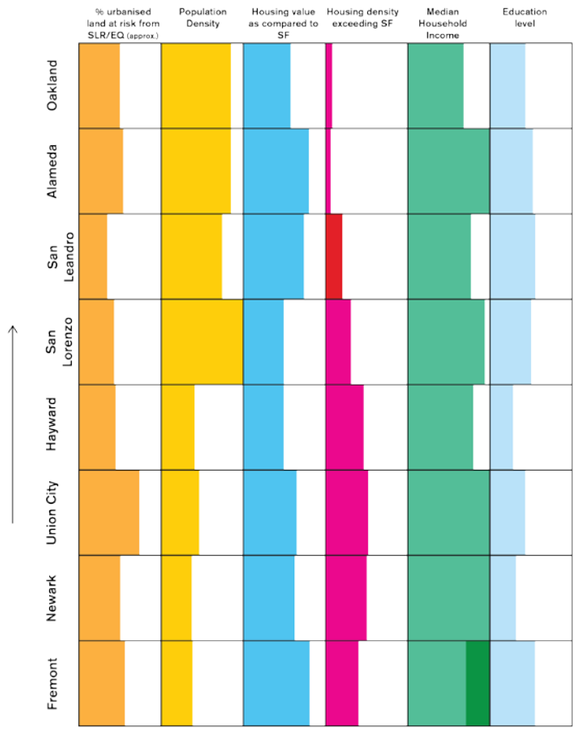


fig 90 *Socio-economic demography of the East Bay (Graphics: Author, with data from http://www.bayareacensus.ca.gov/)*

Information Sources:
— East Bay Corridors Initiative Priorities 2015-16 (Association of Bay Area Governments)
— https://www.hayward-ca.gov/discover/hayward-history
— http://ssrf.climatecentral.org.s3-website-us-east-1.amazonaws.com/Buffer2/states/CA/downloads/pdf_reports/Town/CA_Hayward-report.pdf
— https://en.wikipedia.org/wiki/Hayward,_California
— http://www.apg-wi.com/sawyer_county_record/news/local/video-flooding-continues-in-hayward-thursday-july/youtube_ccf04a40-49f4-11e6-83ad-67ff619b3fdd.html
— Climate Central (2016). Sea level rise and coastal flood exposure: Summary for Hayward, CA. Surging Seas Risk Finder file created July 21, 2016. Retrieved from http://ssrf.climatecentral.org.s3-website-us-east- 1.amazonaws.com/Buffer2/states/CA/downloads/pdf_reports/Town/CA_Hayward-report.pdf

SITE CHARACTERISTICS

The site in focus is the '**(Inner) East Bay' of San Francisco**.
A large portion of it is constituted by Alameda County. Alameda County sees the largest number of daily 'work commuters' towards San Francisco City towards the north and Silicon Valley towards the south. It is characterised by a highly diverse migrant population who speak more than 100 languages and 82% non-White people. This is also an indicator of the socio-economic disparity of the region (unequal health an educational levels).
—Rents escalate close to 50% each year
—Hub of innovative communities : innovative companies in industries ranging from robotics to chocolate
—The extension of BART transit line to Silicon Valley in the next decade will continue to increase access to jobs and regional attractions rising housing costs often leads to displacement
—The Hayward fault places homes, businesses, and infrastructure in harm's way during earthquakes.. East Bay is by most accounts not prepared for a major earthquake or the impacts of climate change.
—The three fastest growing sectors in the Bay Area economy - Tech/R&D, Food Services, and Healthcare/Education - are all poised to expand in the East Bay.

S — Strong industrial / manufacturing sector – 1000 companies related to life sciences, biotechnology, biomedical and healthcare — Strong Community structure for sustainability initiatives — Largest fire station control centre in South Bay	W — Socio-economic vulnerability: Average income lower than state — Bedroom community: Lack of a strong district centre — Poor soil conditions in the alluvial plain that drops from the East Bay Hills to the eastern shoreline of San Francisco Bay which amplifies the effect of a quake due to surface instability.
O — Medium population density — Marketed as an upcoming neighbourhood for investors — Upcoming sustainability initiatives — Largest watershed of the bay area with two distribution channels — Accessible to important centres Oakland and Santa Clara — Hayward Executive Airport generates substantial revenue through business and tourism	T — High flood and earthquake risk. The site lies on the Hayward fault that has caused magnitude 7.0 earthquakes in the past (Great San Francisco earthquake) — Can be cut off for longer periods if Bay Bridge is damaged in a disaster — Outflow of population for jobs in existing centres — Urban decay

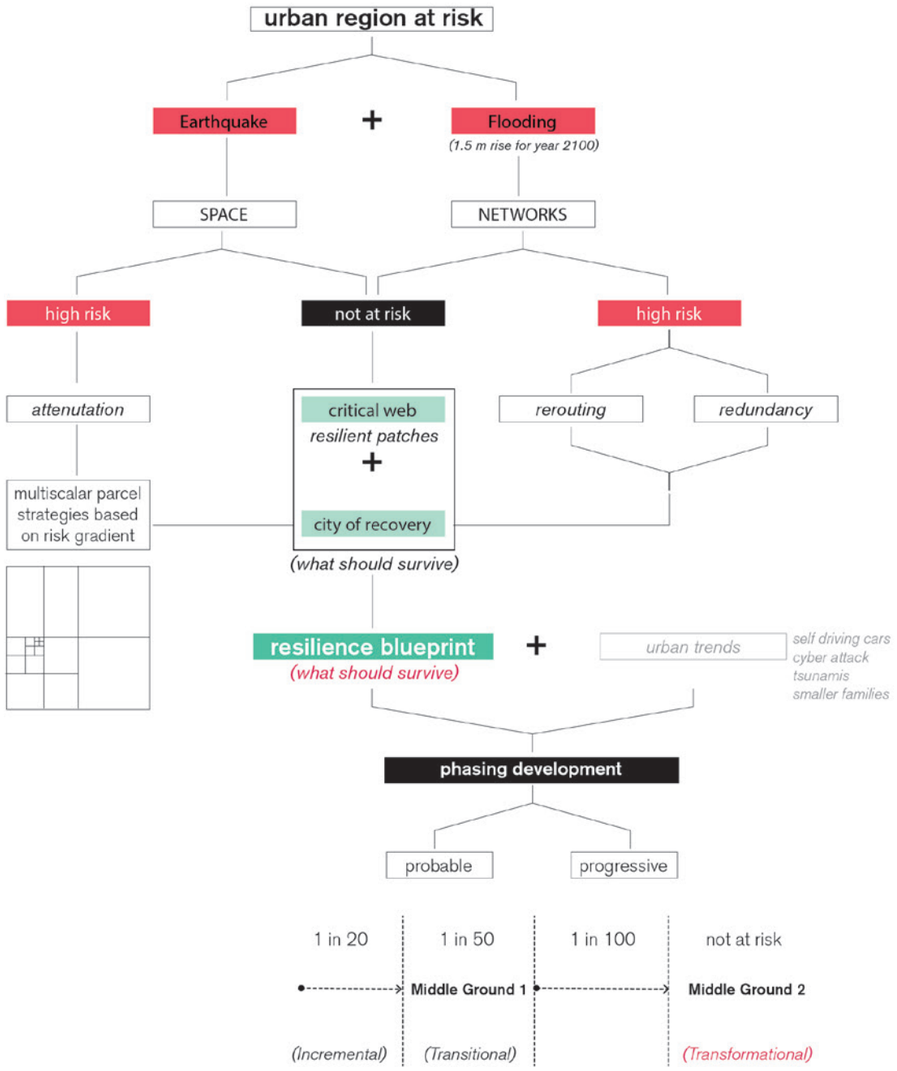


fig 91 *Methodology to determine a Spatial Resilience Blueprint*

SPATIAL RISK ASSESSMENT

A spatial risk assessment of the East Bay site is conducted to derive the resilience blueprint that can guide long range planning for the East Bay. Two risks (flooding and earthquake liquefaction) are projected separately and in combination with one another to determine the 'gradient' of risks that the site is exposed to.

The risk exposure to Networks (road network) and Spaces (land parcels) are studies separately, to then combine to form a final conclusion.

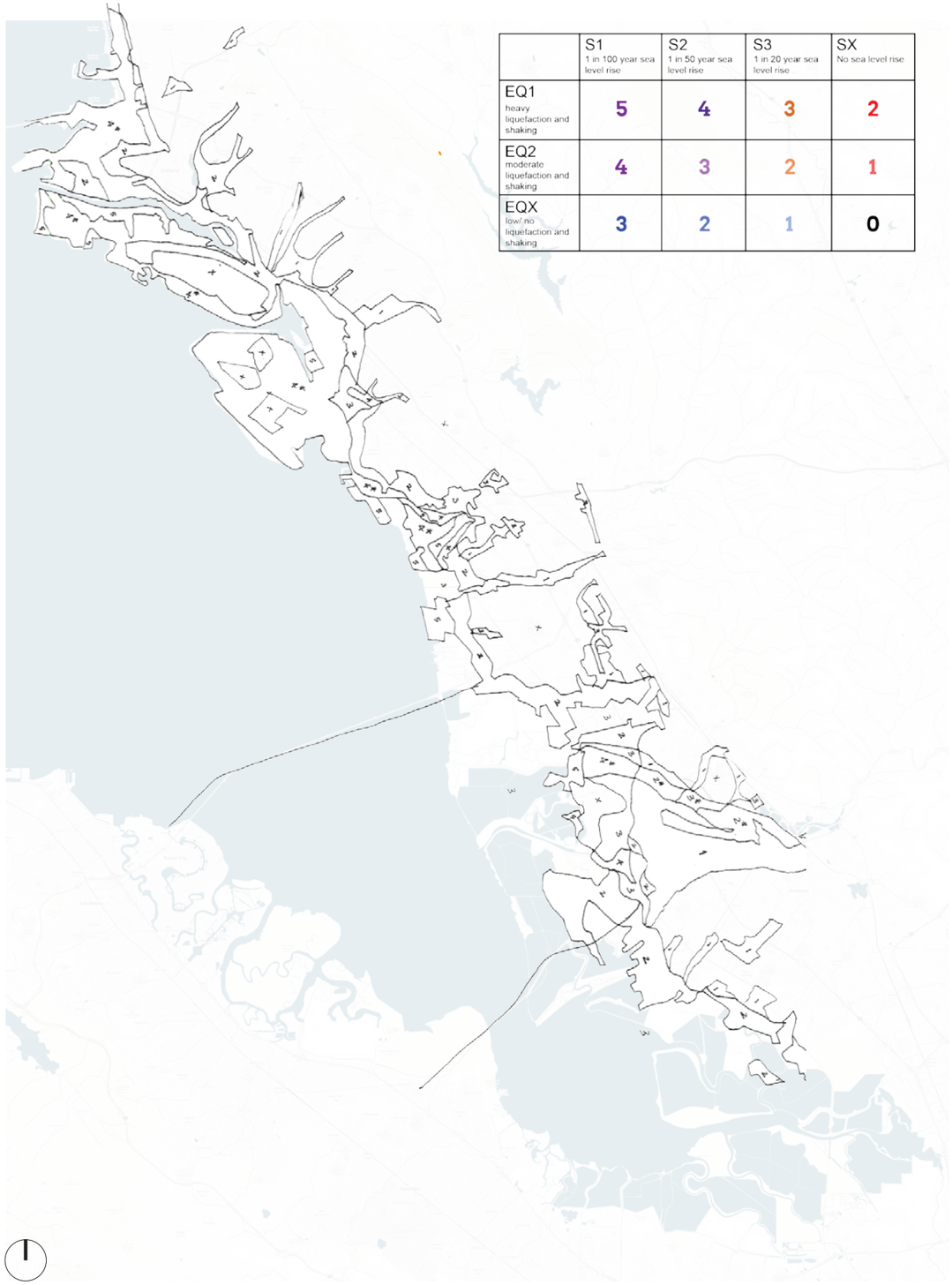
Space:
Projecting risks highlights the range of risk (least risk to most risk) the site is exposed to establish a 'risk gradient' to determine the line of spatial actions to 'attenuate' risk.

Networks:
Risk are projected on networks (as barriers) to find inherent redundancies and rerouting. The networks that survive a combination of risks form the 'critical web' of the road network.

Resultant spatial system:
—(Middle Ground 1): The spaces and networks that are least vulnerable to damage form the 'resilient patch matrix' of the region.
—(Middle Ground 2): The spaces and networks at moderate to high risk vulnerability must be prioritized based on the level of risk, interconnectivity, economic and social relevance to determine a series of spatial actions.

These two systems together form the 'Priority Resilience Areas' (P1, P2, P3) based on the probability of risk. It utilises the 'probability' as a factor to pahse the plan as opposed to the traditional planning for progressive risk for the region

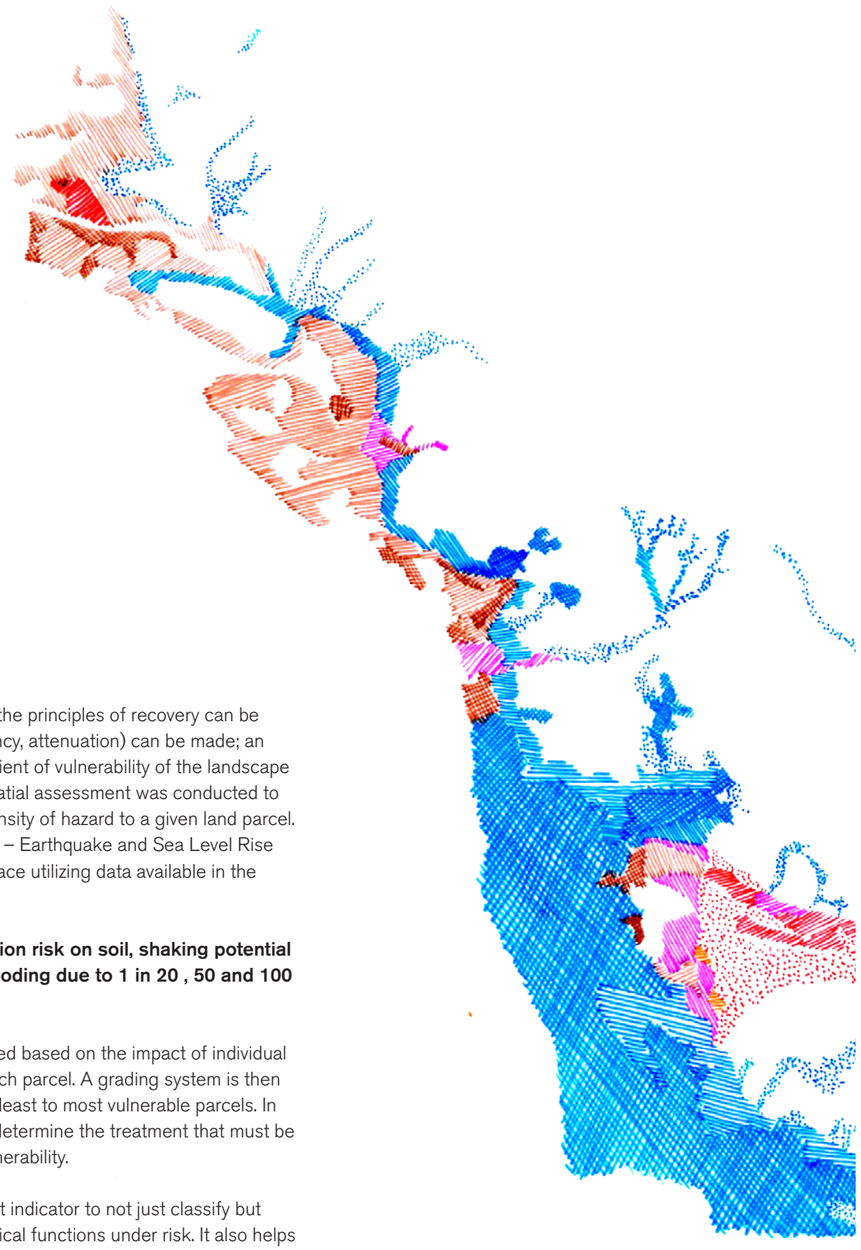
The next three pages looks at spatial actions that can be implemented for (Middle Ground 2) across scales to deal with within different levels of Governance:
—It looks at the existing hierarchies that impact land use planning in the San Francisco Bay Area
—It studies their overall roles and correlates the same to their role during a crisis.
—In doing so, it brings for the essential synergies that must be built to facilitate faster spatial mainstreaming to mitigate climate risk



	S1 1 in 100 year sea level rise	S2 1 in 50 year sea level rise	S3 1 in 20 year sea level rise	SX No sea level rise
EQ1 heavy liquefaction and shaking	5	4	3	2
EQ2 moderate liquefaction and shaking	4	3	2	1
EQX low/ no liquefaction and shaking	3	2	1	0

fig 92 *RIsk coding for parcels to determine level of expected damage*

RISK TAXONOMY



Before an assessment of the principles of recovery can be made (rerouting, redundancy, attenuation) can be made; an understanding of the gradient of vulnerability of the landscape must be established. A spatial assessment was conducted to evaluate the type and intensity of hazard to a given land parcel. The extent of two hazards – Earthquake and Sea Level Rise are projected on urban space utilizing data available in the open domain.

—Earthquake: Liquefaction risk on soil, shaking potential
—Flooding: Extent of flooding due to 1 in 20 , 50 and 100 year sea level rise

A gradient of risk is mapped based on the impact of individual and combined risks for each parcel. A grading system is then established to assess the least to most vulnerable parcels. In addition, the grades help determine the treatment that must be made for each kind of vulnerability.

The risk taxonomy is a first indicator to not just classify but quantify the areas and critical functions under risk. It also helps gauge a basic understanding of the 'type' of expected damage to the urban elements in that parcel. This is done to understand the inherent self-organization (absorption, redundancy) of the parcel and to improve the 'attenuation' capacity of the landscape. It must be noted that parcels at highest risk are often outside the 'resilient patch matrix' backbone of the region. Hence, this is an important guideline to re-programme the land..

fig 93 *Mapping Risk type and gradient for East Bay to derive the parcel risk taxonomy. Hazard Data derived from US Geological Survey database (https://www.usgs.gov/)*

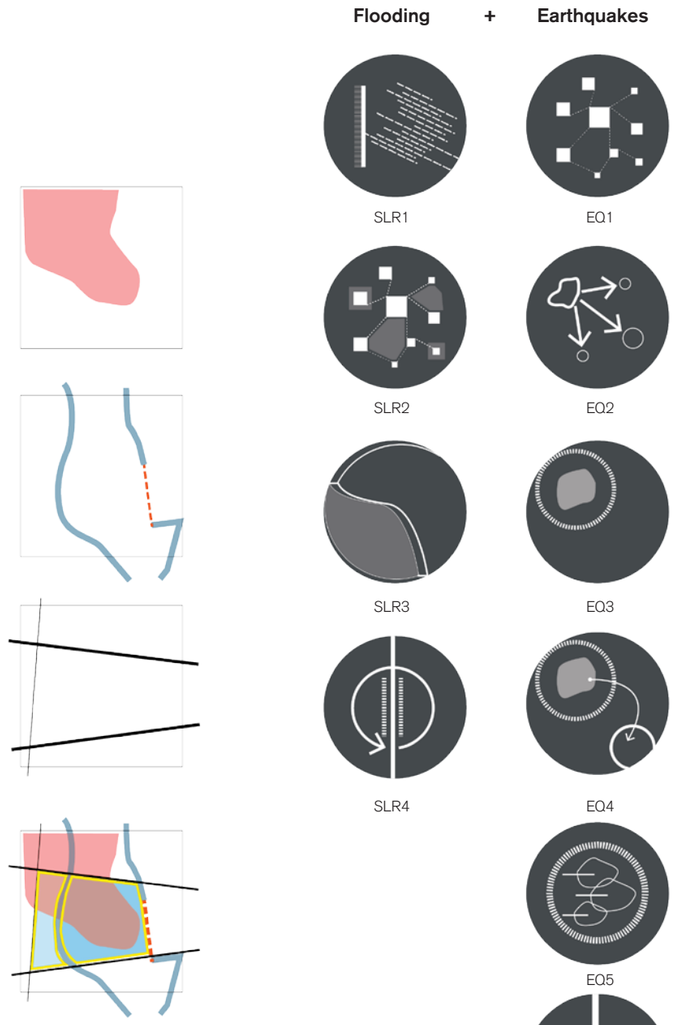


fig 94 *Spatial treatment based on risk taxonomy gradient (Source: Author)*
fig 95 *Risk+Road+Creek = new parcellation*

SPATIAL ACTIONS FOR HIGH RISK PARCELS

A literature study of cases that are subjected to earthquakes and flooding helps derive a set of spatial evaluation and transformation measures that can be applied to these parcels to suggest modifications in the spatial morphology of the region:

Recommendations for parcels at risk of earthquake:
— EQ1: Strong, accessible public space network to serve quality recreation and emergency evacuation.
— EQ2: Quick and convenient access from seismic to non-seismic zones (by foot and by vehicles)
— EQ3: Isolation of heavy soil liquefaction regions using landscape buffers
— EQ4: Moving away high density development and centralities away from high seismic intensity zones
— EQ5: Retrofit important occupation and infrastructure elements

Urban design characteristics:
Multi-functionality, permeability, strong elemental axis, visual accessibility, buffers

Recommendations for parcels at risk of flooding:
— SLR1: Improve infiltration capacity of ground (public spaces, unused spaces, roof tops)
— SLR2: More space for surface water collection, wider streams and channels
— SLR3: Elevated portions of land that inhabit critical functions and networks
— SLR4: Retrofit heavy, immovable infrastructure to accommodate water or channelize water away from important zones

Urban design characteristics:
Green-blue network, corridors, porosity

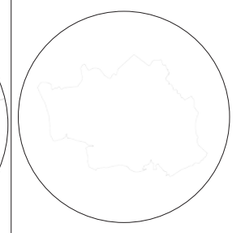
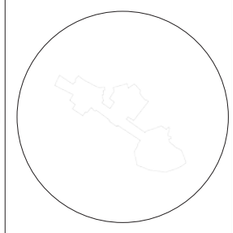
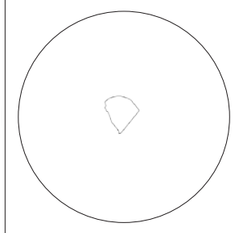
Combined risks:
Earthquake and flood risks do not exist in isolation. Combined gradients exist with varying degrees of each risk. Learning from the spatial recommendations for individual risks leads to emergence of combined approach to re-planning a set of parcels under consideration. For example:
EQ3+SLR2
Both initiatives involve enhancing natural buffers to accommodate water and isolate high risk parcels. For this, we begin to look at elements that naturally compartmentalize the urban landscape. These include:

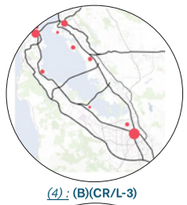
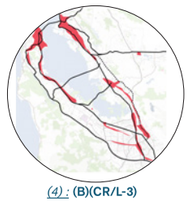
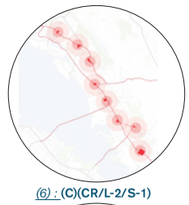
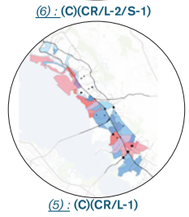
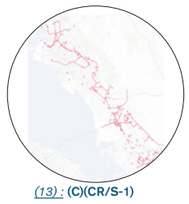
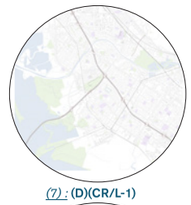
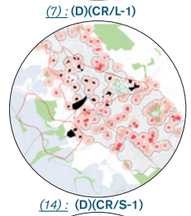
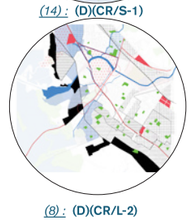
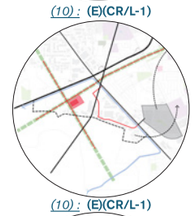
— The water network (natural, engineered and hidden channels)

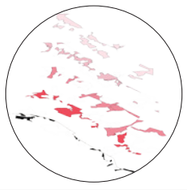
— The road network (Primary and secondary routes)
The risk parcels (Earthquake and flooding)

Overlaying three forms of land division systems leads to the emergence of a new form of division system that can help achieve parcel isolation and combining parcels of common risks. The next step would involve understanding the interface of the new parceling system for a land function configuration study

fig 96 Interscalar Spatial scheme for parcel treatement based on level and type of risk

	MEGA **(A) State**	MACRO **(B) Regional scale/Bay**	MESO **(C) County**	MICRO **(D)City**	NANO **(E) District**	PICO **(F) Neighbourhood**
						
Main Actors	(A1)Strategic Growth Council (A2) California Dept of Water Resources (A3) California Natural Resources Agency (A4) Metropolitan Transport Commission (Metropolitan planning Organisation) (A5) State Plan of Flood Control, (A6) Amtrak	(B1) San Francisco Bay Conservation and Development Commission (B2) San Francisco Water Dept (B3) San Francisco Bay Water Transit Authority (B4) Lifeline Interdependencies Council (B5) Association of Bay Area Governments (B6) Pacific Gas and Electric Company (B7) SF Public works (B8) San Francisco Public Utilities Commission (B9) BART	(C1) Alameda County Government	(D1) City Councils of Oakland, Hayward, San Leandro, Cherryland, Ashland, Union City ,Newark, Fremont	(D1) Sub Committees of City Councils of Oakland, Hayward, San Leandro, Cherryland, Ashland, Union City ,Newark, Fremont	(F1) Community units
Current role with a focus on infrastructure and amenities	+ Land Cover management + Regional accessbility to resources + Regulate global infrastructure (airports, economic centers, ports, rail corridors, industrial corridors, trade routes) + General Plan outlining broad economic functions	+Regional transport corridors, intermodal transit points +Regulate accessibility to resources (fuel, food, housing) +Regulating overall growth pattern, landscape and baylands +Priority Development Area (PDA) +Priority Conservation Areas (PCA)	+Accessibility to regional transport nodes +Broad functional classification (residential, agricultural, non residential, hazardous, open spaces, institutional, large scale industries) +Station area development, green corridors, land parcellation and zoning, development guidelines, +Public works and infrastructure retrofits	+Detailed land use allocation, urban design guidelines +Live-work circulation , land parcel classification (housing typologies, retail, amenities, sports, recreations, schools, religious), open spaces, regulate living standards and quality +City level public works and infrastructure retrofits	Specialised corridors (business, retail, green), detailed urban design guidelines	Treatment of the built fabric, open space maintenance and individual retrofits, citizen participation to influence decisions making

	MEGA **(A) State**	MACRO **(B) Regional scale/Bay**	MESO **(C) County**	MICRO **(D) City**	NANO **(E) District**	PICO **(F) Neighbourhood**
(CR) Role during crisis **(L)** Long term (Mitigation/Adaptation)	**(1)** Policy benchmarks to combat natural hazards *(1)*	**(1)** Identify overall risk gradient and population at risk *(2)* (2) Evaluate the state of critical infrastructure assets (transport, water, energy) to respond to a crisis *(3)* **(3) Regulate FAR for optimum economic and density distribution.** **Intergrate short range (20 years) and long range (100 year) resilience goals in the current 'General 'Plan'.** *(4)*	**(1)** Spatialise risks from climate to understand reparcellation priorities ,build a parcel taxonomy of risks, determine broad parcel treatment based on risk *(5)* **(2)** Identify and enhance the role of natural/ manmade corridors that can help mitigate damages, reinforce flood defence infrastructure *(6)*	**(1)** Redesign character of physical networks to channelise water in/out of identified parcels and facilitate easy movement of people *(7)* **(2)** Regulate urban forms and volumes to adapt/resist change *(8)* **(3) Add 'resilience' rating in the zoning plan to inform parcel actions** *(9)*	**(1)** Parcel treatment (soil treatment to reduce liquefaction, green-blue networks to improve infiltration) *(10)*	**(1)** Earthquake resistant construction, flood proofing buildings, rain water harvesting initiatives, orienting citizens for short term and long term changes *(11)*
(S) Short term (Emergency response)	**(1)** Global infrastructure assets and networks as emergency response web, natural resource management *(17)*	**(1)** Identify regional base for disaster control *(12)*	(1) Identify points for emergency shelters/medical help, find patterns of recovery or redundancy of assets *(13)*	**(1)** Evaluate sufficiency and resiliency of amenities to accommodate people in emergencies, identify main axis for evacuation *(14)*	**(1)** Devise community support kit for emergencies, refurbish parks to hold water and as spaces for gathering *(15)*	**(1)** Building social resilience and response *(16)*
		 *(4) :* **(B)(CR/L-3)**  *(3) :* **(B)(CR/L-2)**  *(4) :* **(B)(CR/L-3)**	 *(6) :* **(C)(CR/L-2/S-1)**  *(5) :* **(C)(CR/L-1)**  *(13) :* **(C)(CR/S-1)**	 *(7) :* **(D)(CR/L-1)**  *(14) :* **(D)(CR/S-1)**  *(8) :* **(D)(CR/L-2)**	 *(10) :* **(E)(CR/L-1)**  *(10) :* **(E)(CR/L-1)**  *(15) :* **(E)(CR/L-1/S-1)**	 *(11) :* **(F)(CR/L-1)**

	MEGA **(A) State**	MACRO **(B) Region /East Bay**	MESO **(C) County**	MICRO **(D) City**	NANO **(E) District**	PICO **(F) Neighbourhood**
(EQ) Earthquakes						
						(EXF)(1) XXX
(a) Strong, accessible public space network	(EQ)(A)(a) Regulatory policies	(EQ)(B)(a) Identify major attractor nodes such as railway stations, harbours, civic amenities to act as the control base during disasters and the points connecting them (by road) *(12)*	(EQ)(C)(a) Large amenities- malls, parking lots, city centre areas to be retrofitted as as emergency shelters **(include in 'General Plan')** *(13)*	(EQ)(D)(a) Public amenities -schools, institutions as emergency refuge zones, evaluate walking radius (4 mins) to determing sufficiency of amenities *(14)*	(EQ)(E)(a) Retrofit high density corridors to prevent obstruction and enhance escape *(7)*	(EQ)(F)(a) XXX
(b) Access from seismic to non-seismic zones	(EQ)(A)(b) Regulatory policies	(EQ)(B)(b) identify risk impact and redundancies in national/state highway system to ensure flow of critical supplies during/after a disaster *(3)*	(EQ)(C)(b) Identifying and enhancing routes (pedestrian+motorable) towards emergency base *(13)*	(EQ)(D)(b) Identifying and enhancing routes connecting neighbourhoods to refuge zones *(7)*	(EQ)(E)(b) Enhancing pedestrian axis towards refuge areas, incorporating visual indicators to aid awareness *(7)*	(EQ)(F)(b) XXX
(c) Isolation of heavy soil liquefaction regions using landscape buffers	(EQ)(A)(c) Large scale vegetation management	(EQ)(B)(c) guidelines to manage land-water interface system to ensure flow of critical supplies during/after a disaster *(3)*	(EQ)(C)(c) utilising, enhancing existing green corridors/water channels as buffers for revised parcel boundaries based in risk, administrative boundary may be maintained but must adopt the adaptations *(6)*	(EQ)(D)(c) prioritise transition from weak areas or improve investment and awareness to adapt to risk *(7) (9)*	(EQ)(E)(c) soil stabilisation techniques *(10)*	(EQ)(F)(c) XXX
(d) Moving away high density development and centralities away from high seismic intensity zones	(EQ)(A)(d) Re-establish new economic regions at areas of least risk	(EQ)(B)(d) Priority development areas (PDA) to be re-zoned to minimise high risk parcels. **Propose Priority Resilience Areas (PRA)** *(4)*	(EQ)(C)(d) Reprogramming parcels based on PDA , guidelines for displacement in 'General plan', regulate FAR to reduce densification in high risk zones *(5)*	(EQ)(D)(d) promote resilient urban layout and forms *(8)*	(EQ)(E)(d) XXX	(EQ)(F)(d) XXX
(e) Retrofit important occupation and infrastructure elements	(EQ)(A)(e) XXX	(EQ)(B)(e) Identify risk impact and redundancies in national/state infrastructure to determine resilient growth trajectory *(3)*	(EQ)(C)(e) Prioritise development activities in parcels based on proximity to stronger transit networks, remodulate densities *(5)*	(EQ)(D)(e) Retrofit large civic, public amenities *(8)*	(EQ)(E)(e) Keep public spaces well maintained and equipped *(10) (16)*	(EQ)(F)(e) retrofit individual buildings based on hierarchy of importance *(11)*

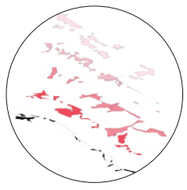
	MEGA **(A) State**	MACRO **(B) Region /East Bay**	MESO **(C) County**	MICRO **(D) City**	NANO **(E) District**	PICO **(F) Neighbourhood**
(S) Sea Level Rise						
						(EXF)(1) XXX
(a) Adaptation: Improve landscape capacity for water - infiltration / flow/ surface water / subsurface utilities	(S)(A)(a) Intensify development of regional green-blue corridor connecting to regional ecosystems *(17)*	(S)(B)(a) Enhance existing green-blue corridors to balance water and identify sites for forced flooding *(2)* (S)(B)(a) Retrofit heavy, immovable critical infrastructure (rail, highways) to accommodate water or channelize water away from important zones, Identify zones for large scale forced inundation to prevent other critical assets *(3)*	(S)(C)(a) Identify level of inundation expected in parcels to determine categories of risk for improving adaptation: complete inundation, adaptivity, improve protection *(5)*	(S)(D)(a) Urban design guidelines to Improve porosity of the city fabric, increase ground cover permeability (material guidelines), identify potential green streets Identify/Retrofit public amenities (swimming pools, underground parking garages, plazas) as potential spaces to store excess water (eg Parkeergarage, Benthemplein) *(8)*	(S)(E)(a) Community gardens, farms, rooftops to store water *(10)*	(S)(F)(a) Improve infiltration surfaces in individual backyards *(11)*
(b) Protection: Crtitical urban functions to develop resilience	(S)(A)(b) XXX	(S)(B)(b) Buffer critical infrastructure networks (transport, water ,energy lines) and the nodes that link them *(3)*	(S)(C)(b) Identify service areas, vicinity of CI to improve accessibility for maintenance *(13)*	(S)(D)(b) Identify and retrofit / elevate CI networks and utilities (waste water treatment plant, substation, pumps, fire stations, energy plant, cell towers). Build cooperative model between rail operator and the city for development incentives *(14)*	(S)(E)(b) Identify and retrofit social amenities (parks, religious spaces, supermarkets) to prevent localised damage *(15)(16)*	(S)(F)(b) XXX

fig 97 *Multifunctional urban elements to attenuate risk and help recovery (Graphics: S Krishnan)*

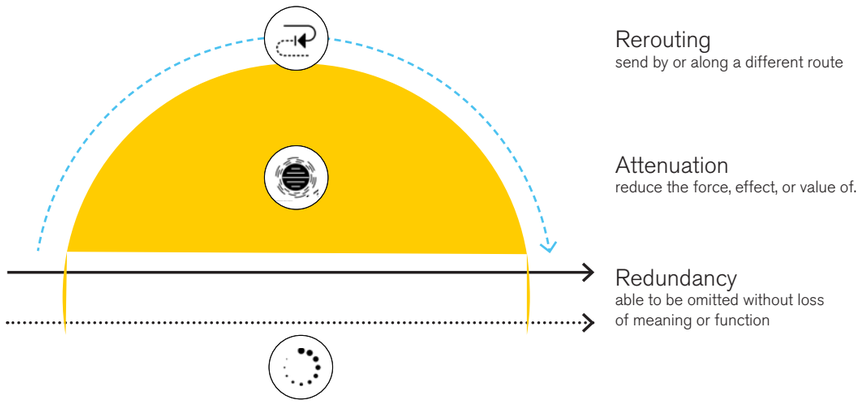


fig 98 *Guiding Principles of the City of Recovery (Icons from The Noun Project)*

THE CITY OF RECOVERY

"If you don't give people information, they're going to make their own decisions."

Introducing a system of 'ingrained' resilience within an already developed, expanding urban fabric under the threat of natural disasters has multitude of challenges.

While conflicting timelines, urban component lifecycle, investment bargains are major problems, an overarching concern will be the 'will' to adopt such an approach to an uncertain risk.

Identifying vulnerable channels and spaces in order to determine the line of action to face a crisis is an essential step that dictates spatial quality for the region. For example, Tokyo embraces risk in its urban system by a well-articulated evacuation system that is a part of daily life for its inhabitants. Rotterdam, on the other hand uses a very high standard of flood protection system (1 in 10000 year probability). This means that the probability of facing a hazard is so less that the average inhabitant has perhaps no clue about his actual exposure to risk.

Understanding how a system behaves in the event of a crisis formed the fundamental knowledge pool that guided further planning and design strategies. In the event of a calamity, the urban space can be divided into – safe and unsafe zones based on levels of vulnerability. Both zones can be evaluated using different parameters.

Rerouting: Understanding the conditions of the channels that enable movement and how they can be routed away from danger

Redundancy: Studying the layout of urban functions and channels to determine if backups exist that can enable a system to survive if impacted by a hazard

Attenuation: Studying the characteristics of the natural landscape and urban design to evaluate the existing capacity of the system to withstand or absorb change (permeability helps a more accessible network for emergencies, porosity helps increased capacity of the terrain to store excessive water, configuration of live-work patterns, etc)

The three spatial evaluation principles can be applied differently for the 'safe' and 'unsafe' zone. In a situation of an emergency, a smooth transition must be established from the 'unsafe' to the 'safe' zone. The supporting framework for the urban analysis is a comparison of movement patterns in normal conditions versus conditions of crisis.

The movement of people, resources and information in a crisis is derived based on understanding the following:

— the routes utilized for critical supplies
— the routes that accommodate critical infrastructure networks (transport and communication)
— by establishing a hierarchy of emergency evacuation spaces in the urban landscape. The existing capacity of a landscape to accommodate change
— existing defenses and buffers inherent resilience, coping systems

These three principles guide the main analysis and design backbone for the region, subsequently determining the 'regional contingency plan'. Overestimating possible failures in an essential part of the exercise. These are combined to evolve a 'resilient patch-matrix' backbone that acts as the essence of growth for the region.

The backbone of San Francisco's urban expansion, like many cities across the globe has been the expansion of the US National Highway system. In addition to being a 'personal' automobile oriented society, the emergency evacuation system in the United States is also closely linked to the highway route. Hence, safeguarding the integrity of the road network and maintaining its functionality form a crucial part of maintaining system health in a crisis.

fig 99 *Evacuation movement on highways before Hurrican Katrina (http://cdn.c.photoshelter.com, http://thedisasterkits.com)*

THE CITY OF RECOVERY

The city of recovery is based on the guiding principles how people respond to crisis in space. Based on the previous chapter three activities that determine these principles are:

Moving away from danger,
—finding alternate routes
—improving capacities to absorb changes

Hence understanding how a systems gets back on its feet is an indication of system's strength to recover. Evacuation and emergency behavior is seeing massive escalations in terms of scales of engagement and volume of people and assets at risk. Hence, understanding system behavior during a crisis situation provides essential feedback to inform the channels that are adopted towards recovery.

Soft strategy
—Movement and forecasting
In sync with large scale centralized defence systems, reinforcing evacuation flow networks will ensure lower damage and recover efforts. Nearly 1.5 million people evacuated in 36 hours to safer refuge zones during Hurricane Rita. This ensured saving human lives in a big way. If a similar system of understanding crisis behavior is applied to urban systems, it might help us inform some ways reprogramming land for risk reduction.

The evacuation hierarchy was established based on a case study of the evacuation system of Tokyo metropolis. The city, that has lived through some of he highest frequencies on combined natural hazards in the world. It has adopted a comprehensive river management programme to ingrain flood defence system and a system to retrofit built infrastructure for earthquakes. It joins this with a comprehensive emergency evacuation system in the public domain. Every ward (municipality) of Tokyo has an evacuation plan that allocated the role to public parks/ amenities in the event of a calamity.

The following hierarchy of spaces are described in the evacuation plan:
—Types of Evacuation Site
—Temporary Gathering Site

It is where you can evacuate to in order to stay out of any dangers caused by a disaster, or where you can stay while waiting for public transportations to recover when they are not operating. Open spaces within parks where no building is around are often assigned as temporary gathering sites.

Wide Area Evacuation Sites
Local public authorities assign wide area evacuation sites that are capable of accommodating a large number of people. They will be used in case of major disasters including earthquakes. Large open spaces such as large parks, public housings and universities are assigned as wide area evacuation sites.

Stayed-in Areas
These are areas where people do not need to evacuate to Wide Area Evacuation Sites in case of earthquake or fire because these areas are designed and structured to have very little risk of fire spread caused by such disasters.

Evacuation Shelters
They are shelters where you can stay for a certain period of time if you were forced to live in an evacuation shelter due to damages caused by a disaster. Local school gyms are often assigned as evacuation shelters. Such shelters have a disaster storehouse keeping necessary food supplies and other necessities to support living for a certain time period.

Secondary Evacuation Shelters
They are temporary living places for the elderly and the disabled citizens who need extra attention and care and who will have difficulties living in an ordinal evacuation shelter

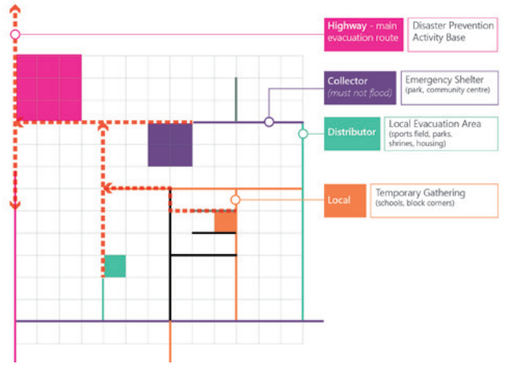


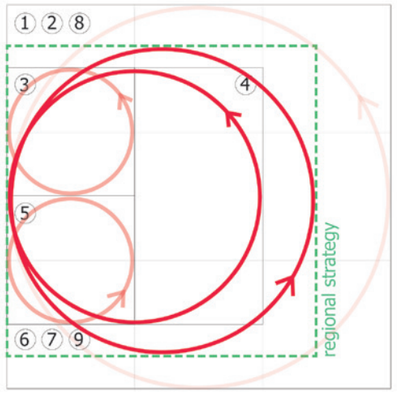
fig 100 *Hierarchy generated using information from http://www.realestate-tokyo.com/news/evacuation-sites-in-central-tokyo/, http://www.citylab.com/cityfixer/2014/05/the-future-of-evacuations-in-the-climate-change-era/371584/*

Inductive I
Deductive D
Abductive A

Sr no	Reasoning	Scale	Methods	Tools	Learnings
1 Understanding context socio economic vulnerability	A	MACRO	-3X3X3 approach (nature, occupation, infrastructure + socio economic vulnerability)	Hand drawings, ArcGIS	-urban system structure -broad overview of socio-economic vulnerability of the region in the face of projected hazards
2	I	MACRO	-Critical Infrastructure Networks mapping in space (transport, energy, water)	Hand drawings, ArcGIS	-indications of area with a high density of critical networks at risk of direct damage
3	A	MICRO	-1st iteration: Spatialising risk on an urban block	Hand drawings,	-direct impact on space to derive 'critical' safety routes and 'refuge parcels' in a crisis situation (Analysis of 1 network - transport)
4 Networks in space	I	MESO	-accurate mapping of transport ,water and power networks and simulating expected risks to understand vulnerable nodes and how they can be rerouted	ArcMap data+ Adobe suite	-understanding the critical accessibility routes that must be kept alive for evacuation in case of a crisis
5 Transformation	I	MICRO	-spatial impact of urban trends until 2100	Hand drawings	-modifications in urban components and its relationship to infrastructure changes
6	I	MESO	-5 layer approach to map the following layers (based on the framework by Roggema): Critical networks, Focal points of high density network zones, open space network ,land use patterns -mapping exercise to address 'State and Analytical Variables from the Risk Assessment Framework'	ArcMap data+ Adobe suite	-determine vulnerable network nodes (3 networks - Water, Transport, Energy) -formulate trajectories for future urban growth based on current land use patterns
7	D	MESO	-Iteration 2: Detailed simulation of 100 year Sea Level Rise and Earthquake Risk to understand redundancies and rerouting of road transport network.	ArcMap -Network Analyst Plugin	Critical' network determined for two'-risks.-direct and indirect impact of CI damage on space. -risk taxonomy to classify level of vulnerability on urban patches to determine next line of actions
8	I	MACRO	-Iteration 3: Utilising 'critical network' and risk taxonomy to establish urban transformation vision	ArcMap data+ Adobe suite	-backcast decremental sea level rise levels (1:50, 1:20) to determine probabilistic growth patterns -aim to establish a resilient 'patch-matrix' (network+urban patches) as the Middle Ground for priority resilience actions
9	I	MICRO	-spatialising temporal strategies on a selected urban clusters (identified from the risk taxonomy)	Hand drawings	-scaling down the implementation scheme and prioritising clusters for growth -land and infrastructure re-programming towards a resilient growth for 2100 -3 phases leading to the transformative vision

ADD TO BEGINNING

RESEARCH AND DESIGN FLOW



(What + How = Outcome)

[D] Deductive : (What + How) = 'x'
[I] Inductive : (What + 'x')= Outcome
[A] Abductive : ('x' + 'x') = Outcomes

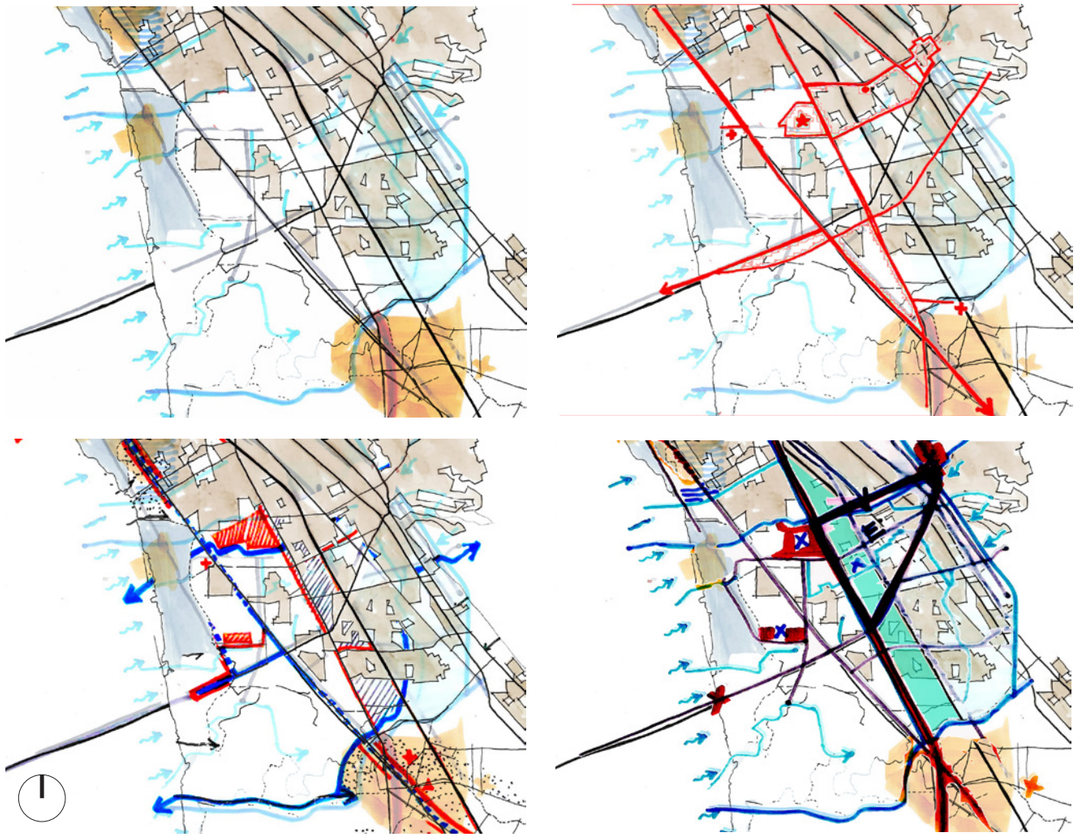
fig 102 Cycles of Research and Design with ways of Reasoning

The analysis and strategy making process of the thesis is guided by design thinking style of urbanism that synthesis learnings from different domains. Three main scales - macro, meso and micro were the frames for analysis and design iterations. As an analysis that attempted to understand the behaviour of networks in space, the methodology oscillated between spatial analysis across different boundary conditions in a nonlinear way.

Design Thinking
Design thinking stands out in its ability to establish connections, join the dots and find alternatives without the need for definitive inputs. While establishing the relevance of engineered elements in space, design thinking helps work with a set of assumptions to connect the technical, social, environmental spheres to generate an inventory that can be then tested using more valid methods. The hypothesis and limitations evolve based on the coherence required in the output.

The thesis fluctuates between three kinds of reasoning- inductive, deductive and abductive follows the philosophy of abductive reasoning where it works with an overall objective to be achieved (risk reduction, reduced recovery effort). While the body of analysis formed an excessively large part of the thesis ,each analysis loop acted as feedback to the next round of analysis/ design for an added level of information. The thesis zooms out to look broadly beyond the context to derive ways of approaching the same problem with a different set of skills/ elements.

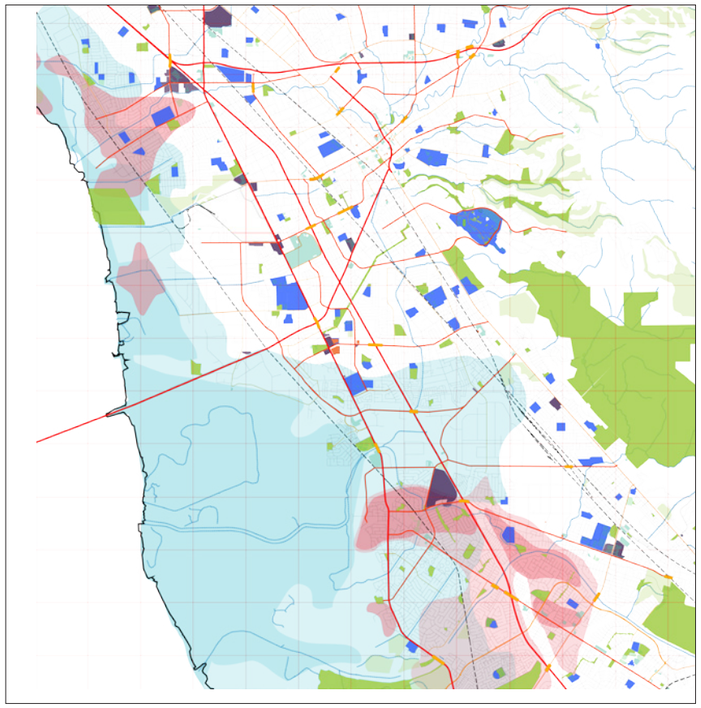
Research by Design forms an important tool to iteratively validate analysis outcomes. The design process forms a pathway through which new insights, knowledge, practices or products come into being. Research by design generates critical inquiry through design work that may include realized projects, proposals, possible realities or alternatives which can be discussed by stakeholder. A study of the analysis steps adopted will indicate a zoom in-zoom out pattern with sometimes, unclear conclusions. But each of the nine steps contributed to refining the frame of the problem at hand and the strategies it could add up to.

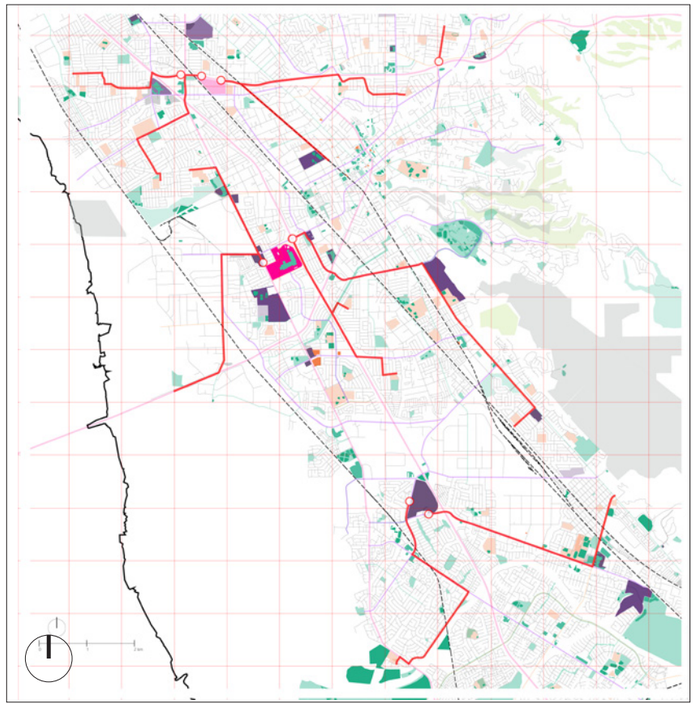


(from top left clockwise)
-urban footprint with flood risk+ earthquake liquefaction risk zones
-routes connecting main amenities (city center, airports)
-critical routes connecting amenities and natural channels
-rerouting routes to find ‹the middle ground› for refuge

fig 103 *Identify direct impact of risk on space to derive 'critical' safety routes ‚public spaces for refuge and natural channels that can be enhanced during a crisis situation.: City of Hayward in East Bay*

A3
MICRO
Identify direct impact of risk on space to derive 'critical' safety routes and public spaces for refuge in a crisis situation.
Accurate mapping of the three Critical Infrastructure Networks (transport, energy, water) and nodes (substations, waste water treatment plant, cell tower) in space to mark important streets, public amenities (schools, parks) that can play a role during a disaster
Explorative mapping





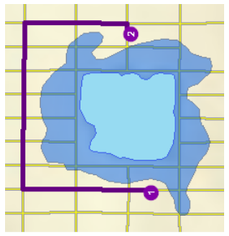
A4
MESO
Understanding the critical accessibility routes that must be kept alive for evacuation in case of a crisis. Evaluating the sufficiency of critical amenities (for refuge or medical help) within walking radius. Identify a city level ‹point of control› to manage crisis (malls, parking lots).
Accurate mapping of the three Critical Infrastructure Networks (transport, energy, water) and nodes (substations, waste water treatment plant, cell tower) in space to mark important streets, public amenities (schools, parks) that can play a role during a disaster.
Open Data from ArcGIS, AutoCad and City Councils

primary - highway
secondary - collector
tertiary - distributor
local road
critical route

Disaster control
commercial
point of gathering
schools/ emergency shelter
commercial
parks
inundation risk
liquefaction risk

hospital
fire station
religious block
cell / data tower

fig 104 *Analytical mapping to identify critical amenities, publi spaces and the routes connecting them during a crisis*



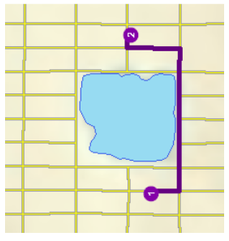


fig 105 *http://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/what-is-network-analyst-.htm*

VALIDATING RECOVERY

Initial rounds of assessment determine (R+R) involved projecting hazard from earthquake and sea level rise on the landscape. This presented a 'blanket' that covered portions of the landscape that may be rendered damaged due to a disaster. Rerouting was analysed and designed manually to look at options in which 'alternate' routes may be used and where existing routes may need retrofitting. While manual rerouting is a fairly logical exercise, larger boundary conditions reduce the accuracy of the assessment. This is because, although a manual assessment may provide a general idea of unsafe routes, considering all possibilities, modes of travel and varying levels of complexity might prove difficult.

To conduct the rerouting exercise in a comprehensive way, the ArcGIS platform with the Network Analyst plugin was adopted. ArcGIS Network Analyst provides network-based spatial analysis tools for solving complex routing problems. It uses a configurable transportation network data model, allowing organizations to accurately represent their unique network requirements.

Network Analyst can find the best way to get from one location to another or to visit several locations. The locations can be specified interactively by placing points on the screen, entering an address, or using points in an existing feature class or feature layer. If you have more than two stops to visit, the best route can be determined for the order of locations as specified by the user. A restriction polygon barrier prohibits travel anywhere the polygon intersects the network. One use of this type of barrier is to model floods covering areas of the network and making road travel there impossible.

The main components of the analysis are as follows:

—**Route**
California geodatabase was the parent dataset. This was used to extract the network of 'roads' which was used as the principle network for analysis. (Source: https://www.usgs.gov// http://portal.gis.ca.gov/geoportal/catalog/search/search.page)

—**Barriers**
The analysis involved projecting the spatial extent of the aforementioned risks in space. A rerouting simulation was made for each risk separately to determine the 'safe' routes in the event of occurrence of the calamity. In both cases, the 'maximum' risk until 2100 was simulated on the existing road network. (Source: USGS)

—**Locations**
The point of access that must be kept alive was the public space network that existed already within the system. Within the existing network, a hierarchy of public space is correlated to the hierarchy of emergency evacuation. The system of hierarchy was adopted from the emergency evacuation system of Tokyo Metropolis which has the most extensive system of evacuation within a dense urban system. (Source: Site studies, Google earth and municipality website of the cities).
Public spaces, in this case, include neighborhood parks, schools, religious spots, community centers, large institutions with sufficient open space around. The multifunctionality of each typology can be determined to allocate a role to them in the event of a crisis.
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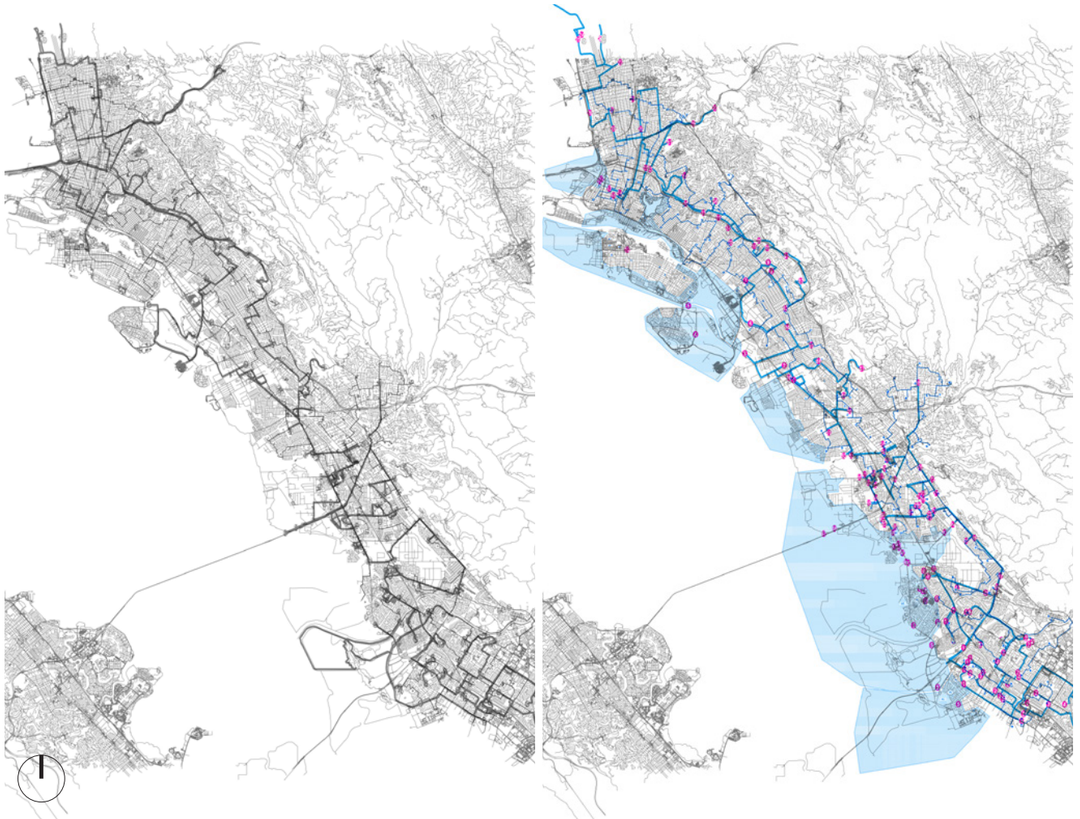
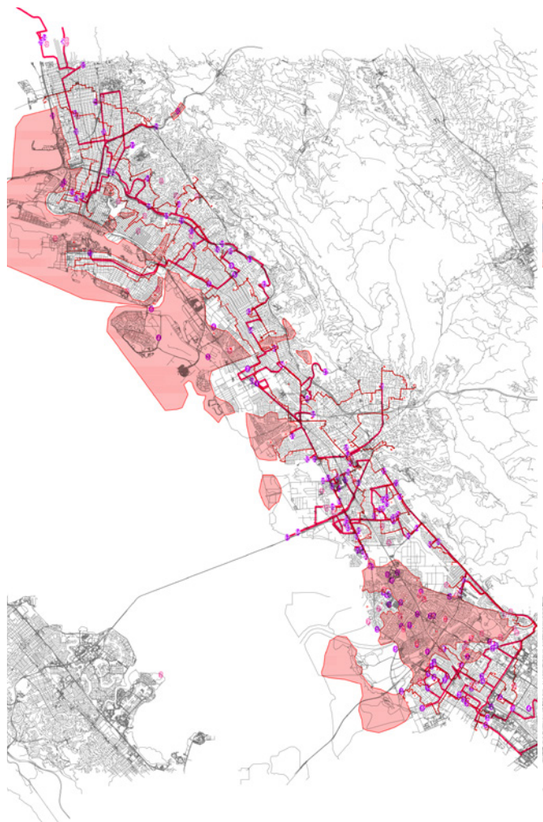
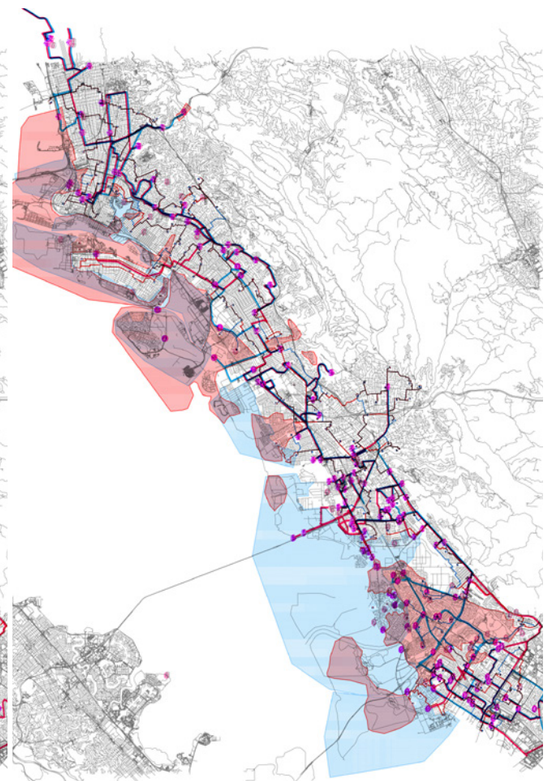






A7
MACRO
Finding the ‹Critical Web› of the Transport Network that will survive in the face of multiple projected hazards.
The existing and proposed public spaces/amenities that can act as ‹safe› points during a crisis are marked on the transport network. A first simulation is run to map the road segments connecting the public spaces The two hazards in consideration (flooding and earthquake liquefaction) are projected separately. A simulation is made keeping the hazards as barriers to connect the same ‹safe› points. This removes the ‹impacted› segments from the network.
ArcGIS/ArcMap Network Analyst

fig 106 *Simulating Risk as Barriers on the road network to find the 'Critical Web' of the region that will suffer least damage during flooding/ earthquake liquefaction*

0 2.5 5 10 20 km

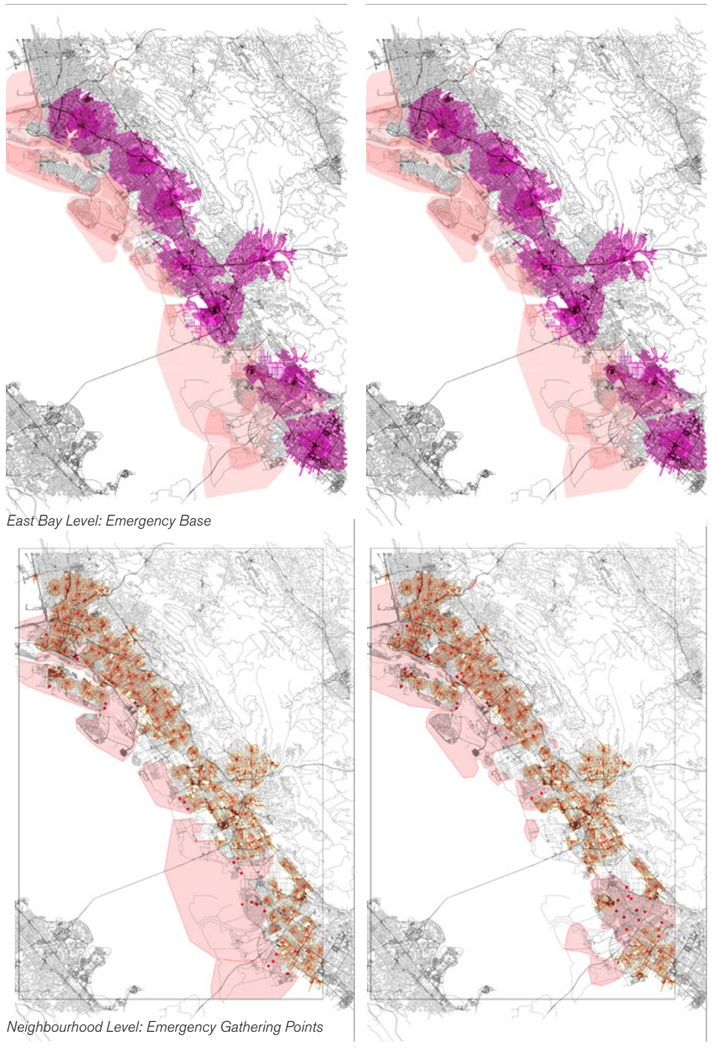


fig 107 *Service Areas for to manage emergency evacuation within the neighbourhood and regional scale (Nettwork Analyst Plugin in ArcMap)*

IDENTIFY CONTROL POINTS IN THE CITIES TO MANAGE A DISASTER

The 'locations' that were marked as part of the emergency evacuation system were checked for their accessibility from surrounding areas and determining the sufficiency of refuge/ safety spaces. This can be done considering the minimum acceptable walking/ driving radius to the facility in the event of a calamity. A Service Area simulation (also part of the Network Analyst plugin) was used to simulate the radius for the public space system on the network.

With Network Analyst, you can find service areas around any location on a network. A network service area is a region that encompasses all accessible streets, that is, streets that lie within a specified impedance. For instance, the 10-minute service area for a facility includes all the streets that can be reached within 10 minutes from that facility.

Two types of facilities were determined based of the role they play in the event of a crisis:

Large public nodes (shopping malls, city centers) are allocated as 'disaster prevention activity base'. The nodes are well connected to either the state of national highway system. These may house emergency contact point, temporary shelters and supplies in the event of a calamity.

Rule: Node must be accessible within a 2 mile driving/ walking radius.

Medium and neighbourhood level public spaces/ amenities are allocated are 'local evacuation areas' of spaces for 'temporary gathering'. These spaces are connected to the neighborhood and tertiary road network.

Rule: Node must be accessible within a 4 minute walking radius
The walking speed in an emergency situation was 2.1 m/s .Hence ,a 4 minute walking distance came to be 504 m.

A Service Area analysis was run to map the 'radius of accessibility' of both types of facilities and to establish what new facilities need to be introduces in areas that are not covered.

The 'optimized route' simulation was conducted with the routes that connect the public space system overlaid with the projected risks. Separately for 'motorable' routes and 'pedestrian' routes

In combination with the two types of routes and two systems of rerouting, the emerging 'reduced' road network formulates the 'critical web' of the system that 'may' possibly survive a calamity. This web can be utilized to determine the 'resilient patch matrix' for the region. This patch matrix can help inform the following decisions:

—Diverting growth of critical urban functions towards the critical web
—Directing investment to retrofit infrastructure in the critical web
—Determine how to treat the infrastructure outside the critical web, in the 'unsafe' zone

This web eventually becomes the backbone of the urban design strategy for the region. It helps reconfigure the regional growth trajectory

The Middle Ground

This section explains and illustrates the chief concept and the resulting spatial strategy that attempts to answer the research questions posed in the previous section ‘Risk+Space’. It proposed a new masterplan for the East Bay (Alameda County) and establishes a system to embrace uncertainty to break down spatial actions to plan for long term transformation. It quantifies the actions for one case to prove the tangibility of the method.

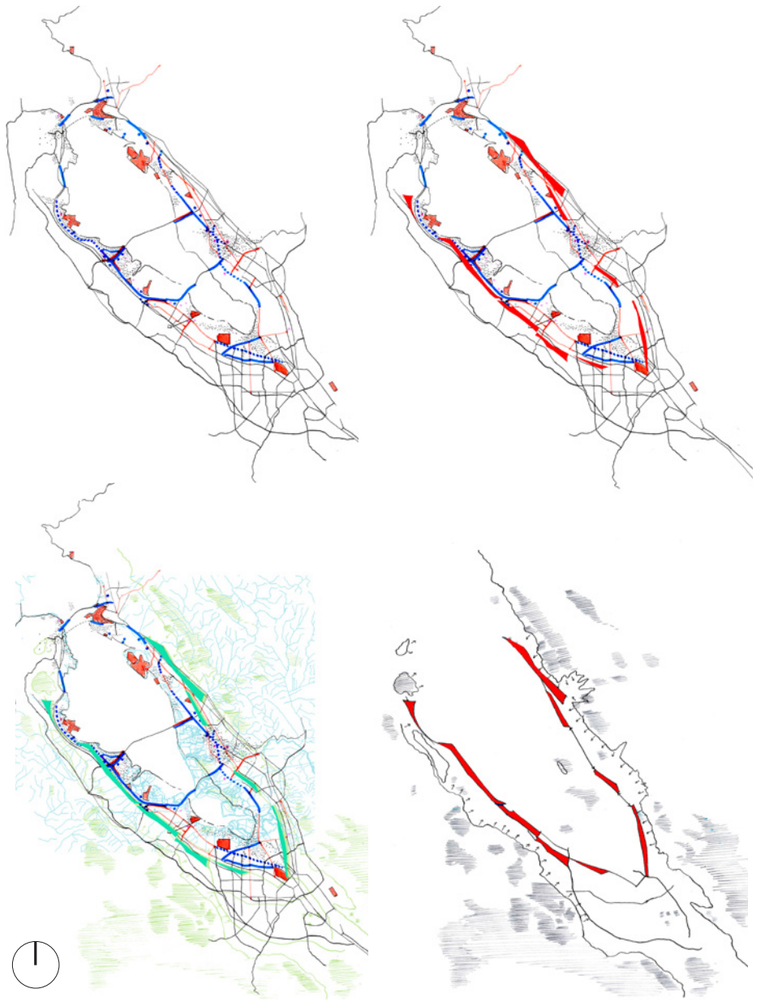


fig 108 Possible Regional Restucturing 'Finding the Middle Ground' (Source: Author)

THE MIDDLE GROUND

a position between two opposite opinions in an argument, or between two descriptions / An alternative that does not necessarily have to fulfill the needs/ wants of 2 parties but is at least satisfiable (Cambridge Dictionary / urban dictionary).

The Middle Ground (MG) is a spatial concept that is proposed to accommodate urban development that 'grows with risk'. As a spatial intervention, that involves optimizing network routes to find least vulnerable zones, reprogramming of the landscape and re-densification of the terrain.

It wants to find a synergy between the natural hazards, the natural landscape and the critical infrastructure that is laid on it. Based on the objectives of the resilience framework, the middle ground can act as a dynamic entity that demodulates over the time to accommodate urban growth and external stresses.

An inter-scalar, cross-objective analysis will be utilized for 'research by design exercise' to find the middle ground across different scales. This structure will then be utilised to simulate 'back' the risk projections of lesser intensities (1 in 50, 1 in 20 year seal level rise). This highlights the 'points of transformation' of the urban elements in space that are the boundaries of risk intensities. This lays out an idea of risk impact on space to be then able to adapt to different intensities of risk.

The resultant permutations and combinations will be analysed to arrive at growth scenarios. Deriving optimal spatial restructuring for a new regional identity that incorporated resilience is the aim of the design exercise.

Outcomes:

—**New Networks:** The MG gives a sense of the importance of the critical road systems that will act as chief access corridors in an emergency. Patches of the network the network at risk must be urgently retrofitted.
—**New centrality:** The 'Priority development areas as outlined by 'Plan Bay Area' are project on the site. This gives an estimate of the percentage of future centralities that area 'outside' the MG. Hence, a new trajectory of centralities is established for the region
—**New multifunctionality:** The existing 'special occupation' functions such as large malls, public buildings, important institutions are mapped out. In combination with the MG, we have an idea of what facilities need retrofitting and what must be moved. In addition, it also helps determine the role of the public facilities in the vent of a crisis as emergency base for a disaster.

In conclusion, allocating a Middle Ground, even as a progressive iteration helps rethink the current trajectories of regional growth patterns for the San Francisco Bay Area. While the MG is a condition for transformational growth in case of an extreme calamity, it helps inform growth patterns for three stages:

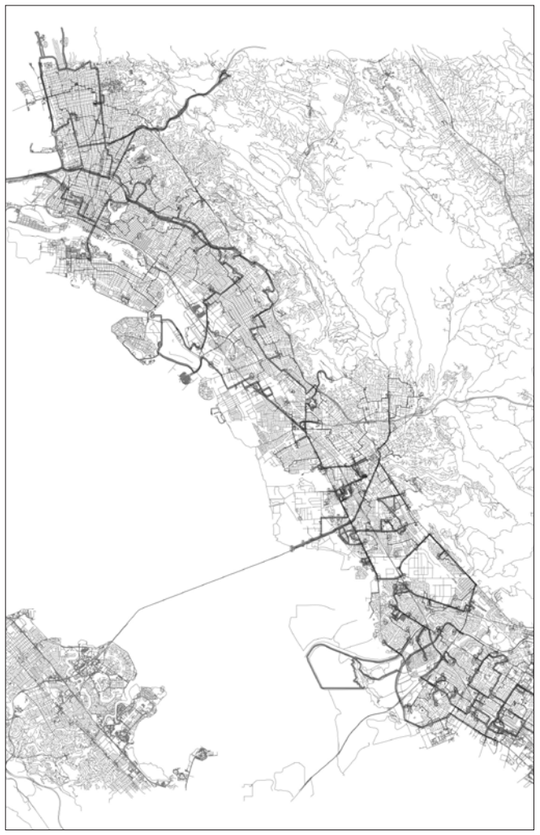
—Incremental : 1 in 20 year Sea Level Rise
—Transitional: 1 in 50 year Sea Level Rise
—Transformational: 1 in 100 year Sea Level Rise

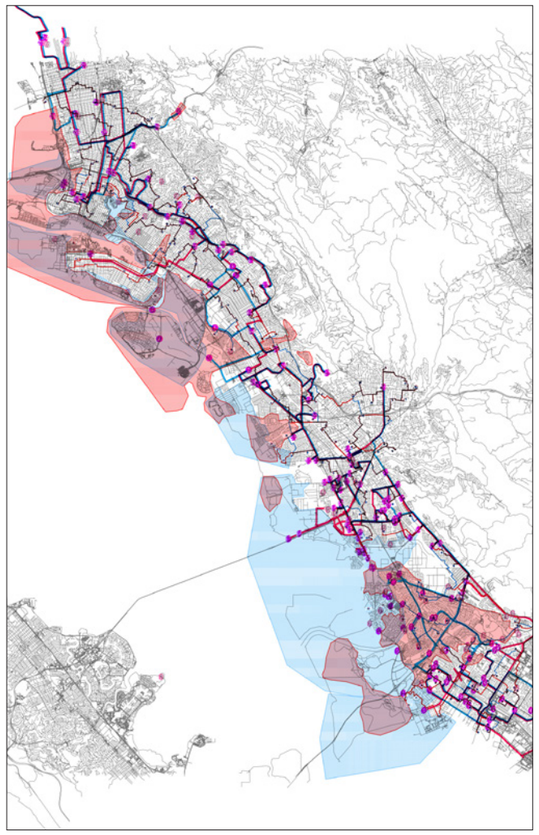
Introducing resiliency within an already developed, dense fabric that is expanding to accommodate accelerating growth under the threat of natural disasters is a complex task. While the problem objectives of 'rerouting' and 'attenuation' ,the bigger challenge as urbanist is determining how interventions and modulations fit within a system set in its ways. Where can we intervene and how can we direct this change of approach from a resource intensive to also a benefit model? How can we design for resiliency through a model that is incremental, interpretative and responsive to the instantaneous nature of urban calamities?

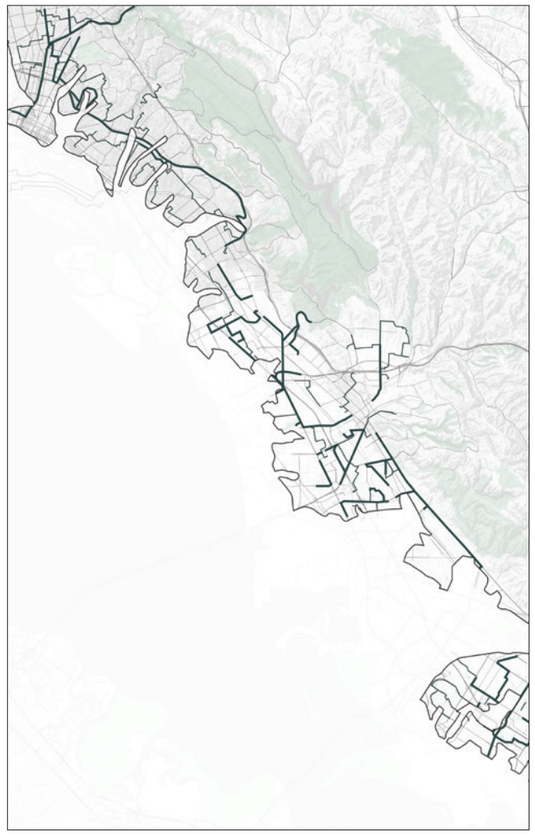
—(Middle Ground 1): The spaces and networks that are least vulnerable to damage form the 'resilient patch matrix' of the region.
—(Middle Ground 2): The spaces and networks at moderate to high risk vulnerability must be prioritized based on the level of risk, interconnectivity, economic and social relevance to determine a series of spatial actions.

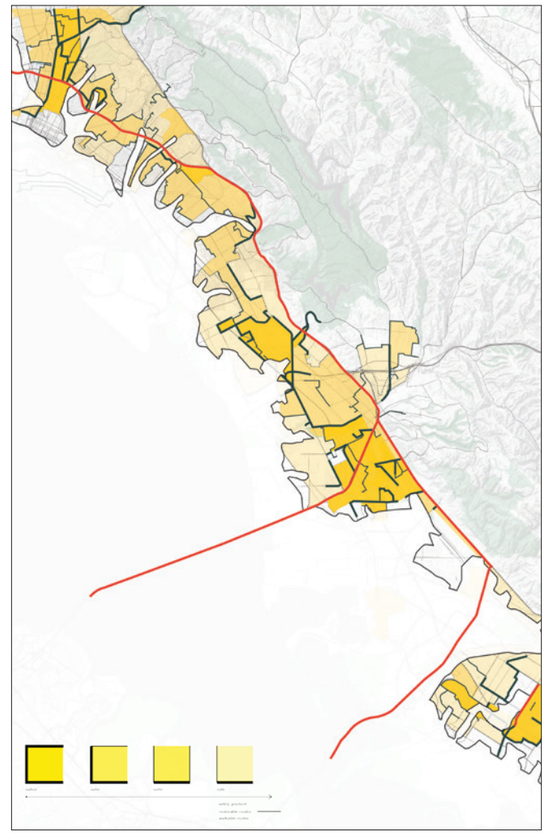
The resilient patch matrix is the product of the network analysis exercise based on the principles of movement in crisis. The resilient gradient of the patches are based on it adjacency to segments of the 'critical road web' that will survive the extreme projection of risk. It acts as the primary ground coverage that be utilized for a contingency plan to feed the rest of the region in the case of a calamity. Three gradients of patch risks can be derived based on levels of safety.

This patch matrix in then the 'Middle Ground' that will hopefully suffer least damage in the event of a calamity .It will act as the space for intense development for urban growth and refuge for risk related events.









Finding the ‹resilient patch matrix› at least risk of damages from hazards under consideration

- risk zone: liquefaction due to earthquake
- risk zone: flooding
- resilient patch bound on 3 sides by critical motorable road segments
- resilient patch bound on 2 sides by critical motorable road segments
- resilient patch bound on 1 sides by critical motorable road segments and two side by pedestrian segments
- resilient patch bound on 1 sides by critical motorable road segments
- road network
- road network blocked by liquefaction due to earthquake
- road network blocked due to flooding
- critical road network that survives both hazards
- critical road web of state highway as backbone for the region

(from left)
-Simulation 1: the ‹base route› of road segments (California geodatabase) connecting the main public spaces and amenities (parks, religious spots, schools, hospitals, civic buildings)
-Simulation 2: the ‹critical route› with a rerouting made by projecting flooding and earthquake liquefaction risk on the road network which act as barriers for access.
-the ‹critical web› of the road networks (motorable+pedestrian) that survives the combinaton of the two risks
-the ‹resilient patch matrix› at least risk of damages from hazards under consideration

fig 109 Analysis Cycle 7: Generating the Resilient Patch Matrix of the East Bay towards hazards projected for the year 2100 (Source: Author)

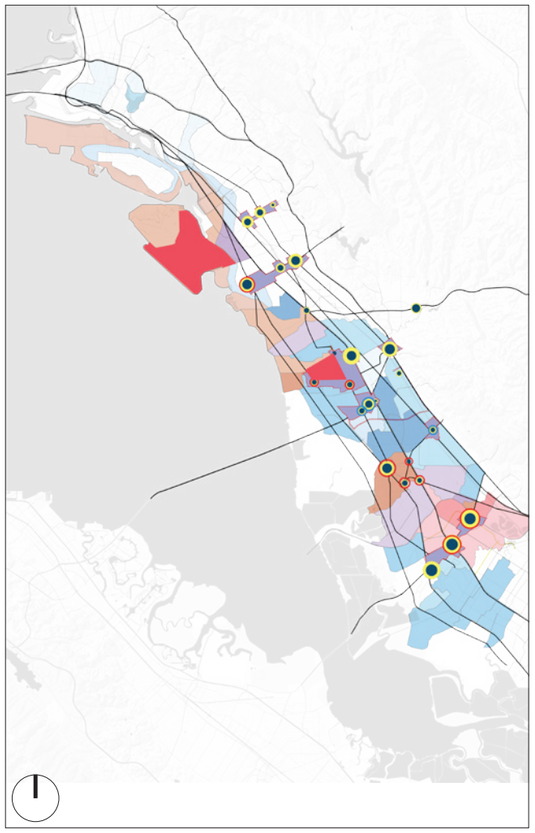
A7+

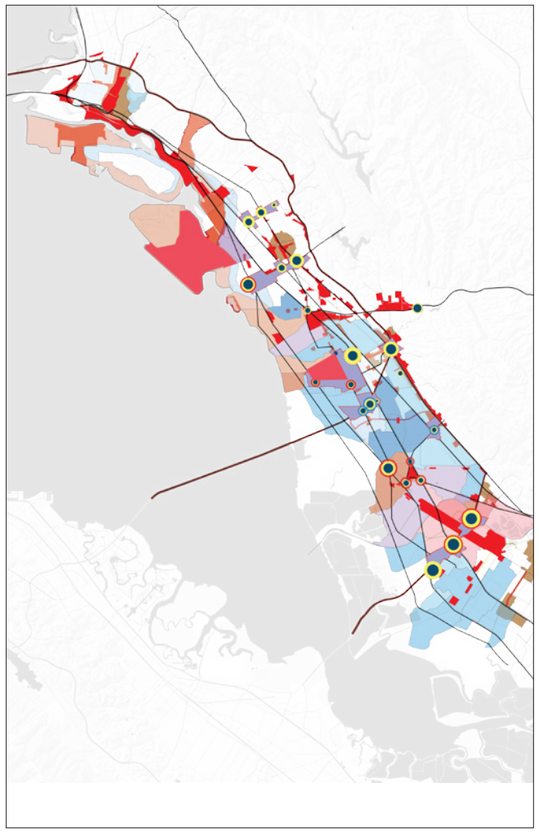
MACRO

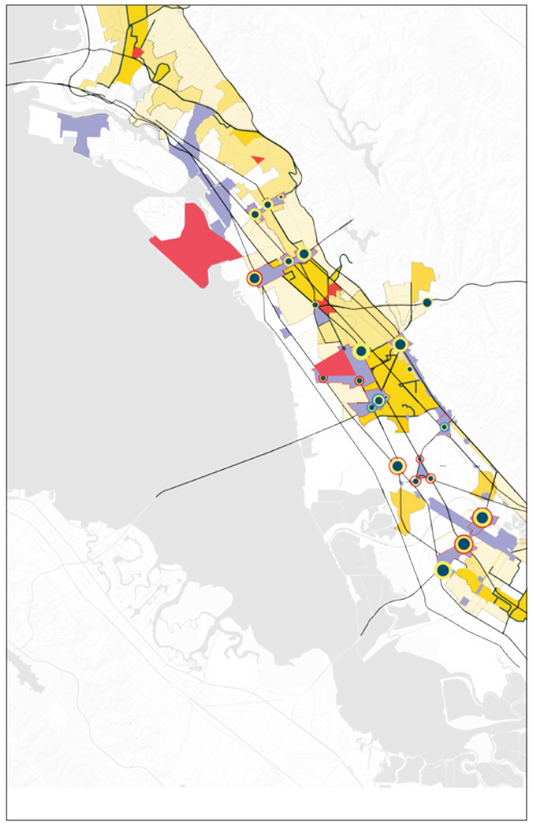
Finding the ‹Critical Web› of the Transport Network
that will survive in the face of multiple projected hazards.

The existing and proposed public spaces/amenities that can act as ‹safe› points during a crisis are marked on the transport network. A first simulation is run to map the road segments connecting the public spaces The two hazards in consideration (flooding and earthquake liquefaction) are projected separately. A simulation is made keeping the hazards as barriers to connect the same ‹safe› points. This removes the ‹impacted› segments from the network.

ArcGIS/ArcMap Network Analyst







Finding zones of high concentration of critical infrastructure networks and nodes to determine their exposure to risks

- risk zone: liquefaction due to earthquake
- risk zone: flooding
- global infrastructure (airport, seaport and disaster bases)
- currently projected Priority Development Areas (PDAs)
- currently projected Priority Development Areas (PDAs) at risk
- proposed Priority Development Areas (PDAs)
- overhead power+ natural gas
- transport - roads, rail
- N1- Intersection of 3 networks (water/transport/energy)
- N2- Intersection of 2 networks (water/transport/energy)
- Network Intersection at risk from hazard impact

(from left)
-risk gradient of the site
-Risk gradient of the site in conflict with the proposed 'Priority Development Area' outlined by the MTC for the year 2040
-Resilient Patch Matrix with proposed New Priority Development Areas and Corridors

A6
MESO
-Mapping to identify nodes with high concentration of critical infrastructure networks (Water, Transport, Energy) .Determing the vulnerability of the network nodes to flooding and earthquake liquefaction -formulate trajectories for future urban growth based on current land use patterns
5 layer approach to map the following layers (based on the framework by Roggema): Critical networks, Focal points of high density network zones, open space network ,land use patterns
Mapping in AutoCad

fig 110 Anlalysis Cycle 6

0 2.5 5 10 20 km

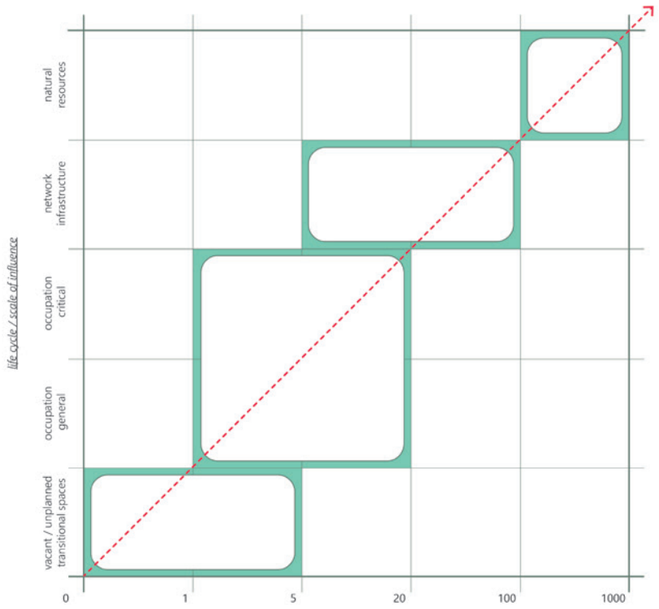


fig 111 *Layers linking long-term climatic trends to several time horizons and spatial scales (Roggema, R. E. (2012). Swarm Planning: The Development of a Spatial Planning Methodology to Deal with Climate Adaptation. Architecture - Climate design and sustainability, TU Delft. PhD.), The adapted Spatce-Time model to implement 'The Middle Ground' (Source: Author)*

PHASING DEVELOPMENT

The thesis aims to provide a series of spatial transformation for 'incremental, transitional and transformational' urban growth. While projections to transform the urban morphology concludes with 'actions' to be implemented , the time frames of implementation involves several dependencies ranging from economic feasibility, political will, collaborations ,but more fundamentally, .the 'lifecycle' of the components that need to be modified

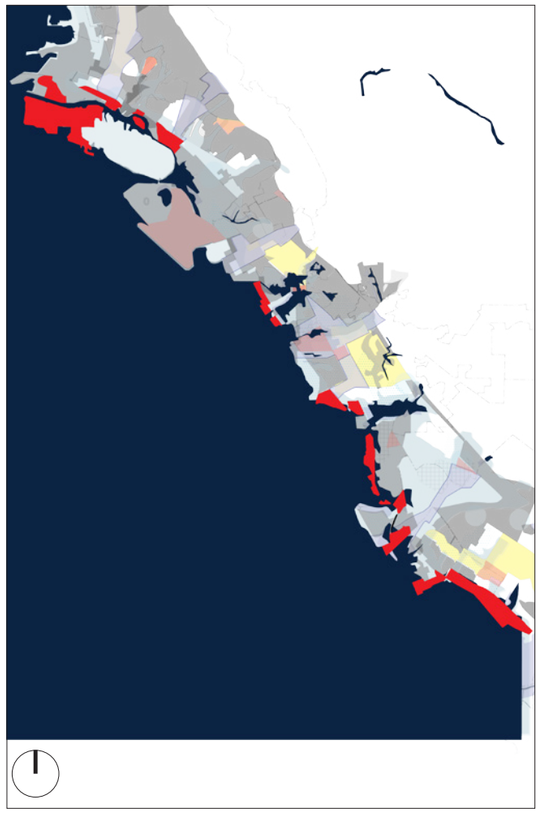
If we look to optimise investment, it
will be essential to target component towards the end of thir lifecycles or the ones that can transform more flexibly. Hence, connecting transformation of urban elements to time is an important outcome of the thesis. In order to consider that, we look back at the 'return period' of the calamity that we are designing for. While the return periods are based on probabilistic design, regular planning practice follows a 'progressive' or 'linear' modification process. For the purpose of the thesis, we consider a 'probabilis-.tic' timeline of urban transformation

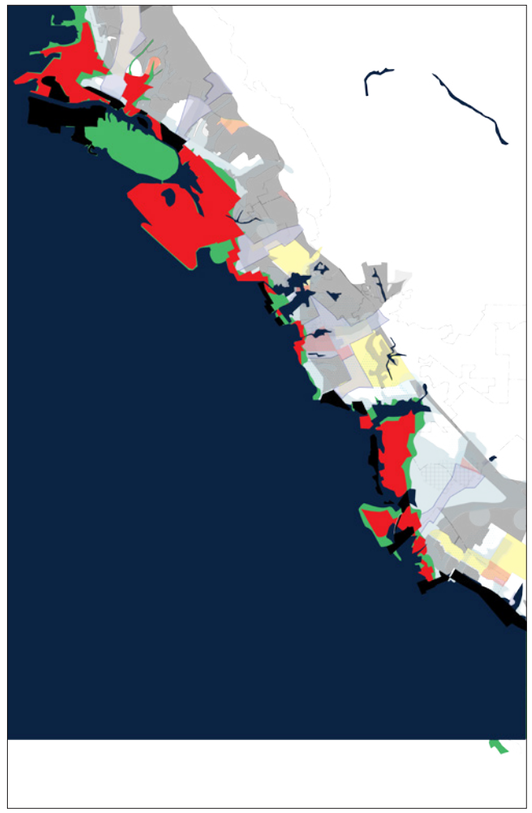
The 'Layers linking long-term climatic trends to several time horizons and spatial scales' is utilized as a basis to develop a spatial .risk transformation framework

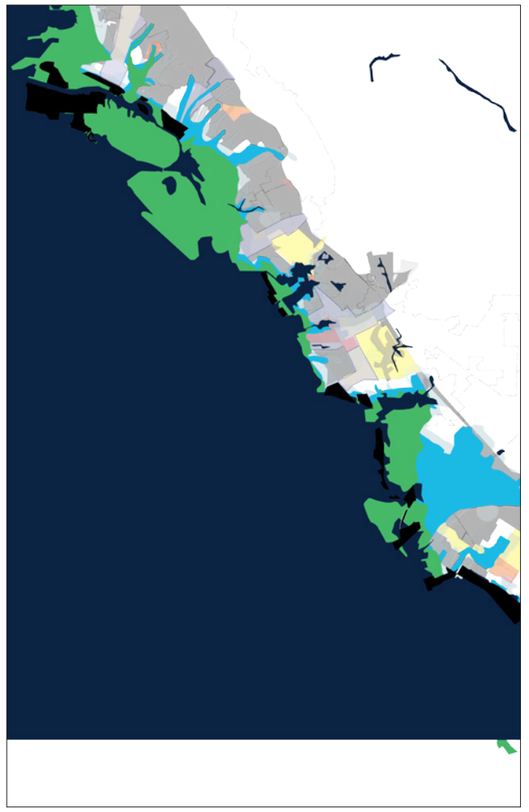
The five distinguished layers [Roggema, Van den Dobbelsteen and Kabat, 2012] (see chapter Two) are linked
to specific time horizons and are also connected to geographical entities. In each layer spatial elements with corresponding timeframes within which they tend to change, recycle or rebuild, are linked. The five layers together span the total required time dynamics: from very quick changing elements to the ones chang-.(ing over very long periods.(Roggema 2012

Climatic trends, which are seen as developing over a long period and at larger scales are downscaled to dimensions that are closer to current development needs and the context institutions operate in, the preferred domain of spatial planning

The Swarm Planning Framework fills up the gap between the 'long-term-large scale' climatic trends and the short term-small scale of the majority of spatial planning practice. The key facility to make this connection possible is found in the layer approach, which was developed to connect spatial elements of the same changeability to certain development or time rhythm. This makes it possible to assign specific (climatic) developments, such as instant flooding (layer three) or longer and slowly developing .temperature rise (layer four or one) to a specific layer







A8

MACRO

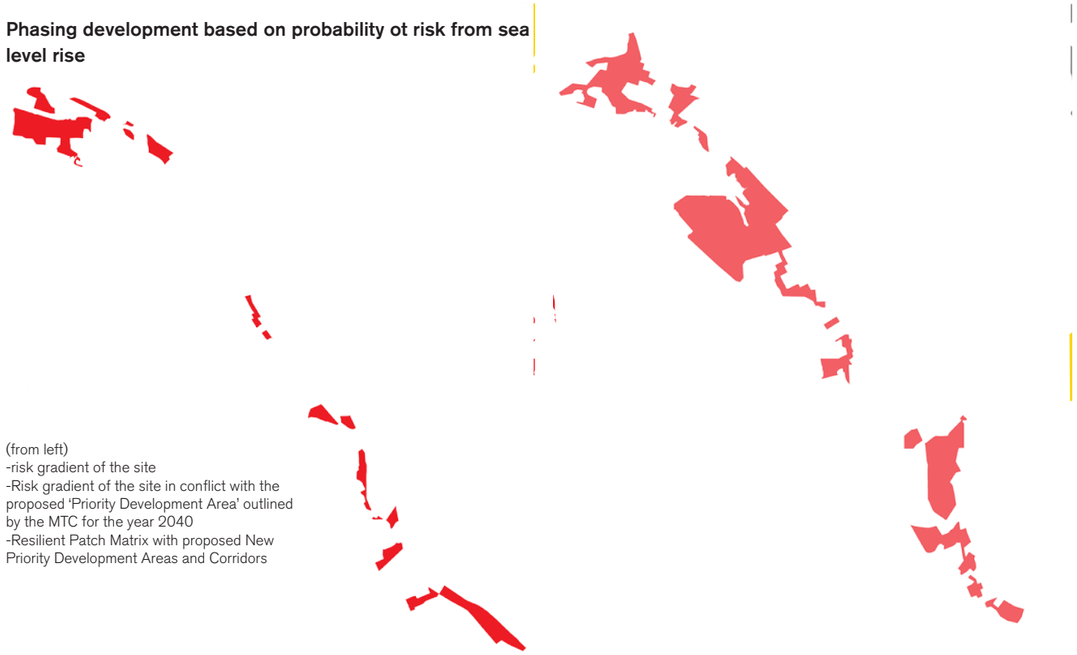
Project incremental sea level rise levels (1:20,1:50, 1:100) to determine probabilistic growth patterns
-aim to establish a resilient 'patch matrix' (network+urban patches) as the Middle Ground for priority investment

Combining 'critical web' ,risk taxonomy and 'resilient patch matrix' to establish the 'resilience blueprint' for the region.

Manual Mapping in AutoCad based in data from previous mapping cycles

- risk zone: 1 in 20 year flooding extent
- risk zone: 1 in 50 year flooding extent
- risk zone: 1 in 100 year flooding extent
- land parcels at risk from flooding
- land parcels at risk of least damage from risks under consideration
- transport - roads, rail

Phasing development based on probability ot risk from sea level rise



(from left)
-risk gradient of the site
-Risk gradient of the site in conflict with the proposed 'Priority Development Area' outlined by the MTC for the year 2040
-Resilient Patch Matrix with proposed New Priority Development Areas and Corridors

0 2.5 5 10 20 km

fig 113 *A levee constructed somewhere along the South Bay of San Francisco (Courtesy: Sumanth Rao)*

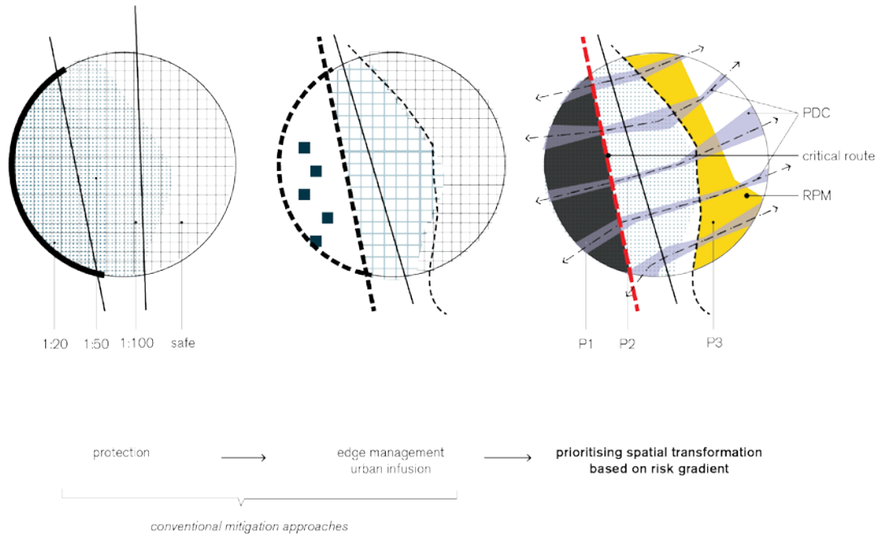


fig 114 *Adaptation principle : 'Growing with Risk'. Transforming the urban landscape to embrace incremental risk*

THE NEW EAST BAY

Based on the aforementioned simulations, a new resilience blueprint is proposed for the East Bay which directly compares and adds upon the proposed plan for the East Bay for the year 2040.

The Master Plan restructures the current land programme to prioritize growth for resilience. The Alameda County identifies Priority Development Areas (PDAs) and Priority Conservation Areas (PCAs) to be realized until the year 2040. This proposal uses that as a template to suggest the following revisions: Revision of the Priority Development Areas allocated based on the risk assessment

Introduction of **Priority Resilience Areas (P1,P2,P3)** that must be phased based on the progression of incoming risk from sea level rise

Introduction of **Priority Development Corridors (PDCs).** These are zones with high concentration of Critical Infrastructure Networks whose damages must be prevented to facilitate faster recovery if a calamity strikes. The PDCs act as the connectors between the PRAs

The above strategies do not imply a direct change of programme, but reinstating new boundaries to direct investment into critical assets with three objectives:
—Reduce (cascading) damages to existing critical infrastructure networks and nodes
—Phasing higher densities of economic and civic development towards the critical patch matrix such that it can sustain the region during a crisis
—Make plot level spatial actions to attenuate risk at vulnerable plots with important amenities
—Making a scheme to make the plots multifunctional in the event of a crisis

The restructuring identifies three main phases of Priority Resilience Areas (P1,P2,P3) with the following characteristics:
—P1 – INCREMENTAL patches
(1 in 20 year inundation): Relocate housing, reinforce levees around light industrial plots, elevates critical infrastructure facilities (substations, waste water treatment plant, FEDx shipping), recreational baylands. In the far future ,the incremental patches can be retrofitted as sites for storage of fresh water that flows in from Sacramento and San Joaquim.

—P2 –TRANSITIONAL patches
(1 in 50 year inundation) Improve permeability of surface, retrofitting existing buildings, introduce amphibious buildings/ water neighbourhoods and evacuate ground level development, flexible medium non-hazardous industries

—P3- TRANSFORMATIONAL RESILIENT PATCH MATRIX (RPM) patches (outside 1 in 100 year inundation): Currently out of the projected risk areas. To imbibe greater densities of development

A 'red line', of the region, which is the critical transit lifeline (that will act as the first line of defence during intensifying climata hazard) is identifies. It forms the connecting link between vulnerable and non vulnerable patches and calles for robust development. The PRAs are connected laterally wih PDCs that forms the new infrastructure investment backbone for the region :

—Oakland Business Corridor
—Oakland Recreational Corridor
—Oakland-San Leandro Corridor
—Hayward Airport Area Corridor
—FUNC Business (Fremont –Union City- Newark) Corridor

A9

MESO

Scaling down the implementation scheme and prioritising clusters (land and infrastructure) for lan re-programming towards a resilient growth for 2100

Finding a spatial structural scheme to breakdown implementation of temporal strategies on a selected urban clusters (identified from the risk taxonomy). Three phased progressive risk correlated with incremental risk leading to the transformative vision

Open Data from ArcGIS and Bay Area Census

Bay water

Open ponds, lakes, streams

1.5 meter sea level rise /1 in 100 years flooding

Parcels at high risk of flooding
Parcels to high risk of liquefaction from earthquakes

P1 – INCREMENTAL patches
(1 in 20 year inundation): Relocate housing, reinforce levees around light industrial plots, elevates critical infrastructure facilities (substations, waste water treatment plant, FEDx shipping), recreational baylands

P2 –TRANSITIONAL patches
(1 in 50 year inundation) Improve permeability of surface, retrofitting existing buildings, introduce amphibious buildings/water neighbourhoods and evacuate ground level development, flexible medium non-hazardous industries

P3- TRANSFORMATIONAL RESILIENT
patches (outside 1 in 100 year inundation): Currently out of the projected risk areas. To imbibe greater densities of development

Plots to function as emergency evacuation centres during a crisis / Plots with global infrastructure (airports, seaports)

2 mile radius around disaster base

PRIORITY DEVELOPMENT CORRIDOR (PDC)
high concentration of critical infrastructure networks

HIGH RESILIENCE PATCHES:
Currently at least damages from flooding and earthquake liquefaction

FEMA high Risk Insurance Zones (V, VE)

Station Area Development : 500m radius

AMTRAK / BART Train Station

Critical Infrastructure Utility (Waste water treatment plant, Electric Substation, Power Plant) Highway network (National/ State)

Critical transit route (rail or road, to be retrofitted, to act as second line of defence)

Enhanced natural buffer (water channels, green streets)

City Boundary

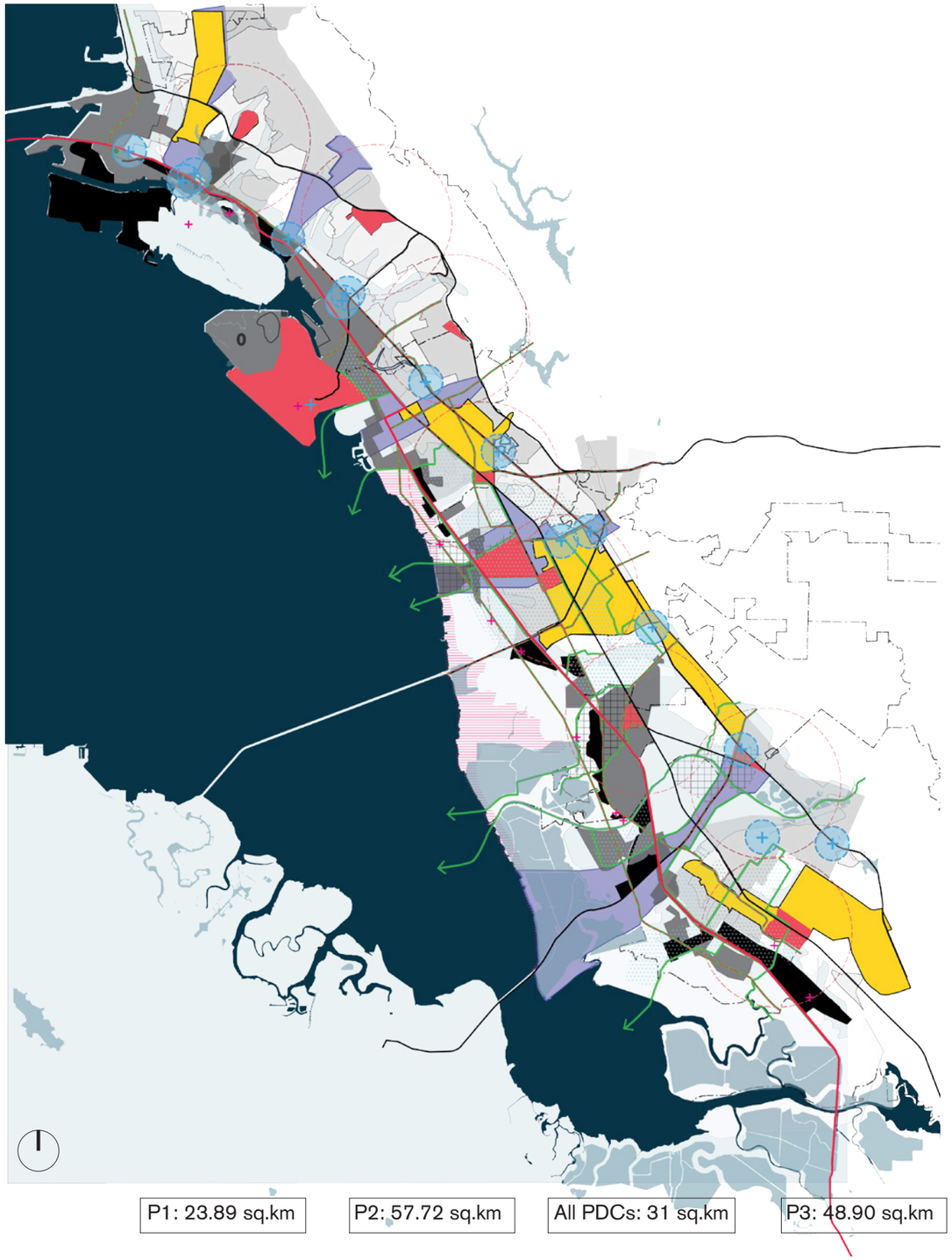
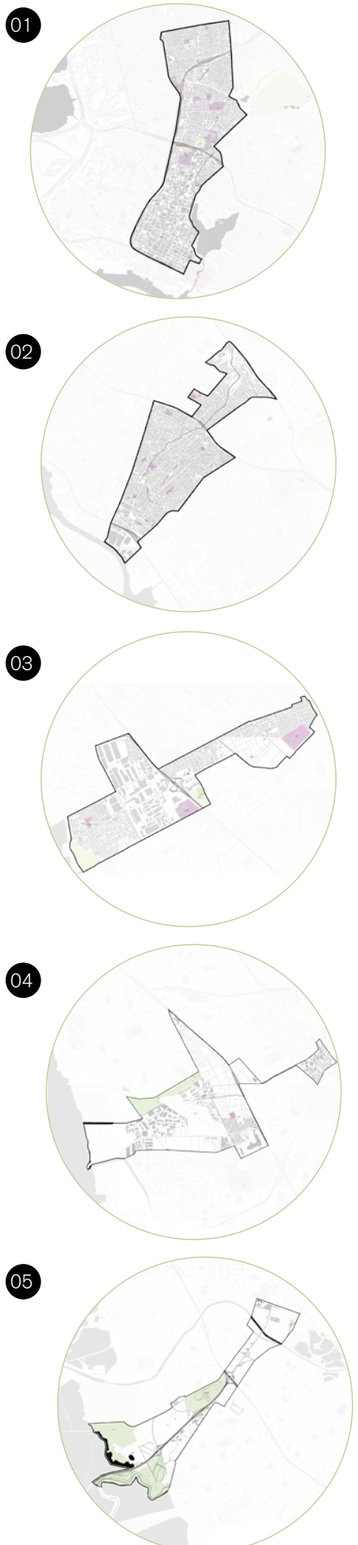


fig 115 Proposed Masterplan

0 2 5 10 20 km



PRIORITY DEVELOPMENT CORRIDORS

Introduction of **Priority Development Corridors (PDCs).** These are zones with high concentration of Critical Infrastructure Networks whose damages must be prevented to facilitate faster recovery if a calamity strikes. The PDCs act as the connectors between the PRAs

1. Oakland Business Corridor (5.82 sq.km)
2. Oakland Recreational Corridor (4.35 sq.km)
3. Oakland-San Leandro Corridor (5.23 sq.km)
4. Hayward Airport Area Corridor (12.28 sq.km)
5. FUNC Business (Fremont –Union City- Newark) Corridor (5.95 sq.km)

fig 116 Proposed Priority Development Corridors Master plan
fig 117 Current state of the Proposed PDCs (left)

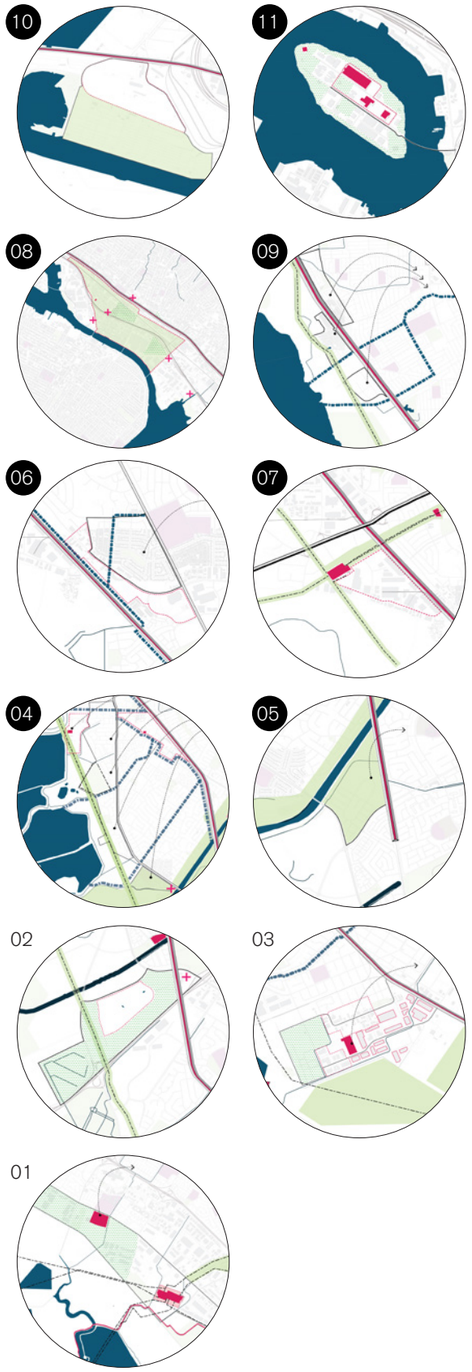
PRIORITY RESILIENCE AREAS (P)

This section illustrates an example of how phasing resilience development into Priority Resilience Areas can help break down implementation for local City Councils. This is done by approximating the PRA to existing parcel boundaries .The following observations are made for each parcel to make spatial recommendations with short term and long term goals:

—Find the existing 'risk gradient'
—Proximity to the 'critical transit line'
—Presence of Critical Infrastructure Networks (Power grids, gas supply line, water line)
—Presence of critical amenities (Schools, electric substation, logistics services, sanitary installations, waste water treatment plants)

fig 118 *Proposed Priority Resilience Area. Spatial break down of P1*
fig 119 *Schematic changes in the Proposed PRAs (left)*

PRIORITY DEVELOPMENT CORRIDORS
QUANTIFYING DEVELOPMENT AND DISPLACEMENT FOR P1



12 **CI: Port of Oakland, ADL Terminal / Adaptive building, amphibious construction**

11 **CI: USCG Base (Civic centre), Columbus College, Post Office, Coast Guard / Reinforce a levee, relocate**
Old blocks poor condition / to be demolished after lifecycle, relocate functions to P3

10 **CI: Gas stations / to be flood proofed**
Parking plots / increase porosity
Commercial, Recreational, Heavy industry, Business /
1:20 years: needs a levee
1:50 transition out to create a water basin

9 Offices : 3 / to be flood proofed
Suburban Housing Type 1 : 74 / to be relocated
Suburban Housing Type 2: 1024 / to be relocated

8 **CI: Grant substation / to be flood proofed**
Electric line / to be buffered, green corridor ,avoid untamed vegetation
Light industry: 20 enterprises / to be flood proofed and moved out

7 Suburban Housing Type 1 : 139
Suburban Housing Type 2: 264 / to be relocated
Suburban Housing Type 3: 100 / to be relocated
Commercial: 2 plots / to be flood proofed
Canal: to be widened

6 **CI: East shore substation / to be flood proofed**
Electric line / to be buffered, green corridor ,avoid untamed vegetation
Industrial technology / Innovation Corridor

5 **CI: School, Fire Station, Union City Sanitary District / to be relocated**
Suburban Housing Type 1 : 431 units / to be relocated
Suburban Housing Type 2 : 607 units / to be relocated
Light industry: 24 units, Commercial: 8 units, Retail : 1 unit / to be flood proofed

4 Plot divisions made for residential use / Avoid development

3 **CI: FedX / to be relocated**
Technology Industries / flood proofing and barriers to keep water out

2 Industry and Innovation Centre / flood proofing and barriers to keep water out
Reinforce the levee / Increase buffer and water storage in the vicinity

1 **CI: Pacific Gas and Electric Substation / to be checked and retrofitted**
Institutional: Ohlone College Campus/ to be flood proofed and retrofitted for as an emergency base
Medium light industries / Retain for their existing lifecycle protect plots against inundation, reinforce levees

fig 120 *Proposed Priority Resilience Area. Spatial break down of P1*
fig 121 *Schematic changes in the Proposed PRAs (left)*

‘CRITICAL LINE’ NETWORK RETROFIT

A combination of Highway I-880 and industrial railroad adjacent to the Inner East Bay together form the critical transit line that can facilitate easier transition of land management from high probability (1 in 20 year flooding) to moderate (1 in 50 year flooding) probability.

The critical line can be divided into smaller sectiosn based on city boundaries. Each city council will have the directive from Alameda County to include the ‹Retrofit of the critical line› into their climate mitigation strategy to combat 1.5 meter sea level rise. A partnership may be forged between the railroad developer, the City respective Council and the county rail operator (AMTRAL/BART) in a mutual real estate benefit (retrfoit ‘X’ m of the rail segment may lead to ‘X’ amount of real estate benefit for the developer within the city transit station)

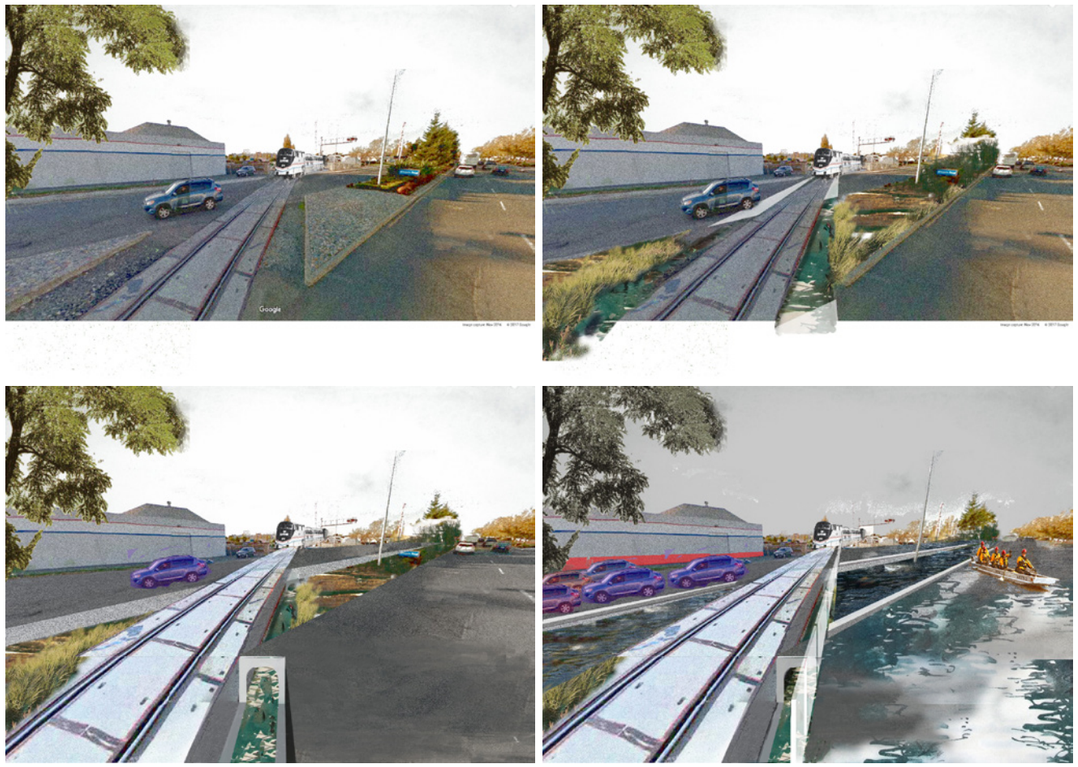


fig 122 Transformation of the critical transit line between Priority Resilience Areas P1 (1 in 20 year flooding probability) and P2 (1 in 50 year flooding)

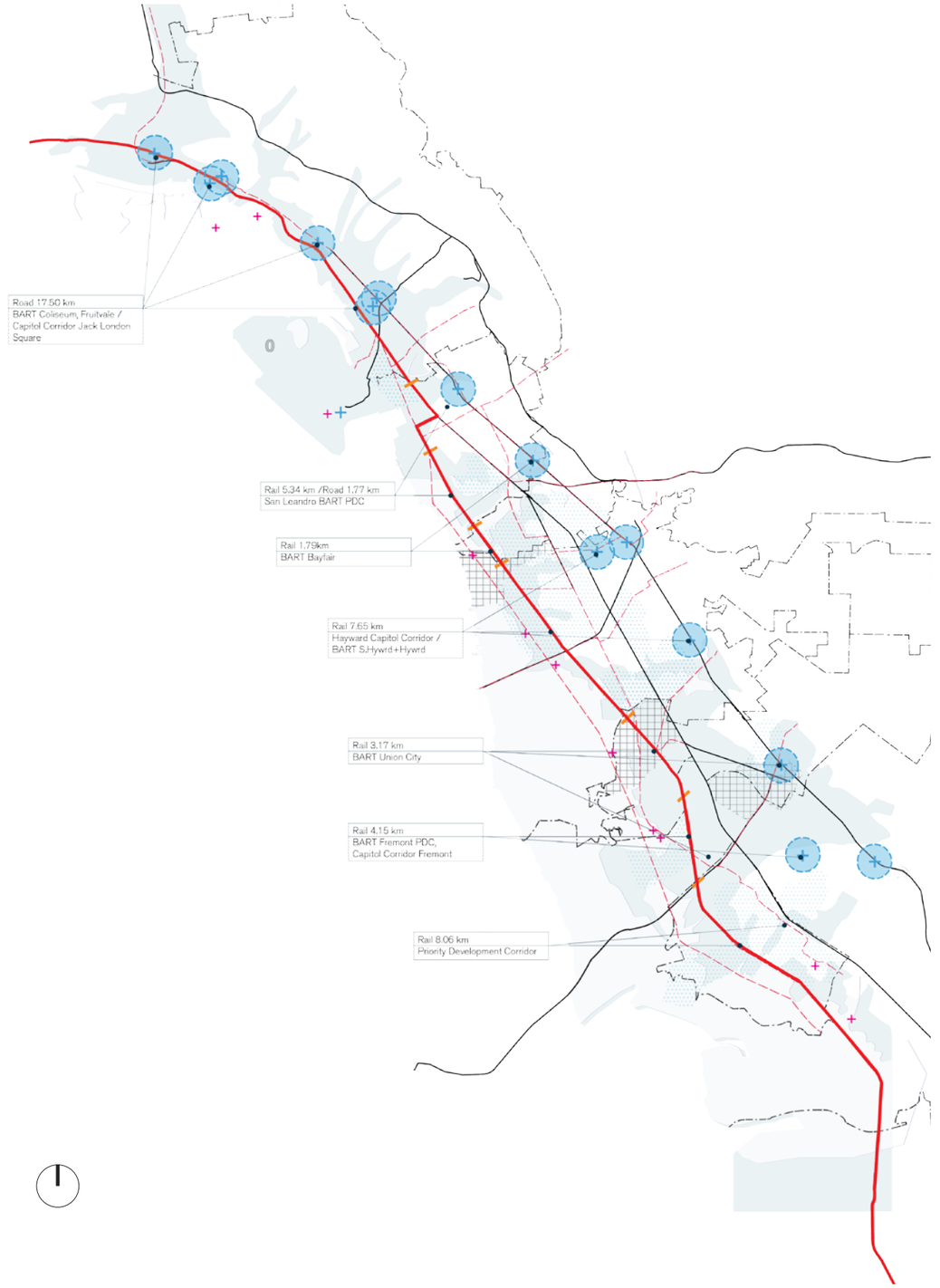


fig 123 The Critical transit line to be retrofit urgently to help easier transition of risk

THE NEW BAY

The interscalarity of spatial interventions may lead to extrapolate the 'Middle Ground' as the backbone to resilient regenrations of the Bay Area. Focused investment in high infratsructure density corridors and classifying risk gradient will help better clarity to determine actions in space. In this way ,a new Resilience Blueprint may be generated for the San Franciso Bay Area.

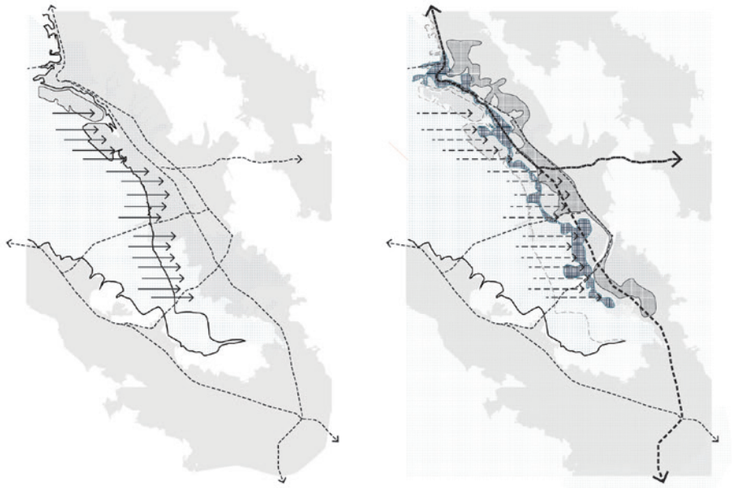


fig 124 The Resilience Blueprint of the Bay

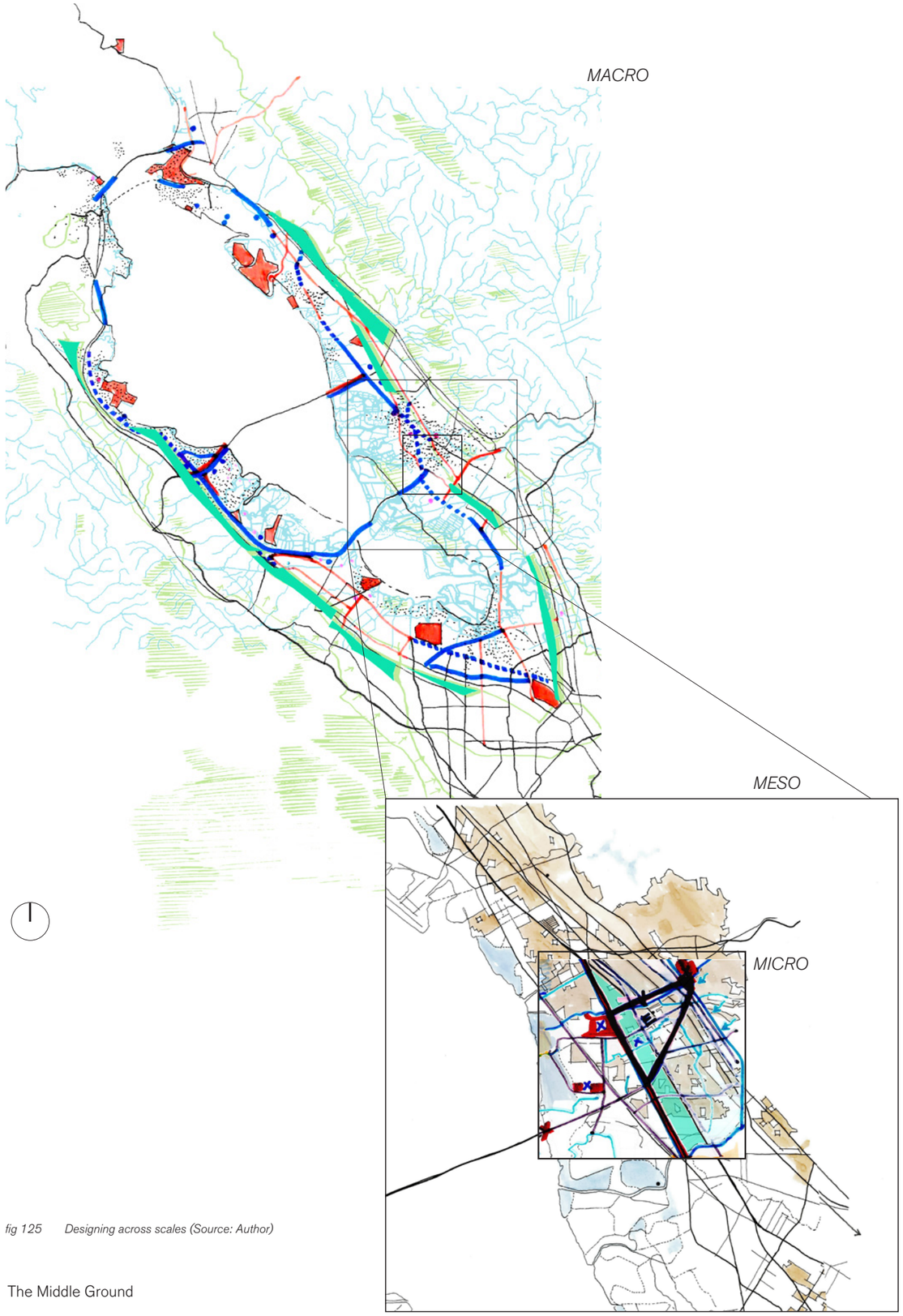


fig 125 Designing across scales (Source: Author)

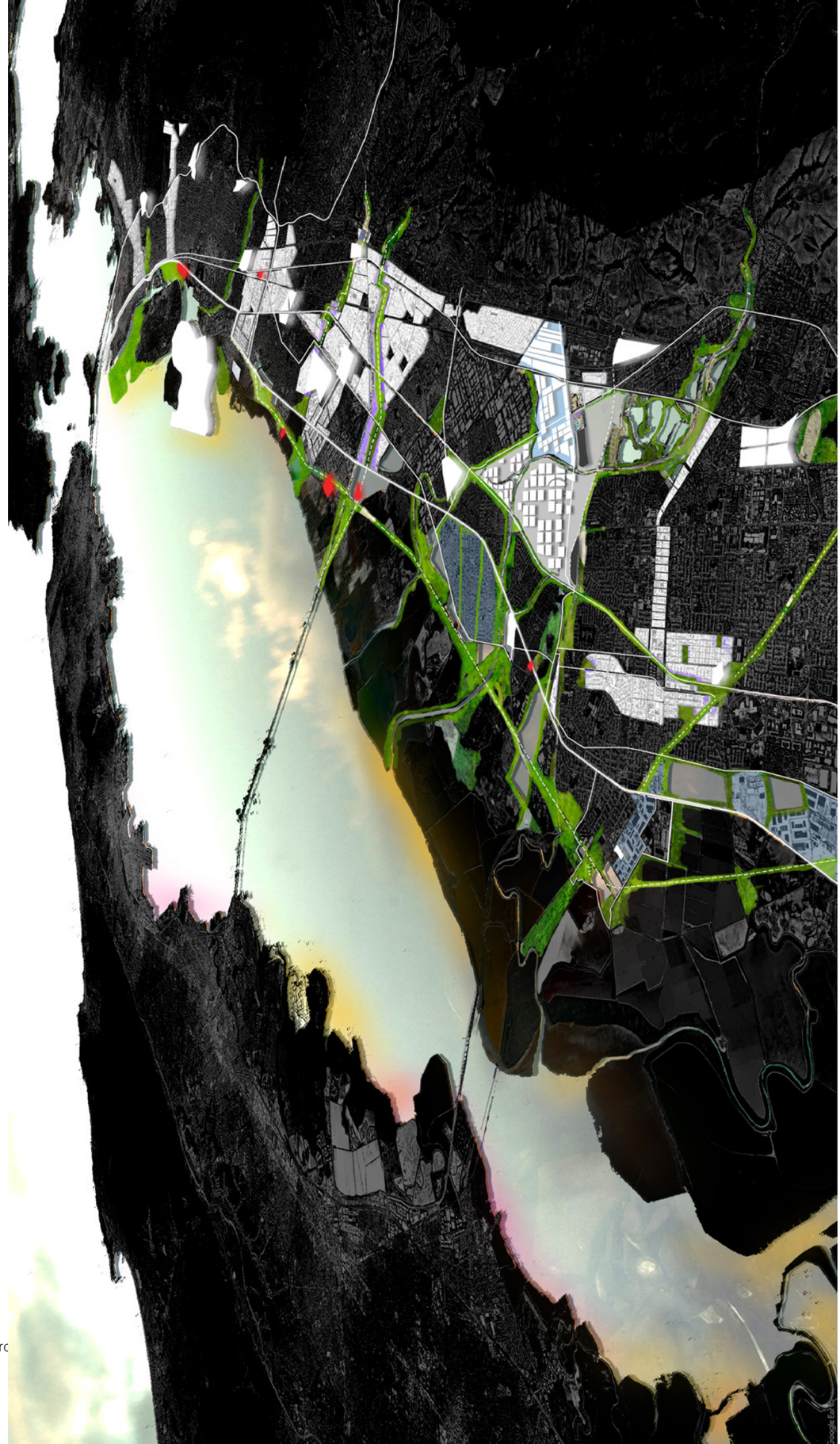


fig 126 *An impression of the East Bay of San Francisco highlighting the future of critical routes and land parcels that must attract investment to become resilient*

Governments should plan for increased relocations for millions of people likely to be displaced by natural disasters and extreme weather linked to global warming, scientists warn

The Guardian

Evaluation

This section works to understand the implications of the proposed spatial strategy – The Middle Ground. It quantifies the spaces that must be transformed and the population that must be managed within the landscape to support the transformation. It makes a study of the current land use planning governance structure and makes recommendations for accelerating implementation of the proposal. In addition ,it explores disruptive urban scenarios that we are looking at towards the future and how flexibility must be maintained to accommodate such changes.

fig 127 *Mapping the critical infrastructure node topology of the San Francisco Bay (S Krishnan) (Quote Source: https://www.theguardian.com/environment/2015/jan/08/prepare-rising-migration-driven-by-climate-change-governments-told)*

Evaluation

—Areas of exploration

—What tangible parameters can be considered to devise transferable 'spatial risk assessment framework' systematically evaluate spatial resilience

—What plans and systems of governance does San Francisco Bay need to modify to effectively position long range spatial planning strategies for risk reduction?

—What kinds of cooperative growth models are available/ can be devised for fruitful partnerships?

—What is the role of the 'urbanist' in the domain of planning for risks and disasters?

—What main urban trends/disruptions can contribute to transformation growth towards the year 2100?

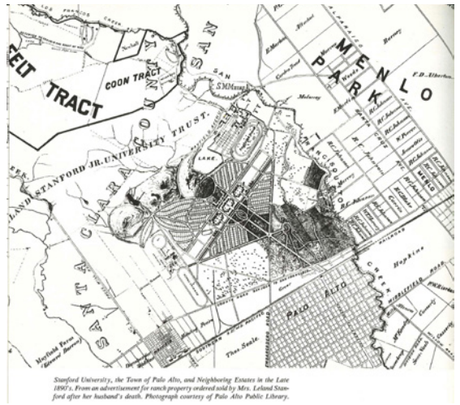


fig 128 *Map of Stanford University Precinct in Palo Alto : (from top) 1890, 2016 and elements that have endured overtime ,Source: (graphics: by author)*

MANAGING PEOPLE AND LAND

An exercise in land reprogramming is an exercise in lifestyle reprogramming and will involve managing large scale movement of people. This chapter looks at existing population density for the test case of the East Bay and the expected redistribution of density patterns based on the new land restructuring.

Density bubbles were generated in ArcMap utilizing datasets of San Francisco Bay Area Census population data. The New East Bay Masterplan involves four main structural patches based on development priority (P1, P2, P3 ,P4)

For the purpose of convenience, the population movement for each patch is looked at separately. The assumption in this case is that population movement will be restricted to within the administrative boundaries of Alameda County only. Based on the population in a patch, two kinds of movements are determined:

- Short term: Temporary refuge movement towards the nearest identified city disaster base that can provide essential supplies and arrange for temporary shelter during a crisis
- Long term: Permanent relocation of vulnerable population towards the 'resilient patch matrix' (P4) of the East Bay.

While this is a schematic study based on real data, it illustrates some important insights with respect to the future growth trajectory of the East Bay:

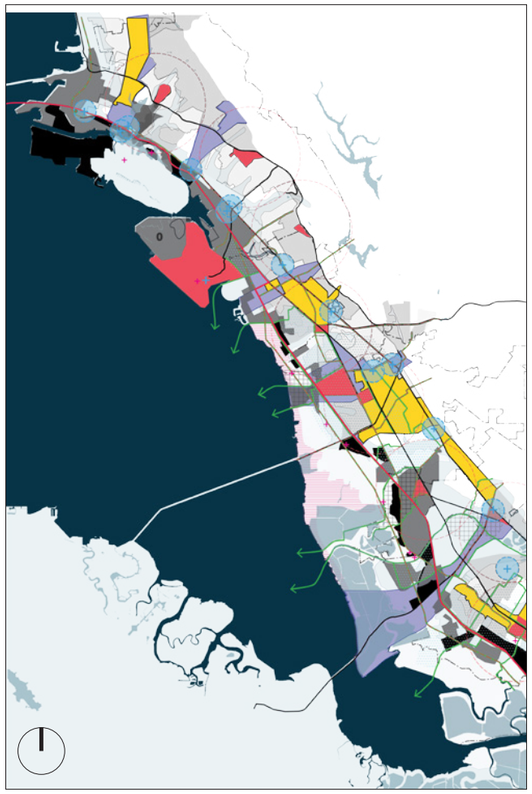
It runs on the backbone of utilizing existing road networks and large public amenities and their changing roles during a crisis.
It gives an understanding of the capacity of densities that the 'resilient patch matrix' may have to imbibe in the case a calamity strikes today and population will need to mass migrate
It highlights the potential capacities that 'city disaster base' must be prepared to handle in terms of supplies and emergency shelters

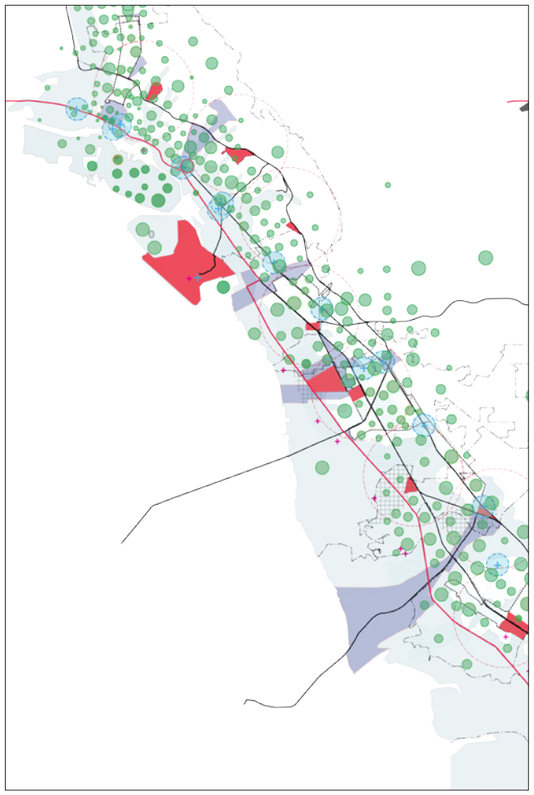
It is a starting point to explore new morphologies of urban growth for the East Bay in the long term.
In conducting this exercise of transformation, we look at three main transformations in the physical networks of the region:
Retrofitting the 'critical infrastructure line' between P1 and P2 to act as the first line of defense during intensifying climate change manifestations

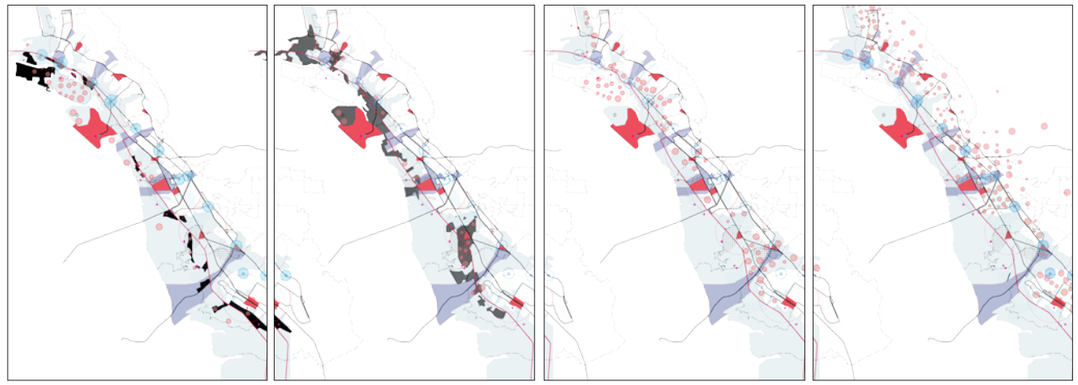
Improving densities of the 'city disaster base' to handle the project population .

Large scale transformations such as these that will span over several decades are easier said than done. The following are a broad set of recommendations that could perhaps facilitate implementation of some of the propositions. These are based on observations of the current system of decision making for land use and transportation investments across hierarchies of administration in the Bay Area:

1. The 'City' forms the fundamental spatial building block in California. Local Councils have the final authority to allocate land functions and climate mitigation plans within their boundaries. Since cities work within the broad parcellations and guidelines set out by the County, the County must include **'Spatial Resilience'** parameters within the 'General Plan'.
2. Network Transformation: The main transit network to be retrofit may be divided into parts based on the boundaries of the city. The rail operator (for example AMTRAK) may set up a partnership with the City Council to retrofit the transit line to adhere to the new spatial regulations of the County. The rail operator will have rights to the profits from the redensifying densities near the transit stations within the 'resilient patch matrix' (P3/P4) in a percentage proportional to the length of the transit line to be retrofit.
3. FEMA plays a major role in administering 'flood insurance rates' for the land parcel based on the level of risk. One of the incentives of to facilitate voluntary retrofit of facilities and movement of vulnerable population is to illustrate graphically the range of risks from earthquakes and flooding to a land parcel. The combined risk will revise the levels of risk and the subsequent insurance rates for plots. This can be utilized as a trigger to facilitate population movement towards safer grounds.
4. Voluntary 'permanent' migration of people must be facilitated within the same city limits. This is because each city administers its own set of facilities for the local population which can then remain same. Logistically, this also reduces the impact of economic displacement as people can still retain convenient access to their original work places.
5. Interjurisdictional cooperation becomes very important as risk parcellations spans across city limits. Priority Development Corridors will involve the cooperation of two or three cities and must be identified and reinforced by the County.







8075 - 9434
6403 - 7675
5547 - 6305
4865 - 5492
4306 - 4839
3814 - 4256
3337 - 3792
2788 - 3323
1954 - 2714
38 - 1784

at risk
emergency relocation
permanent relocation

fig 129 Mapping Population flow during a short term crisis and long term relocation

Large scale physical transformations such as these can be looked to be broken down into more implementable parts:

Plot level analysis and action: As illustrated in the Plot by Plot breakdown of spatial actions for P1 in the previous section, making a simple line of action to advise plot owners about the condition of the plot and the 'expected' action will go a long way in facilitating faster reactions. Smart and clear standard visual communication material must be generated that will make it easy for the citizen to gauge the changes and losses.

Lifecycle: For each development phase (P1, P2, P3), the lifecycle of the urban elements may be outlined based on the 'Space-Time Model' described in Section: Risk+Space
Phasing intelligently: The phasing and treatment of plots must be done with respect to the existing lifecycles of the urban element.

Each development phase (P1, P2,P3) must be able to formulate a gradient of spatial transformation to correlate with the lifecycle of that element (for example: occupation/housing can be transformed over a period of 20 years)

Compensation and Relocation must be restricted within the same administrative city boundaries as much as possible

Major challenges include:
—Stress on existing infrastrcture and resources
—Change of lifestyle patterns from low density suburbs to high density mixed use living
—Finding more cooperative compensation model between stakeholders

0 2.5 5 10 20 km

MAPPING POPULATION FLOW

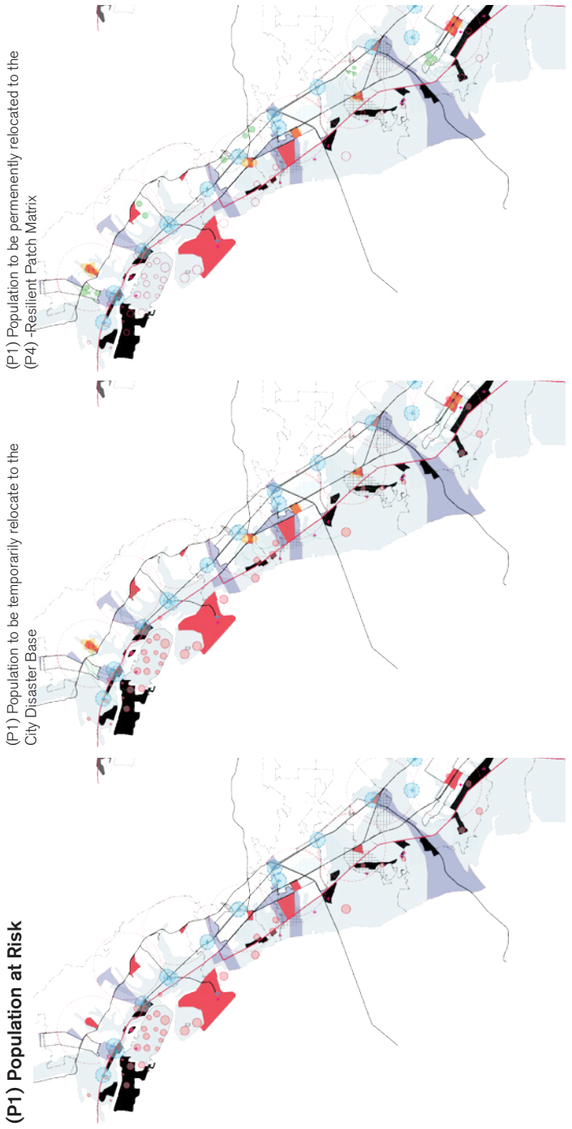
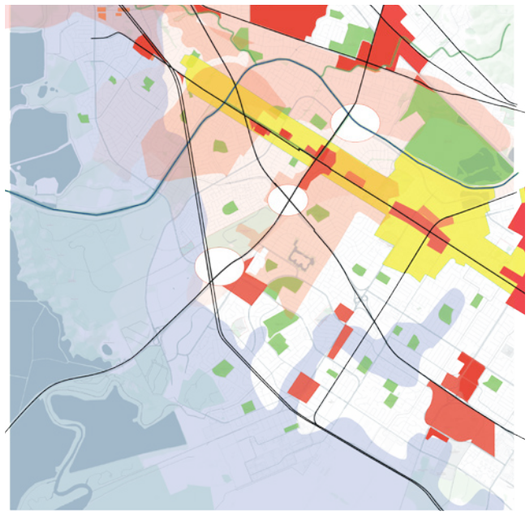


fig 130 *Mapping population flow based on the new spatial structure. (Data from Bay Area Census)*

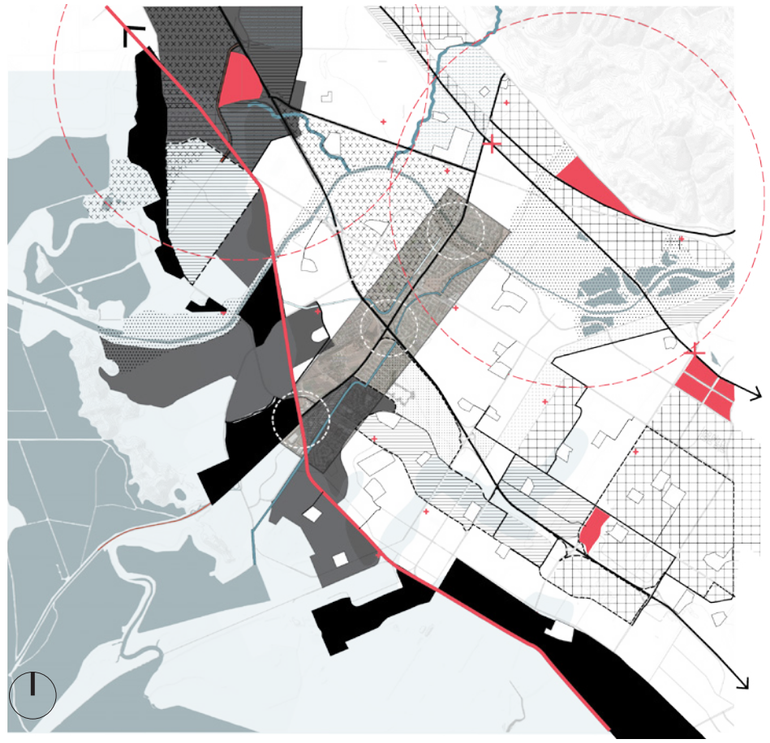
fig 131 *Looking towards the Baylands from Alviso (Courtesy: Sumanth Rao)*



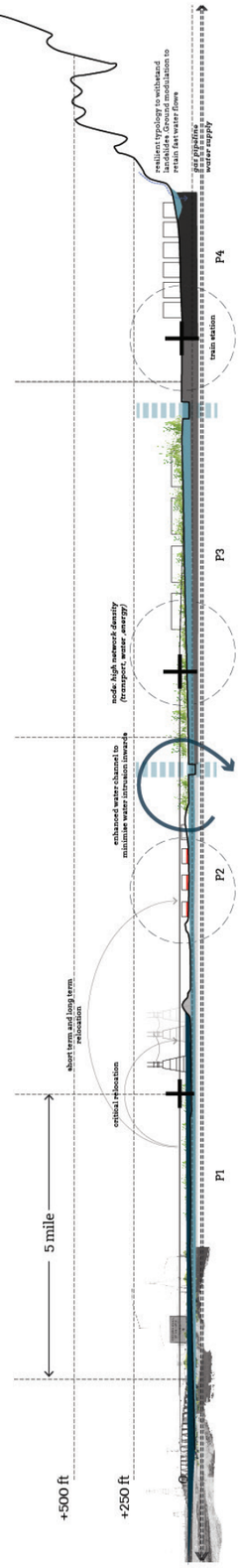
(from top)
-current allocation of centralities and Priority Development Areas
-proposed allocation of centralities and Priority Development Corridor

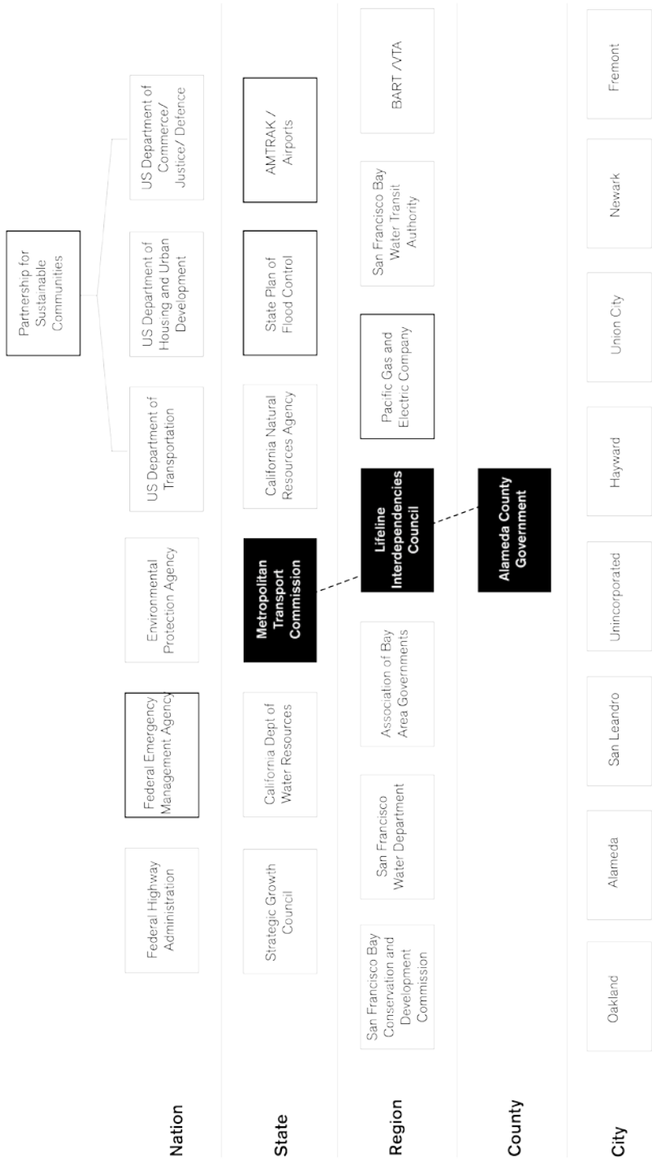
fig 132 *Mapping population flow based on the new spatial structure. (Data from Bay Area Census)*

NODE TRANSFORMATION



(from top)
-current allocation of centralities and Priority Development Areas
-proposed allocation of centralities and Priority Development Corridor





LAND MANAGEMENT FOR RISK

Land Use Management
Land has emerged as an essential tool that impacts climate change. The thesis advocates the importance of spatial planning in building long term resilience. Understanding the ways land use is configured across governance hierarchies became an important area of study. The thesis simulates disruptions in infrastructure routes during a disaster. This information is synthesized to inform new ways of reducing exposure to risk by re-distributing concentration of land functions. Land functions are the most contested territories of the urbanized landscape. It is essential to regulate the most appropriate way to control decision making on long range land management. Several hierarchies and external factors directly and indirectly impact changes in land use.

Land and Environment
The nature of land is impacted by natural processes surrounding it. Slow onset processes like erosion, sedimentation, loss of green cover change the character of land and the associated habitat over centuries.

When the extraneous processes are fast, manmade interventions are brought in to control of keep the processes away. This article enumerates the factors that influence the management of land and how it relates to the context of the San Francisco Bay Area. The objective of the article is to develop an understanding of the land use system and establish parameters that can guide the implementation of the thesis proposal.

Land and Economy
Land use change is a product of economy and was influenced by the phase of economical development of the local population. Housing came along the way near zones of productions. The characters and density was determined by the intensity of and type of production. The transition from agriculture to urban life saw the advent of multilevel developments. Industrialization brought in an explosion of high density growth in the city centres. Unhealthy conditions led to the transition to new forms of housing in the form of suburbs.

Modern metropolises and ‘compact’ cities advocate mixed use, walk able cities. San Francisco did not witness the traditional transition from agriculture to industries as most of the supplies came from outside the current urbanized region. Its growth was mainly dictated by trade and industries .This explains the heavy dependency on the transport grid and proliferation of the ‘American suburb’ typology.

Land and Infrastructure
Infrastructure, specifically transit routes have proven to be attractors of density. Land Use, like in the case of San Francisco Bay, is closely linked to the transportation expansion plan. In fact the ‘Metropolitan Planning Organization’ for the San Francisco Bay that is responsible for regional land use management is the ‘Metropolitan Transportation Commission’. The urban growth of several cities can be traced to the expansion of their transit networks. Transit oriented development continues to be development corridors for mixed use growth. Important infrastructure nodes, such as airports, ports or important railway junctions transform to become main business districts. The land over/beneath overhead electrical power grids ,main water lines, sewage lines must often be kept clear of development.
Sub surface infrastructure (sewage, fuel, data cables) is often laid in reference to the main power / transport grid and have a tendency to have a common cause impact where the same disaster affects all.

Land and Politics
Cultural, communal, religious, political clouts govern land functions tremendously. Specifically in the case of California (United States), land functions are considered to be a highly local matter putting power in the hands of the city. Actual functional ‘Zoning’ is done at the City Level. As long as the City adheres to State regulations for environment and economic functions, it can independently modulate land functions

The main administrative boundaries of land use planning in the United States include the following in decreasing level of hierarchy
— Nation
— State : California
— Region ; San Francisco Bay Area
— Sub Region: East Bay
— County: Alameda
— City : Oakland, San Leandro, Alameda, Hayward, Union City, Fremont, Newark

LAND MANAGEMENT IN THE UNITED STATES

Characteristics of land use planning in the United States:
US land use regulations are fragmented. California's benign climate was marketed as an asset for growth leading to migration of thousands of people. Fast growing urban population that responded to phenomenon like the gold rush, Silicon valley boom, quick to adopt to changing economy

- The pattern of urban development is in the form of am modern metropolitan suburb
- Large scale subdivision of land and widespread use of superblock
- Master planned communities of single family homes with small single family lot size by national standards
- Auto orientation, tethered closely to the freeway system, which was developed in the 1950s, 1960s
- Increasing land cost lead to smaller lots and 'suburbs of suburbs'
- In California, the only general local governments with land use regulatory power are cities and counties
- Planning and environmental review processes are highly localized
- The state's extensive planning law is mostly procedural, not spatial; (exception – affordable housing)
- The Council of Government is composed of elected officials from cities and counties (ABAG) which deal with understanding fulfillment of transportation and housing needs but do not directly impact land use planning.
- Most planning is related to implementation of transportation lines, but not the adjacent land use directly.

According to 'Land use regulations in the United States: An intergovernmental framework Patricia Salkin'

- Local governments make most of the very basic but important decisions with respect to how land use is allocated and regulated
- The National Land Use Pollcy Act (NLUPA) was introduced in 1970 with the intent of supplementing and enhancing the coordination of government action at the state level (Kayden, 2000), but it was never adopted
- Since, 1990, the federal government has enacted a series of federal laws that continue to influence local land use decision making, but none of them set forth a national policy or plan.
- Federal influence on land use control: 'state planning' concerned with broad land use issue that have statewide implications, such as economic development, environmental issues, infrastructure, housing and coordination among municipalities

Some areas where the federal statute influences local land use control

- Americans with Disabilities Act
- Religious land use and Institutionalised Persons Act
- Telecommunications Act
- Energy Policy Act, Federal Energy Regulatory Commission
- Department of Defense

Department of Housing and Urban Development provides federal funds for local land use planning, surveys, healthier growth (Model Cities Program)

Characterising Local Land Use Planning (Ciy Level))
Emphasis on local planning results has benefits including:

- o Directly addressing needs at the ground level
- o Generation of wealth
- o Better live-work patterns
- o Better social benefits
- o Creation of close knit communities

In contrast, localization of planning tends to neglect issues that require consideration of larger geographical context. This leads to regional imbalances due to local political processes that control land use. Retrofitting the main highway for accommodating flood water may not be a significant concern to a city that does not suffer inundation. Upstream measures in a creek stream to control sedimentation that clocks creeks in a city, may not fall under the jurisdiction of spatial control of the city. In this situation, state and national agencies set out guidelines for development, but most of them do not have a direct say in local space utilization. Despite the extensive general plan requirements, they tend to be reactive, in part because they are hamstrung by requirements of the California Environmental Quality Act (CEQA).

In 'The Quiet Revolution in Land Use Control (1971), Bosselman and Callies found that land use in the United States ,dominated by a local government decision making process had developed into a feudal system in which municipalities decided land use issues for their own egocentric benefits, increasing their tax base and alleviating their perceived social problems. They explained that locally dominated systems provided municipal officials with paltry incentives to consider the land use needs of nearby communities

Highlights of land use governance and responsibilities of the main administrative agencies can be described as follows:

State
Governor's Office of Planning and Research's (OPR)
State comprehensive planning agency

- Formulate long-range goals and policies for land use, population growth and distribution, urban expansion, land development, resource preservation, and other factors affecting statewide development patterns.
- Assist in the preparation of functional plans by state agencies and departments which relate to protection and enhancement of the state's environment.
- Ensure that all state policies and programs conform to the state's adopted land use planning goals and programs
- Create regional planning districts
- OPR has developed numerous resources to assist local governments in managing land use related issues, including information related to infill, renewable energy, general plan guidelines, transportation, and more
- OPR provides technical assistance to cities, counties, regional governments, state agencies, and the general public covering the state planning, zoning and development laws, and other miscellaneous related statues.

County
The County General Plan (General Plan) guides land use and development for the County. The county has a strategic and supervisory rule

- Outlining service areas, Special development districts, Scenic route corridor, Future width lines, Special buildings, Historic preservation, Density, Abatement
- It acts as the mediator between state regulations while keeping a tab on local development not interfering with critical state interests
- Plans and oversees new development and redevelopment plans, creates policy for land use
- Creating specific area and general plans with community participation, thus guiding the development and conservation
- Enforcing the General Plan and the zoning ordinance and responding to citizen-initiated concerns about land use.
- Long range documents such as the General Plan, Specific Plans, Design Guidelines, as well as, Zoning Ordinance amendments and other policy documents.

City
The Planning Division is responsible for regulating land use and development within the City, processing development applications, disseminating land use information to the public and carrying out the City's long-range planning efforts including maintaining the City's General Plan Land Use Map and Zoning Map

It addresses spatial elements such as:

- City Goals- consistent with general plan
- Site Development- convenience, connectivity
- Building Design And Architecture - building massing, articulation, heights, materials, styles, and creativity
- Open Space And Landscape - private and common open space, community amenities, retention of mature trees, new planting of large trees, aesthetics
- Context Sensitive- building design, types, and orientation with site improvements
- Sustainability - sustainability techniques for site planning and construction, energy efficient construction

With excerpts from:
(https://www.acgov.org/cda/planning/ordinance/maps.htm, https://www.municode.com/library/ca/alameda_county/codes/code_of_ordinances?nodeId=TIT17ZO_CH17.30SDI, https://www.acgov.org/cda/planning/generalplans/index.htm)
(https://www.opr.ca.gov/m_landuse.php)

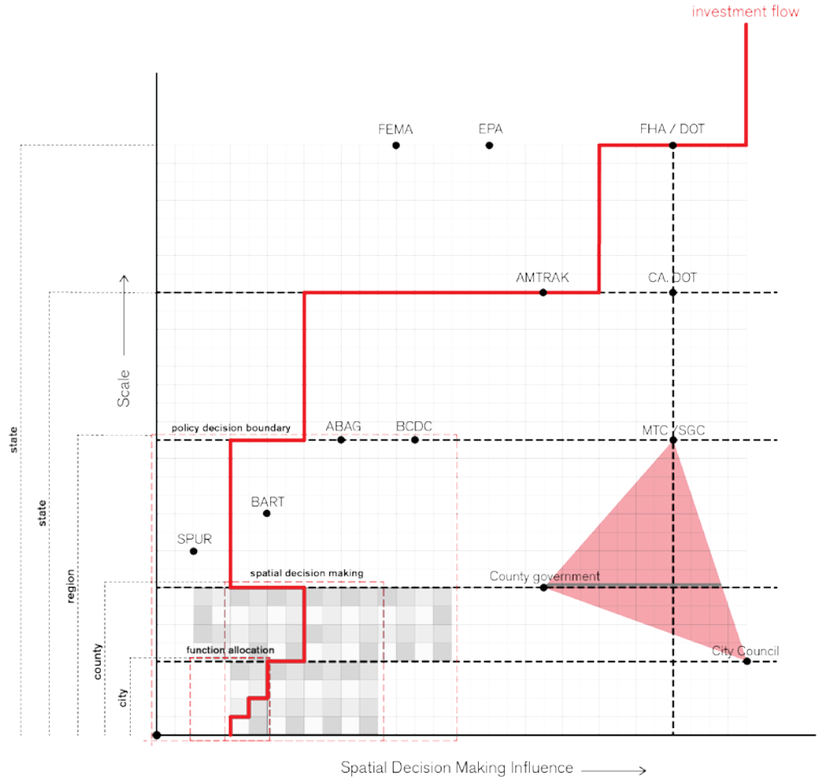


fig 133 *A schematic diagram of the decision makers regarding land use planning in California highlighting the flow of funding and the role in decision making (Graphics: Auhor)*

CONCLUSIONS- FOR LAND MANAGEMENT

—Create a platform for identifying and achieving shared priorities.
—Regional impacts be evaluated as part of local land use planning and local planning be in consistence with neighboring jurisdiction
—Reactivation The National Land Use Policy Act (NLUPA). Legislation would have created a 'Federal agency' to ensure that all federal agencies were complying with state plans and would have provided incentives for states to create similar agencies to coordinate with their local municipalities

—Metropolitan Transportation Committee of San Francisco (that acts as the Metropolitan Planning Organisation) must assume a larger role in incorporating risk gradient for spatial actions for resilience. MPO creates a plan called SCS- Sustainable Communities Strategy that must be incorporated in transportation investments. Under SB 375, an SCS must undertake the following activities:

- Identify existing land use
- Identify areas to accommodate long-term housing needs.
- Identify transportation needs and the planned transportation network
- Consider resource areas and farmland.
- Consider statutory housing goals and objectives.
- Lay out a future growth and development pattern*
- Comply with federal law for developing an RTP

—An addition that must be made:

- Mainstream 'risk' gradient of the land parcel for treatment of the built environment accordingly.

—Build a partner between MTC, LIC and the County to determine long range spatial goals to mitigate impacts of climate risk

- The 'General Plan' formulates by the County must include the risk gradient for parcels. The gradient must lay out a set of parameters to treat the parcel of land.
- System to spatialise interscalar actions for resilience from local municipal scale adhering to state goals
- Build a partnership between the main transport agency and the City Councils .Retrofitting the main transport line should lead to a real estate benefit around the 'resilient patch matrix'.

The adjacent diagram is highlights the hierarchy of agencies who currently have a say in decisions regarding land use planning in the State of California that houses the San Francisco Bay Area. It positions the scale of the thesis and the main synergies that must be facilitated to put the plan into action.

Transportation forms the backbone of planning investment in the Unites States. It has the strongest physical presence in the automobile oriented landscape and guides access to housing and economic activities. The routing of transport also guides flows of essential supplies and correlates with the layout of other critical networks (water supply, power lines). Rebuilding transportation infrastructure post a disaster also forms the highest rebuilding expenditure as failure of transport cuts off accessibility to not just resources for life but also for rebuilding activities. Hence, looking at the transformational role of transport in guiding the future or (resilient) urban development is critical. While the project considers three main critical infrastructure networks, the terrestrial transportation network (roads and railways) have been utilized for accurate projection of risks to identify the critical recovery routes during a crisis.

—With excerpts and insights from:

- https://www.acgov.org/cda/planning/generalplans/documents/110603_Alameda_CCAP_Final.pdf
- Knaap, G., Nedovi -Budi , Z. and Carbonell, A. eds., 2015. Planning for States and Nation-states in the US and Europe. Lincoln Institute of Land Policy. / Land use Regulation in the United States – Patricia Salkin
- Fulton, W., 2015. Will Climate Change Save Growth Management in California?. Planning for States and Nation-States in the US and Europe.
- Kayden, J.S., 2000. National land-use planning in America: Something whose time has never come. Wash. UJL & Pol'y, 3, p.445.
- Nolon, J.R., 1996. The National Land Use Policy Act.
- Bosselman, F. and Callies, D., 1971. The quiet revolution in land use control.

CONCLUSIONS AND RECOMMENDATIONS

The thesis focuses on sustaining life by remodulating the way land is used in cities to **sustain life in the light of urgencies. It acknowledges risk in spatial planning and attempts to forge new relations between the characteristics of risk to the suitability of space.**

Planning an uncertainty is an inherent paradox. Long range planning, even with the availability of concrete risk data can remain a vague prospect. Planning for an incoming 'danger' involves objectifying the risk to determine actions, the expected progressive or disruptive changes in the urban development pattern remains a huge challenge. The thesis looks are imagining the worst case scenarios of climate change.

It is essential to consider the potential growth, degradation of the urban fabric that is looking to gain resilience. Several technological disruptions, morphological changes due to live-work patterns can impact the 'resilience' of the space tremendously. As an example- the shrinkage and disappearance of the shopping mall and the age of e-deliveries opens up vital spaces up for alternate forms of development.

The project questions the current approaches adopted for resilience planning that focuses of 'planning with fear' and advocates embracing failure. The thesis evaluates the effects of two natural hazards (earthquake+sea level rise) on urban elements and the subsequent role of recovery infrastructure networks to develop a critical land reprogramming strategy . Framing the problem of resilience as an opportunity of growth as opposed to an 'added cost' is an essential part of the reasoning adopted for the thesis.

The main outcomes include:

A temporal growth strategy that can grow in sync with intensifying climate change towards 2100. Re-appropriation of the 'Priority Development Areas' as outlines by the Plan Bay Area 2040. Addition of 'Priority Resilience Areas' (PRAs) to accelerate investment for higher robustness of critical Infrastructure and reduce damages during a hazard. This is derived by analyzing recovery patterns of urban networks that informs the 'critical web' of the urban system that must survive a calamity.

A 'spatial risk assessment framework' highlighting tangible urban design parameters to systematically evaluate spatial resilience .The framework is derived from analyzing a combination of mathematical logic of risk assessment ,military assessment and civil engineering report conclusions from existing studies on the role of critical infrastructure and the city (SF lifeline Interdependency Report, EU Horizon 2020, INTACT EU) .

A Space-Time incremental planning method, phasing the resilience investment for a region based on the probability of flooding event. Each phase (P1, P2, P3) has associated spatial actions based characteristic of the plot and exposure to risk

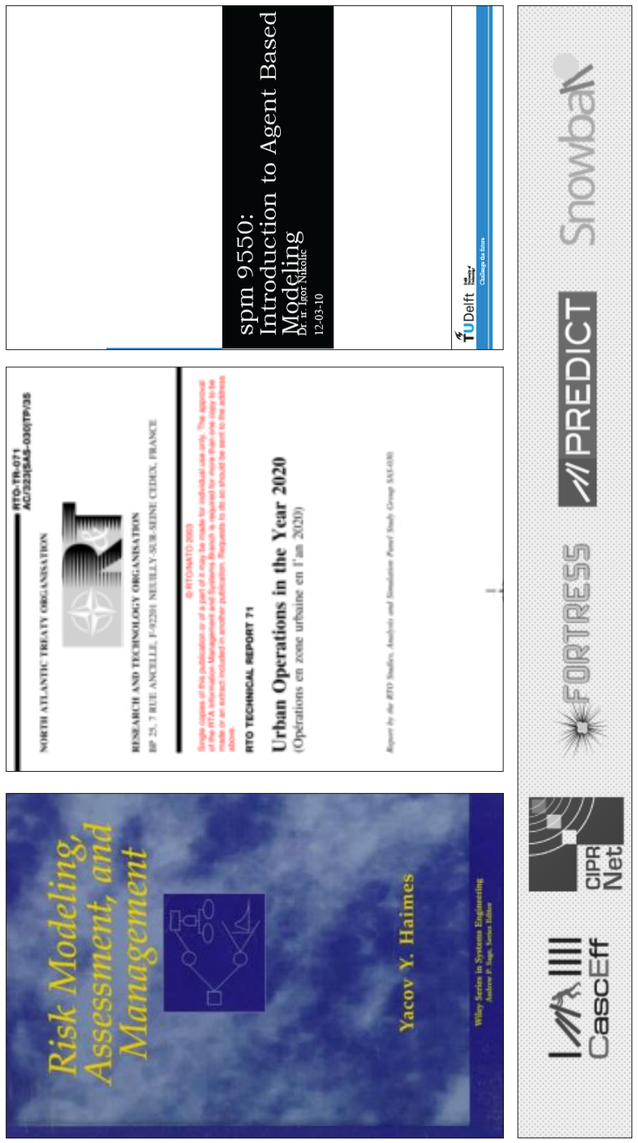
In conclusion, the project attempts to contribute to the debate on 'resilience thinking' from continuous change and adaptability to 'transformational' decisions that can guide spatial robustness for long range planning. It synthesizes the trajectories - regional growth and regional risk. The coalesced product of the exercise goes beyond the framework that is utilized to assess vulnerabilities of critical infrastructure to spatialising the outcomes within the framework of a 'regional plan'.

This calls for a paradigm shift in thinking: systemic instabilities can be understood by a change in perspective from a component-oriented to an interaction- and network-oriented view (Helbing, 2013) . This becomes crucial parameters in the way we invest in envisioning and developing our future cities.

As a reflective study, the projected urban trends are enlisted on a timeline from 2017 until 2100. This is utilized to then determine the spatial impact of the proposed modification. While a detailed incorporation of the scenarios remains outside the scope of the thesis, the reflection helps validate the framework of the 'Middle Ground' and its possible capacity to endure disruptive changes

Reflections

fig 134 *Looking towards the Golden Gate Bridge (Courtesy: Sumanth Rao)*



Spatial Risk Assessment Framework generated from understanding the logic of evaluating risk across domains (Source: Author)

TRANSFERABILITY: SPATIAL RISK ASSESSMENT GUIDELINES

"In order to get a grip on it, one must be able to relate resilience to other properties that one has some means of ascertaining, through observation."

Martin-Breen & Andries (2011) Resilience: A literature review. The Rockefeller Foundation: New York City, p. 11

The evaluation of spatial resilience for existing situation and understanding the variables that can be modulated based on the Resilience Blueprint proposed in the thesis requires an understanding of the urban elements, their interactions and the capacity of the urban system to self-organize in a crisis. Translating global risk assessment frameworks into planning action involves 'application' of the principles laid out in the document. While the overriding principles of maintaining services, quality of life etc. remains constant, the spatial variables often change for each context. While a blanket approach is not the solution, determining a framework that evaluates common variables in the face of a hazardand can accommodate special/ disruptive variables is essential.

On the urban scale are made through a combination of several parameters in the social, economic, environmental, political, geographical, legal domains. Finding models that include some or all of these aspects are at a risk of being extremely qualitative with half-baked knowledge inputs or extremely quantitative with impossibly large datasets, not really an option for time bound assessment.

Hence, formulating a framework that categorized and prioritized these systems, their interactions and their behavior under a crisis is essential. The objective was to find a reductive model with complex parameters that can be tested against changing environmental (in this case sea level rise, earthquakes) and technological disruptions.

A Broad study of risk assessment, mapping methods, software, case studies was studied to draw conclusions and thoughts from each. Traditional urban mapping techniques such as the layer method, ArcGIS fell short primarily due to the accurate nature of the models that prevented brisk dynamic manipulations. The other methods assessed include:

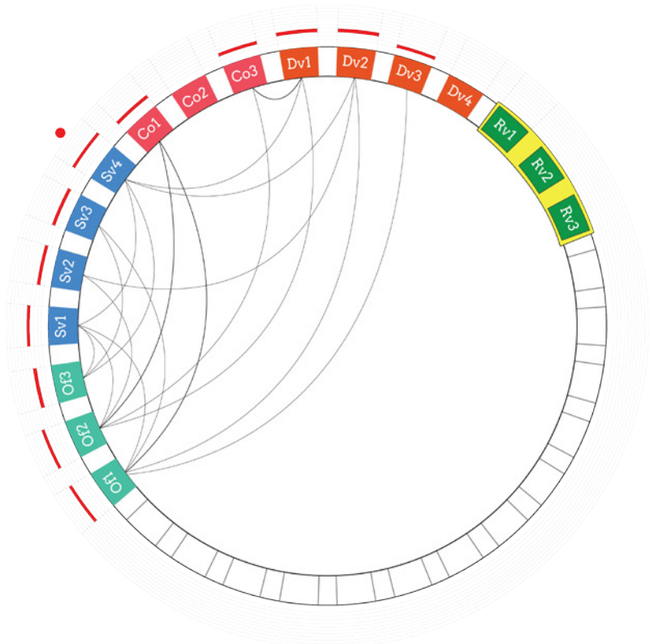
Mathematical Risk Assessment models
Basics of Systems Approach/ Agent Based Modeling of Complex Adaptive Systems
Urban Operations 2020 (NATO)

EU Horizon 2020 studies focusing on critical infrastructure (STREST, RAIN, INFRARISK, SNOWBALL, INTACT ,www.cascadingeffects.eu)

Of all the studies, the one that offered the most fundamental understanding of risk variables was the mathematical logic of risk. A mathematical model is a set of equations that describes and represents the real system. This set of equations uncovers the various aspects of the problem, identifies the functional relationships among all the system's components and elements and its environment, establishes measures of effectiveness and constraints, and thus indicates what data should be collected to deal with the problem quantitatively. These models are often solved or optimized through the use of appropriate optimization techniques. In the formulation of mathematical models, five basic groups of variables need to be defined:

1. Decisions variables
2. Input Variables
3. Exogenous variables
4. Random variables
5. State Variables

To analyze system robustness to risk, we have to be able to imagine the least desired state of the system (highest hazard intensity based o available data) .The framework helps gauge the worst state of a system and how that can be traced back to determine better decisions in planning. Each of the possible ways can then be examined independently to find out how it can occur, until it is no longer feasible or cost effective to carry out analysis further.



Of1 Minimize damage to critical functions and infrastructure assets
Of2 Maintain continuity of critical services
Of3 Minimize Cascading Failures

Sv1 Location and characteristic of high density of critical infrastructure systems
Sv2 Accessibility: Distance and available redundancy to travel for safety/ emergency services
Sv3 Landscape characteristics
Sv4 Urban Design

Co1 Frequency and intensity of hazards (sea level rise, earthquakes)
Co2 Regulatory constraints
Co3 Transition between different modes of transit, obstacles in accessibility

Dv1 Movement behavior compared for normal conditions and under crisis (people, supplies, energy)
Dv2 Volume of people to be evacuated and the carrying capacity of the channels
Dv3 Socio-economic demography (Population, Community structure, school schedules)
Dv4 Governance and organization structure

Rv1 Critical Infrastructure reliability: State of Performance (0 to 100%) – based time/season/type of threat
Rv2 Deep uncertainty due to extreme weather
Rv3 Disruptive elements (technological, cyber-attacks, tsunamis)

fig 135 *Spatial Risk Assessment Framework generated from understanding the logic of evaluating risk across domains . (Source : HAIMES, Y. Y. 2015. Risk modeling, assessment, and management., John Wiley & Sons. RINALDI, S. M. 2004. Modeling and Simulating Critical Infrastructures and Their Interdependencies. IEEE.)*

The spatial risk assessment framework has been formulated based on the case studies. The spatial risk assessment framework can be utilised to evaluate the risk levels of the existing site and understand what urban components may need modifications to adapt to risks of a disruptive nature

OBJECTIVE FUNCTIONS:
Minimize Recovery Time / Effort due to flood risk / earthquakes

—OF1: Minimize damage to critical functions and infrastructure assets
—OF2: Maintain continuity of critical services
—OF3: Minimize Cascading Failures

STATE VARIABLES
SV1: Location of high density of critical infrastructure (CI) at risk Services

—Water: Drinking water treatment plant, waste water treatment plant, main supply lines
—Transport: Highway, Rail, Global infrastructure (Airport, Sea ports), Inland port and harbors
—Energy: Electrical towers, substations, cell phone tower, oil refinery, power station

Characteristics:
—Individual / high risk / single site : Waste water treatment plant, Oil refinery, Power Station, Dams
—Distributed/ geographically extended/ high individual impact: Electricity networks, electric substation, highway network
—Distributed/ multiple sites/ low individual-large collective impact: Cell phone towers

—SV2: Accessibility: Distance and available redundancy to travel for safety/ emergency services
SV3: Landscape characteristics

1. Geographical Terrain, Flows, Buffers
2. Surface cover
3. Geomorphology (terrain, permeability)
4. Underground streams, green-blue-grey networks

—SV4: Urban Design
1. Land use and configuration, amenities
2. Permeability and Porosity
3. Street pattern, Building Typology
4. Spatial morphology

CONSTRAINTS
—CO1: Frequency and intensity of hazards (sea level rise, earthquakes)
—CO2: Regulatory constraints
—CO3: Transition between different modes of transit, obstacles in accessibility

DECISION VARIABLES
—DV1: Movement behavior compared for normal conditions and under crisis (Focal Points, community zones, religious or cultural affiliations)
—DV2: Volume of people to be evacuated and the carrying capacity of the channels
—DV3: Socio-economic demography (Population, Community structure, school schedules)
—DV4: Governance and organization structure

RANDOM/ EXOGENOUS VARIABLES
—RV1: Critical Infrastructure reliability: State of Performance of Critical Infrastructure (0 to 100%) – Based on time/season of threat
—RV2: Deep uncertainty due to extreme weather
—RV3: Disruptive elements (technological, cyber-attacks, tsunamis)

The factors are analyzed using the combinatory analysis method to draw which components influence most interactions and to gauge the most affected parameters. With reducing disaster recovery efforts as the main objective of the risk assessment framework, both ‘Urban Design’ and ‘Landscape characteristics’ emerged as factors that can most influence the behavior of critical urban systems and networks.

An additional study that contributed to understanding risk impact in urban space was the Military assessment - NATO Urban Operations 2020 (NORTH ATLANTIC TREATY ORGANISATION / RTO Studies 2003). As a thesis that is utilizing ‘recovery’ and ‘failure’ as learning processes for resilience planning, the NATO reports provides an essential insight to understanding how a military strategy is utilized to safeguard or capture an urban territory from the enemy (see Appendix VI).

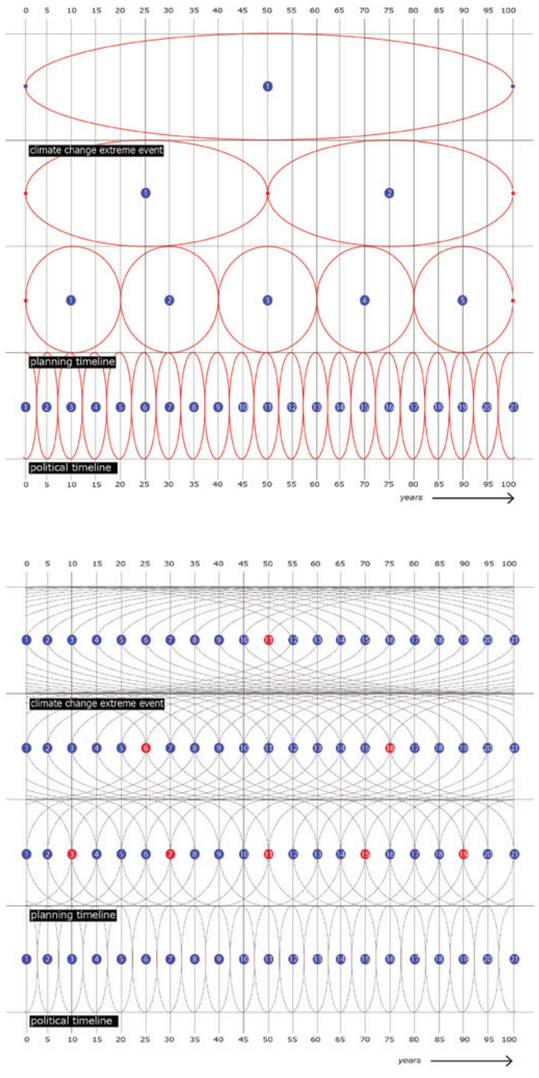


fig 136 *'typical timelines: Climate change manifestation v/s urban planning v/s political term. Each circle indicated possibilities of probabilistic design scenarios*

THESIS REFLECTION - RESEARCH AND DESIGN

The thesis advocates mainstreaming the role of spatial planning for risk reduction in urban landscapes. It decides to embrace risk in physical space to understand the impact and draw lessons for changes in the spatial morphology. The logic of interconnections between urban elements (components and networks) in a situation of crisis as compared to normalcy is documented to restructure growth patterns .

Current Practices
One of the best ways to understand a system is to disturb it

Manifestations of climate change are becoming pronounced with increasing frequencies of fast onset disasters (floods, earthquakes) and chronically rising hazards (sea levels, global temperature). According to a UN report, water related risks will alone account for 90% of future risks.

As part of the Delta Urbanism research group that researched the future of water landscapes, the thesis reflects upon current major initiatives of the domain such as 'Rebuild By design' initiative made after Hurricane Sandy, Sendai Framework for Disaster Risk Reduction (Plan for Haiti), open space network of Kobe facilitated after the earthquake of 1995 that illustrates the current approaches to planning towards and after modern disasters that focuses on protection, rebuilding and rehabilitating. Two popular spatial approaches to building resilience can be identified:

-Protective: Physical defenses such as dikes, sea walls, levees that form a compound around urban regions against incoming waters remain the single largest investments to reduce risk. The reliance on 'fail safe' design as propagated by the idea of 'engineered resilience' has seen massive downfalls (eg the damage of defenses in Hurricane Katrina that caused much havoc).

-Adaptation: It involves improving the state of a landscape to better accommodate changes by strategies like improving landscape porosity, green-blue networks as well as community level adaptation measures to risks. While, it works on the level of the built environment and landscape, it is still designed towards a single static probability.
Both cases involve adding an additional layer to the urban environment which has its own lifecycle and upkeep. The issue is that this additional layer does not always respond to the changing urban dynamics with its own socio-economic and technological trends. Hence, understanding the behaviour of space in an emergency is essential to form a paradigms to 'respond' to and grow in spite of the disruption (self-organization) and not to resist it.

Aspect 3: the relationship between research and design

Reasons for current approaches of 'resistance' or partial adaptation:

1 Conflicting timelines : How do we plan for something we may never see?

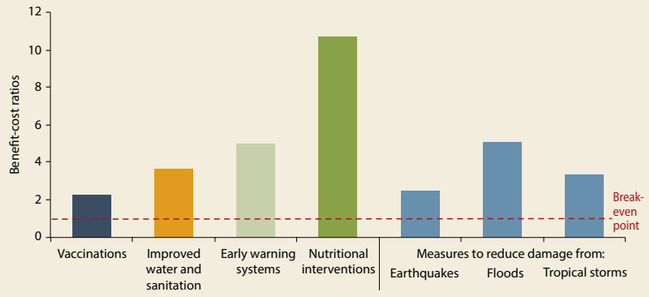
Since, climate change occurs over a longer period of time, the consequences or actions cannot be constructed within legible return periods, delaying the urgency to invest and act on a holistic scale. This coupled with different timelines followed by urban planners, political entities result into conflicts in both realtime and far future implementation.

2 Planning conventions: Disaster People v/s Development people

An overarching problem is that traditional 'urban planning' adopts a 'fixed objective', rationalized exercise that is inflexible to external disruptions .In addition there is the traditional disjunction between 'development people' (urban planners) and 'disaster people' (who rehabilitate after a disaster). In a paper by (Wamsler, 2006) that argues for the cause of 'Mainstreaming risk reduction in urban planning', some interviewees suggested that the easiest way to integrate risk reduction and urban planning is 'to wait for the next earthquake, let the city fall down and start again' (Maskrey, UNDP–BCPR). Ironically, the Global Risks Perception Survey by the World Economic forum also ranks 'failure of urban planning' as having the least impact in the global risk landscape (WEF, 2016).

Perceptions such as these on global platforms are important indicators to critically analyze the reasons that relegate urban planning a secondary status while speaking about urban resilience.

FIGURE 2 *The benefits of risk management often outweigh the costs*



Source: Wethli 2013 for the WDR 2014.

Note: The figure shows the median of benefit-cost ratios across a range of studies in each category (with a minimum of at least four estimates in each category). Above the dotted line, expected benefits exceed expected costs. The range of estimates within each category can be substantial, reflecting a diversity of intervention types and locations, and the sensitivity of estimates to variations in underlying assumptions. However, in almost all cases, even the 25th percentile of the ranges are above the break-even point.

fig 137 *Public space evacuation hierarchy related to road hierarchy (inspired from evacuation system of Tokyo metropolis) (Source: Author)*

fig 138 *The benefit of risk management outweights the costs (Source: Wethli 2013 for the WDR 2014)*

3 The need to 'bounce back':

The fundamental need to 'bounce' back' to normalcy brings with it the need to protect a system fiercely. It is human tendency to gain back the state of inertia or 'bounce back' to how things were before. This is manifested in the blanket approach to disaster recovery strategies that focus on fast track 'reinforcing' or 'building back' damaged buildings and infrastructure .While this is usually in adherence with political timelines and 'risk averse economics' , it leaves again no room for flexibility or response to future disturbances. The systems of research and experimentation that are embedded in ecological resilience are unable to gain traction as long term intentions are not considered due to these conflicts.

1 Back casting to bounce forward to a resilient design strategy:

Learning from failure and recovery

A substantial part of the study of risk reduction involved understanding the sequence in which a disaster event occurs to back cast the flow to find vulnerable tipping points and interdependencies in the system. This was done by studying the case of three modern disasters caused due to natural phenomenon (Hurricane Katrina, Tohoku Cascade, Iceland Volcano). Recovering from a disaster event is closely associated with the resilience of the physical 'emergency' infrastructure. This includes accessibility to transport, essential supplies and information. The outcome of a risk is most manifested in the event of the failure of these fundamental networks and in its ability to hamper movement – of people, vehicles, supplies and water which constitute the 'Critical Infrastructure networks' of the region. Hence, the spatial impact of Critical Urban Infrastructure Networks forms the central part of the thesis. The first level design involved understanding the role of the public space network in responding to a slow and fast crisis. A hierarchy of evacuation and accessibility to space was mapped.

2 Urbanism and Resilience

Pressing cultural and environmental concerns are demanding new levels of accountability as we measure ecological performance, energy use, mobility and density relationships, and the deployment of dwindling resources in the face of climate risks. Urbanism essentially becomes the cohesive media that amalgamates learnings from several other domains that directly impact urban life (transportation planning, seismic studies, landscape ecology, sociology).Hence, the title of the thesis holds true in two ways:

Utilising spatial growth opportunities to generate the critical 'middle ground that can survive hazards and guide the growth of a city towards the next century. This is made by a detailed analysis and design framework that informs stepwise land reprogramming process of the site boundaries

Synergies

Data science has enabled the processing of massive amounts of data to simulate future scenarios ,quantify vulnerabilities, redundancies, origin-destination optimization and crisis management.The need for accuracy remains the biggest drawback of data dependency. Data infidelity, high resource and time consumption and the difficulty in modelling all parameters become hurdles in timely ,cohesive decision making. The challenge in understanding an interconnected system requires certain levels of abstraction and aggregation that qualitative thinking offers. So while, understanding system behavior is an expert domain ,visualizing its implications on space keeping in mind the 'soft' aspects falls under the expertise of the urbanist. Understanding that there is no conclusive planning methodology that connects space directly with a risk reduction framework, the project attempts to contribute to this knowledge domain by utilizing data in the 'open' domain for analysis and research based evolutionary planning strategy. In doing so, one of the chief exercises was finding a synergy between contrasting principles, physical systems and methods including but not exclusive to:

—Engineering resilience and Ecological Resilience
—Disaster People and Development People
—Urban design strategies to combat/accommodate —Flood Risk and Earthquake Risk
—Component approach v/s systemic approach
—Direct and indirect damage

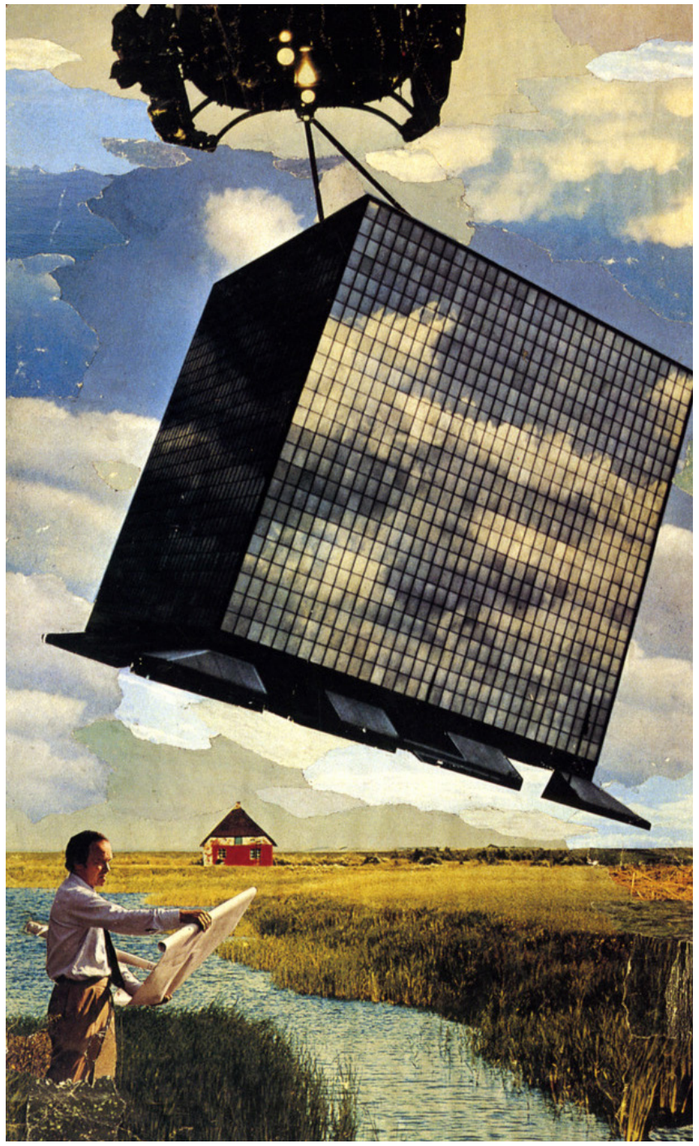


fig 139 First the building then the site Nils-Ole Lund, 1982

Aspect 4 • the relationship between the project and the wider social context

Output

The thesis evaluates the effects of two natural hazards (earthquake+sea level rise) on urban elements and the subsequent role of recovery infrastructure networks to develop a critical land reprogramming strategy .The final outcome for the project site San Francisco Bay is a temporal growth strategy that can grow in sync with intensifying climate change towards 2100. The thesis draws conclusions from the following research and design methods:

_A spatial risk assessment framework derived from a combination of mathematical logic ,military assessment and civil engineering report conclusions from existing studies on the role of critical infrastructure and the city (SF lifeline Interdependency Report, EU Horizon 2020, INTACT EU)
A study of the 'emergency evacuation movement' pattern and the normal movement pattern to determine the critical networks and critical mass of a city

_A Network to Space translation framework to map the impact of a network failure on space. Ths informs the 'critical web' of the urban system that must survive a calamity
A Space-Time matrix to relate urban element lifecycles with disaster return periods

_Framing the problem of resilience as
an opportunity of growth as opposed to an 'added cost' is an essential part of the reasoning adopted for the thesis.

This can only be achieved by ingraining principles of robust growth in overall regional growth strategies. In conclusion, the project attempts to synthesise two trajectories - regional growth and regional risk. The coalesced product of the exercise goes beyond the framework that is utilized to assess vulnerabilities of critical infrastructure in the urban landscape. It questions the way in which we approach planning for the future.

_It delivers a probabilistic urban growth pattern for: incremental, transitional and transformational growth. This is based on the return period of sea level rise (1:20. 1:50, 1:100) .It synthesizes the logic of several theoretical risk assessment frameworks to derive a spatial resilience assessment framework for 'generating' robust interdependencies.

A space-time correlation graph is proposed model to make a chronology of trends in urban development across time.

Redundancy and attenuation capacity of the urban system studies for potential for self-organization

Establishing conditions for transformational regional resilience towards worst case sea level inundation and utilizing the principles for back casting development trajectories. Bringing the importance of intuitive and analytical 'research by design' into focus understand possibilities as opposed to singular engineering oriented focus.

Establish cooperative growth models to aid sustainable investment in planning for resilience

CHALLENGES

The challenges of working in a peripheral domain of planning meant exploring several analyses, data synthesis methods with several rounds of trial and error. While not every analysis iteration led to conclusive solutions, it followed an incremental path of bits and parts of solutions adding up to the final regeneration and assessment parameters. Data collection posed a major challenge as most information related to routes of natural gas, power networks, evacuation routes lie in restricted domains. Hence, the project relies on data available in the open domain along with calculated assumptions of routes

The 'urbanism' track as described on the website of TU Delft 'Practice in urbanism has a huge part to play in the quality of places, often allocating great advantages to some and costs to others.' The dissolving dependency of the importance of physically proximity of space is altering live-work patterns. The same dependency on wireless interconnectivity is intertwining the world and making it more vulnerable to change. The necessity to work on robustness of both our social, technical and physical systems have been brought to forth to reduce the 'costs' of damages that will be inevitable.

The project works on reducing the 'costs' of damages to the physical systems to facilitate better recovery in the case of a disaster. While one can argue that investment to determine costs for an event that has not yet occurred might be wasteful, not being able to gauge how the system fails might increase the costs multifold. Hence the project attempts to formulate a method of assessing the logic of failure and how utilizing that information for long range land programing may help reduce costs. In doing so, it draws from a variety of literature domains, most of which do not fall under the 'expertise' of an urbanism graduate student' .The attitude to the literature and interviews is one of drawing from experiences and logic to formulate a way of re-looking at the power of a spatial system at its core, without any overlays. This does not come without a huge number of limitations and designer' apprehensions which are enlisted as follows:

—lack of thorough knowledge about technical domains
The risk assessment framework studies the logic of mathematical models, military strategies, physical systems, transport planning and technical disruptions among a mix of other domains. It must be reiterated that the thesis is a study of different ways of assessing risk to contribute to the intuitive space management process. While drawing from the conclusions of technical reports, the thesis incorporates qualitative conclusions. This means that the thesis draws from the learning of other specialized domains and in doing so questions the way of approaching 'urban strategy' which is the main expertise of the author and makes recommendations to fill certain gaps of knowledge.

A designerly way of doing is assumed to be a subjective process that evolves from the personal knowledge and biases of the designer. While this cannot be denied, it cannot be necessarily used to debunk the validity of the output. The thesis works to establish a strong logical assessment framework that informs 'generative design decision framework' as opposed to 'conclusive' ones. The time frame of a master's thesis allowed for performing a limited number of iterations in illustrating the potential of the framework.

—validation of the spatial outcome and implications
A chief argument is the question of validation of a subjective spatial output. While generative design frameworks are derived from the cohesion of domains, there is no proven mathematical way to determine if this is the right answer. The pace of socio-political-economic-environmental changes also makes this approval impossible. But by understanding trends based on current studies (see Chapter x),the thesis charts out possible disruptions that may be kept in mind while designing. This has been provided in support of the detailed risk assessment framework. The author is self-critical and does not believe this is the right answer. Instead, it is the urge to transform the parameters of approaching urban plans over the next century. This is also an invitation for in depth research through collaboration with other domains on different aspects derived from using a design approach issues in real world implementation

The framework for spatial implementation for resilience for a 100 year probability has several temporal conflicts due to multiple agencies involved each with their own timeframes. Current parameters of planning space work with shorter timelines and a linear, more gradual forward looking masterplan underpinned by a rational reasoning process. The moral of the thesis is to find synergies in practices to devise a transformational vision with incremental stages based on lifecycle of urban systems and components.

—issues in real world implementation
The framework for spatial implementation for resilience for a 100 year probability has several temporal conflicts due to multiple agencies involved each with their own timeframes. Current parameters of planning space work with shorter timelines and a linear, more gradual forward looking masterplan underpinned by a rational reasoning process. The moral of the thesis is to find synergies in practices to devise a transformational vision with incremental stages based on lifecycle of urban systems and components.

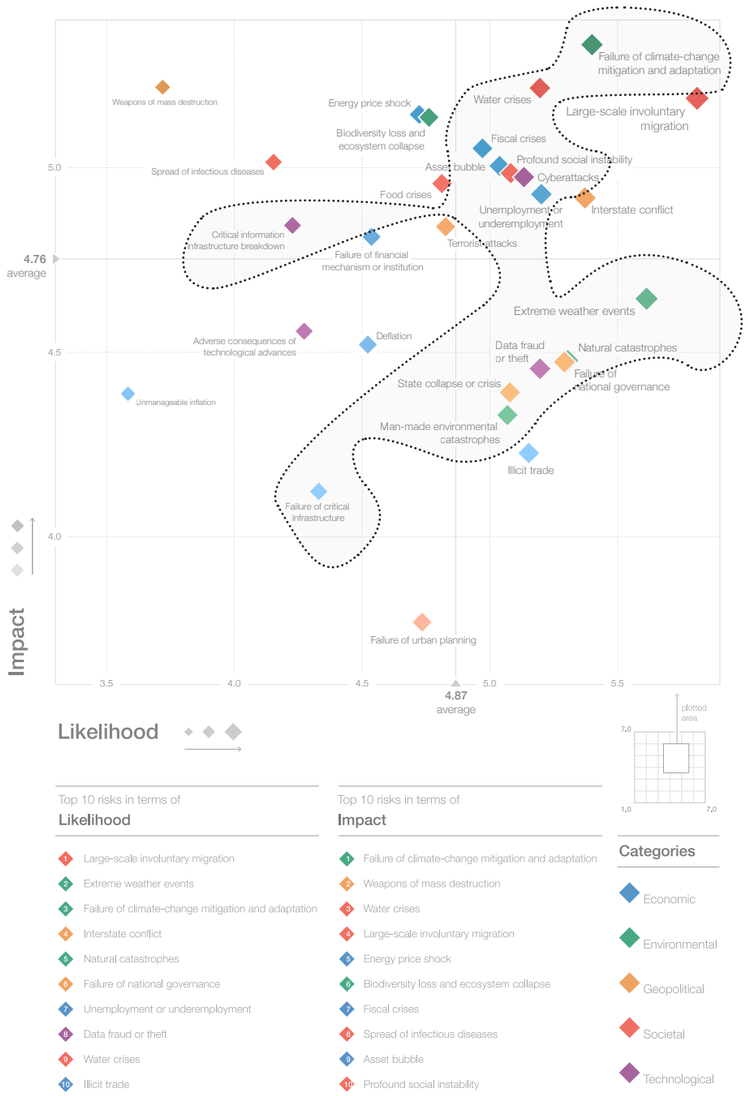


fig 140 *Source: Global Risks Landscape 2016, Global Risk Report 2016 , World Economic Forum (www.weforum.org) with the cloud of knowledge domain for the thesis project highlighted by the author*

RELEVANCE

Societal

Critical urban infrastructure networks and their behavior in a crisis form the central focus of the thesis. The behavior and composition of society is closely linked to the services provided by infrastructure networks and the feedback loop in return influences further innovation of the networks. The role of urban infrastructure utilities is highly valued due to the services they provide to maintain smooth functioning of the urban life. Traditionally, transport networks have guided urban expansions in several main urban centers. Several daily practices such as movement behavior of people, live-work patterns, family composition, shopping behavior, inclination to use public transport, choice of fuel to use personal vehicles guide the slow transformation of an urban network. Emergency behaviour and recovery planning that form the basis of the design strategy are deeply related to the public space networks and how people navigate them . A disruption of this flow of services, due to direct damages to the networks leads to hampering of daily life but indirect cascades of the damage to other networks leads to even bigger losses.

Citizens' trust in the government's crisis management capacity is relatively high largely due to the ignorance of the reality of change. Numerous factors contribute to adaptability, including the availability and number of substitutes for critical processes or products, workarounds and contingency plans, backup systems, training and educational programs for operational personnel ,and even human ingenuity in the face of disaster. (Steven M. Rinaldi 2001). The thesis document could be useful reference to organizations/ lifeline operators whose analysis reports have been drawn from for the project including:

San Francisco Bay Conservation and Development Commission /San Francisco Bay Area Planning and Urban Research Association/ Federal Emergency Management Agency/ California Department of Transportation (Caltrans) District 4 – Regional roads/ Pacific Gas & Electric (PG&E) – Electric power and natural gas/ San Francisco Public Utilities Commission (SFPUC) – Potable water, auxiliary water (for fire-fighting), and wastewater/ San Francisco Department of Public Works (SFDPW)– City streets Urbanism

It can be treated as one possible outcome that could result in as part of the institutional framework of the Bay Area.

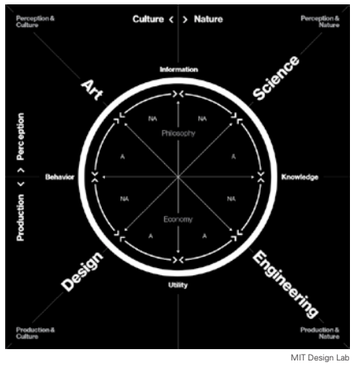
Scientific

The thesis focuses on the role of critical urban infrastructure lifelines that keep an urban system running. Traditionally urban networks were controlled and laid by the engineering (civil, water, transport) domains. The growth of these networks guided urban sprawl and subsequently the feedback of consumption guided the expansion of the networks. In a situation of a crisis, failure of these networks led to increased recovery time and effort. A study of reconstruction costs of Hurricane Katrina show that rebuilding transport networks consumed almost half the budget for reconstructions after the disaster. The main hypothesis of the thesis is that, 'The recovery period after a crisis is inversely proportional to the redundancy of critical infrastructure networks that keep communication alive in order to resume system equilibrium.'

This is based on the fact that due to the very complex, interconnected nature of urban issues, there is a limit to prediction and 'accidents are inevitable'. The thesis draws upon behavioral studies of CI made by the domains of transport engineering, seismic studies, landscape ecology and complexity theory in understanding ways of network disruptions. In doing so, it starts amalgamating conclusions to formulate a spatial risk assessment framework to gauge the resilience of an urban boundary. It does so to emphasize the importance of physical space in being able to convey and control risk.

It subsequently opens up the playing ground for other domains to fill in vital knowledge gaps essential for better macro scale restructuring of landscapes of risk.

$$\text{recovery period} \propto \frac{1}{\text{redundancy / robustness / flexibility of Critical Infrastructure networks}}$$



MIT Design Lab

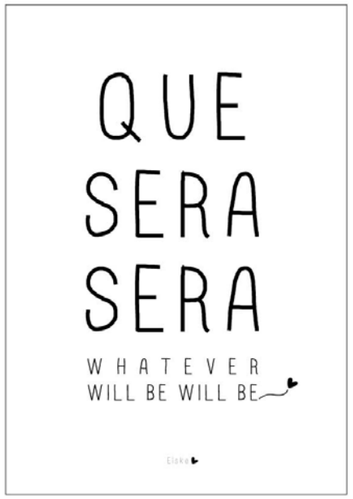


fig 141 *fig 10: living with uncertainties (image source: MIT)*

It follows this by an exercise of iterative analysis-design loop (research by design) to apply risk assessment framework incrementally through scales to understand the context for intervention. The main argument that invalidates this exercise if the necessity to employ accurate data to predict change. While a study of complex adaptive systems involves understanding interdependent networks in a quantitative way, complexity theory tells us that 'Due to the very complex nature of the social issues there is a limit to prediction and that as a consequence the pressing social issues will not be solved by the power of technology alone' (D. Helbing 2011).

The synergy between the qualitative 'research by design' and the quantitative lessons from engineering domains forms the essence of the thesis analysis and design framework. Since the urban domain has no one right answer, generating a set of possibilities is an important exercise. This provides an inventory for comparison and debate to select optimum solution based on available resources that could assist decisions for the built environment.

Urban Design

The Urbanism track at TU Delft investigates the relationships between urban patterns, society and design and planning interventions that may promote a more sustainable and fair urban environment.Hence,It is a domain that depends on the feedback from analytical sciences, for rational decision making.

The focal point of the thesis is relooking the way we approach planning for natural hazards.Ways of growing in an urban system are often the pattern in which the changes to the physical components of the landscape are guided towards the future. The influences could range from social, technical, environmental, political and economic changes. Flows and networks that transmit these changes form the lifeline of the urban system. Networks can act both as connectors and barriers. This role is evaluated in understanding spatial quality.

The transformation of the physical components is based on their lifecycles. Matching these lifecycles with the return period of risks for sustainable growth is an important trade off the thesis addresses by the proposed spatio-temporal risk-growth timeline.

The thesis reflects on this rational, logic oriented approach to analysis that forms the basis of a design that answers one set of problems as a 'complete 'masterplan'. While urban analysis is a combination of quantitative and qualitative research, the 'design' output is not attributed the scientific validity to be considered a truly legitimate product. The thesis establishes a risk assessment frameowk that can be utilised to validate the output over multiple iterations.

As opposed to creating a 'protection' strategy towards the hazard, the approach adopted is understanding 'evacuation' movement of people and resource accessibility in a crisis situation to determine the critical lifelines of a system. This input is combined with urban trends to understand land programme transformation.
This includes changing urban centralities, trajectories, densities and live-work models.

The Way Forward

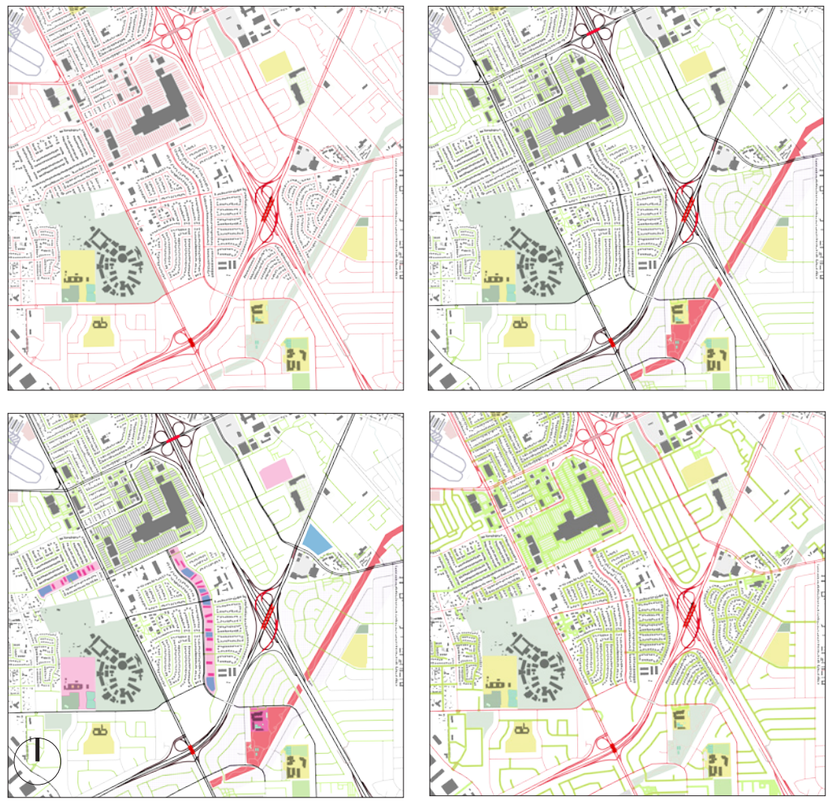
Robustness for adaptation and the Flexibility to change are the key characteristics that support resiliency of an urban region. The thesis delivers a robust patch-matrix system in the landscape that can guide flexible growth in the future. As a thesis that synthesises a broad amount of data obtained from other domains, it reinforces the importance of spatial planning and the role of urbanism in being able to translate theoretical, engineering learning into space. The spatio-temporal framework is a step in understanding the potential of flexibility of static urban components to change by improving redundancies of lifeline networks. The value of the thesis lies in its nature of explorations and the possibilities it begins to open up within the domain of urbanism and to collaborative domains to understand spatial implication of their actions. To be able to classify long term change into a tangible urban transformation framework is the chief contribution of the project.

Appendix

Somewhere in Newark (Courtesy: Sumanth Rao)

APPENDIX I : LIST OF FIGURES

List of Figures



(from top left clockwise)
-Urban block under consideration. All motorable routes in red
-Rising importance of the electricity grid due to end of the oil age. Electric power lines zone as spines for new development axis
-Smaller family sizes and lesser hours at work. New ,flexible building typologies. Make more space to store water
-Adoption of car sharing, reduced necessity of local roads/ cul de sacs, can be made pedestrian friendly with walkable radius

fig 143 Spatial manifestation of selected trends

APPENDIX II :URBAN TRENDS AND UNCERTAINTY

Planning an uncertainty is an inherent paradox. Long range planning, even with the availability of concrete risk data can remain a vague prospect. Planning for an incoming 'danger' involves objectifying the risk to determine actions, the expected progressive or disruptive changes in the urban development pattern remains a huge challenge. Adaptation by a system may be inhibited by process originating outside the system (in this case indirectly affected infrastructure); it is therefore important to consider "external" obstacles to adaptation, and links across scales, when assessing adaptive capacity (Brooks 2003). Both external impact and internal behavior may contribute to exacerbate the impact of a hazard.

It is essential to consider the potential growth, degradation of the urban fabric that is looking to gain resilience. Several technological disruptions, morphological changes due to live-work patterns can impact the 'resilience' of the space tremendously. As an example- the shrinkage and disappearance of the shopping mall and the age of e-deliveries opens up vital spaces up for alternate forms of development.

As a reflective study, the projected urban trends are enlisted on a timeline from 2017 until 2100. This is utilized to then determine the spatial impact of the proposed modification. While a detailed incorporation of the scenarios remains outside the scope of the thesis, the reflection helps validate the framework of the 'Middle Ground' and its possible capacity to endure disruptive changes

A5
MICRO
Understanding the multifunctionality of urban elements (spaces and networks) and its relationship to critical infrastructure mapped in A3 and A4
Charting out approximate urban trends until 2100 and how that will spatially impact urban form and lifestyle
Open Data from ArcGIS, http://www.futuretimeline.net/ ,City Lab report on the Future of Transportation and allied articles

2020-29	2030-39	2040-49	2050-59	2060-69	2070-79	2080-89	2090-99
Internet use reaches 5 billion	Extreme heatwaves are commonplace in the U.S.						
Phase 1 of the California High-Speed Rail line complete	Half of America's shopping malls have closed		Smaller, safer, hi-tech automobiles				
Carsharing has exploded in popularity	Self-driving vehicles are widespread	Global average temperatures have risen by 2°C	Continent-wide "supergrids" provide much of the world's energy needs	Insurance crisis	Global average temperatures have risen by 4°C*	Deadly heatwaves plague Europe; traditional agriculture is decimated	Hypersonic vactrains are widespread
Solar grid parity has been reached in almost 10% of the US	"Smart grid" technology widespread in developed nations	"Energy islands" are widespread in coastal regions	The end of the oil age	Tropical cyclones are wreaking havoc in the Mediterranean	Fully automated homes	Hyper-intelligent computers	Sea levels are wreaking havoc around the world
Water Crisis in South West USA	Desalination has exploded in use		Rainfall intensity has increased by 20%	Flood barriers are erected in New York	Rainfall intensity has increased by 20%		The average employee works less than 20 hours per week
The first self-sufficient, car-free city in mainland China	Western manufacturing jobs have largely disappeared	White people are a minority in the USA	Smaller family sizes	Global aging population +40	The distribution of birds in the United States has been altered substantially	USA cedes territory to Mexico	Global fertility has stabilised at below 2.0 children per woman
Water is becoming a weapon of war	The global airline fleet has doubled	Air accident fatalities have been eliminated	Hi-tech, intelligent buildings are revolutionising the urban landscape	Self-assembling buildings made 100% from nanotech	SQL Server databases are hit by a major glitch		
Vertical farms are common in cities							
Wireless electricity is reaching critical mass							

fig 144 *https://cdn.theatlantic.com/assets/media/files/FOT_ebook.pdf, https://thegreatermain.wordpress.com/2015/02/16/what-do-driverless-cars-mean-for-suburban-planning/, https://mic.com/articles/113166/a-nasa-scientist-says-california-only-has-one-year-left-before-it-runs-out-of-water#.L8FdrGpHS, http://www.sfchronicle.com/opinion/article/California-must-adopt-the-electrical-grid-of-the-10827713.php , http://www.pbs.org/newshour/updates/california-preparing-future-full-extreme-weather/(Graphics: Author)*

2020-29	2030-39	2040-49	2050-59	2060-69	2070-79	2080-89	2090-99
Internet use reaches 5 billion	*increased cooling increased water consumption agriculture damage*						
statewide economic growth, tourism boost and job creation	*land opens up*		Smaller, safer, hi-tech automobiles				
environmental benefit, less traffic congestion on highways	*less road accidents, reduced traffic congestion*, local road redundancy*	Global average temperatures have risen by 2°C	*reduced power outages, increased vulnerability due to interconnectivity*	*socio-economic losses, damages*	Global average temperatures have risen by 4°C*	*increased cooling increased water consumption agriculture damage*	Hypersonic vactrains are widespread
solar energy can be introduced for domestic requirements	*reduced power outages, increased vulnerability due to interconnectivity*	*steady sources of renewable energy*	*transition to electric energy?*	Tropical cyclones are wreaking havoc in the Mediterranean	Fully automated homes	Hyper-intelligent computers	Sea levels are wreaking havoc around the world
find ways to store water shortage of supplies	*space for regional desalination units*		*inundation, make space for water, protect from water*	Flood barriers are erected in New York	*inundation, make space for water, protect from water*		*more live-work flexible spaces, reduced traffic congestion*
The first self-sufficient, car-free city in mainland China	disappearance of medium size industrial units, increase in self employment ,service	*White people are a minority in the USA*	*reducing footprints of suburban homes, reduction in schools*	*reducing footprints of suburban homes, senior friendly design*	The distribution of birds in the United States has been altered substantially	*political instability*	*reducing footprints of suburban homes, reduction in schools*
Water is becoming a weapon of war	expansion of aiport area develpment	Air accident fatalities have been eliminated	Hi-tech, intelligent buildings are revolutionising the urban landscape	Self-assembling buildings made 100% from nanotech	SQL Server databases are hit by a major glitch		
Vertical farms are common in cities							
Wireless electricity is reaching critical mass							

fig 145 *Poster of the 2017 edition of 'Lets Talk About Water'*

APPENDIX III : GRADUATION WORKSHOP

Let's Talk About Water MICRO MOVIE FESTIVAL 2017
February 6th to 10th, 2017
Three days of workshop on the same theme in parallel to the film festival will also be conducted in Delft and Amsterdam

Let's Talk About Water (LTAW) is an award-winning festival, combining movies and panel discussions to spark conversations on local, regional, and global water issues around the world. Highlights include a masterclass at the faculty with public lectures by external experts in the first week. In the Amsterdam program also the film makers/directors of two movies will be attending, as well as a live cinema concert will take place.

In collaboration with
— TU Delft Urbanism (http://www.urbanism.nl/)
— TU Delft Landscape Architecture (http://www.landscapearchitecture.bk.tudelft.nl/)
— UNESCO-IHE (https://www.unesco-ihe.org/)
— AMS Institute (http://www.ams-institute.org/)
— Deltares (https://www.deltares.nl/en/)
— WWF Netherlands (http://wwf.panda.org/who_we_are/wwf_offices/netherlands/)
— Johnson Family Foundation (http://www.jffnd.org/)
— Filmhuis Lumen (https://www.filmhuis-lumen.nl/)

The graduation workshop was conducted as an independent wee long day master class and workshop on the theme of communicating the burning issues of climate change and water. This was conducted with the supporting framework of fifth installment of the film and water festival 'Let's Talk About Water' (LTAW).

'Let's Talk About Water' uses the power of cinema to inform and to spark debate on a wide variety of topics that are all connected through water. It takes the form of a fortnight long movie festival held in conjunction at Filmhuis Lumen Delft and AMS Institute, Amsterdam. This year's theme is Water and Power.

Where and whenever water becomes or is a valuable commodity, power over water also seems to be playing a role in events and communities. Information and communication are powerful, as tools for getting people and money involved. And in war facts and the access to useful, true information are often the first casualty. Can we ask scientists to be responsible for communicating their important topics?'

fig 146 *With text borrowed from : www.letstalkaboutwater.com, www.tudelft.nl/en/current/agenda/event/detail/lets-talk-about-water-derde-editie-van-film-en-waterdagen-3/, https://www.unesco-ihe.org/*

Workshop Structure
"Those who have the privilege to know, have the duty to act" – Albert Einstein

Communicating the Power of Water inspired the concept of the 'Micro Movie Festival'. The objective was to understand, evaluate and apply techniques to effectively communicate the crux of the problem the thesis is addressing .Ten students composed of participants from Delta Interventions (Urbanism) and Flowscapes (Landscape Architecture) graduation studios were invited to participate in the week long lecture series and master class exercise. Each student had to utilize the medium of a short feature film. The art of creating a narrative through writing, storyboarding, sketching, image search was a crucial part of the workshop exercise.

Communication plays a very important role, especially when it is about something as important as water, which is part of every individual's life. While communicating water, either as power, as threat, as risk or as a resource; interestingly every expertise or every discipline have its own vocabulary, notions and set of definitions. It becomes necessary to make this knowledge, this information accessible and understandable to every individual to involve them in the process and create awareness. The master class focuses on how to communicate the strategies for water sensitive city between the experts and broader public community.

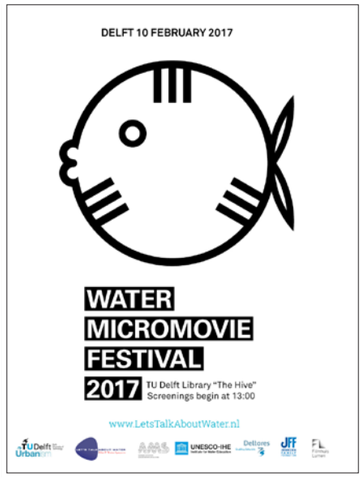


fig 147 *The LTAW team and participants*
fig 148 *Poster of the WATER MICRO MOVIE FESTIVAL (designed by Lorenzo Mattozzi, picture of the team after the completion of the final presentation (pic courtesy: Dr Taneha Bacchin)*

Talking about communication, Bernardo Secchi drew the attention of planners from technical presentation of the planning aspect to more ideas and image production methods.

This conception of urban planning gave rise to combining urban issues with art of narration or storytelling (Throgmorton, 2007, 2003; Sandercock, 2003; Eckstein, Throgmorton, 2003) and established story telling as a prescriptive or descriptive model for planning practices (van Hulst, 2012). Narration refers to selective retelling of elements based on the audiences to whom the intention needs to be communicated. It is based on a premise that a good story is more valuable than mere facts.

Morphology of the tales
Inspired from the idea of narration, the workshop asks the participants to reflect upon their graduation project from a new perspective through a medium of story telling and exploring new perspectives.

To do so, building blocks from Vladmir Propp's The Morphology of Folk Tales have been used. According to Propp, Morphology can be used to anchor a potentially chaotic work to a sufficiently recognizable topos to prevent audience alienation or hostility. Hence, to communicate complex water issues these building blocks will guide to develop a narration which can be relatable to wider set of audience.

Propp analysed around 400 Russian folk tales and found that across all of them, despite having apparent differences, characters and their actions can be categorized into clearly defined roles and functions.

These characters are defined in the later part. Further he also categorized the script or story of a tale in five broad elements which not only constructed the script but the tale as a whole:

1. Functions of dramatis personae (see below)
2. Conjuctive elements (ex machina, announcement of misfortune, chance disclosure – mother calls hero loudly, etc.)
3. Motivations (reasons and aims of personages)
4. Forms of appearance of dramatis personae (the flying arrival of dragon, chance meeting with donor)
5. Attributive elements or accessories (witch's hut or her clay leg)

So in the task of narrating a story or constructing a script, most of the these five characters and elements are present. Further these building blocks of narration are explained in detail.

The organising team consisted of three students – Supriya Krishnan, Rahul Dewan and Sahil Kanekar and Seul Lee. Responsibilities included:

Programme Formulation
— Understanding the time frame and speakers schedules available within the framework of the festival.
— Defining a detailed workshop flow to re-formulate the graduation problem and make an outline for the movie. With guidance from the workshop mentors (Dr Taneha Bacchin, Dr Stefan Nijhuis and Ar Lorenzo Mattozzi), a strong theoretical framework was generated on which the movie narratives will be based.
— Generation of Workshop Inventory with guideline charts and cards for the story telling process
— Publicity posters were made to invite students for the lecture series. The workshop participation was by invitation of the mentors.

Creation of Workshop Manual
A workshop manual complete with the schedule, description of the exercise, the explanation of the theoretical basis and relevant examples was made by the team to be provided to the students in hard copy format

Guidance during the Workshop
Movie development involved reductive writing of the graduation problem, defining a style of storytelling, a visual communication style, storyboarding, developing props, characters and finally rendering a movie on software.

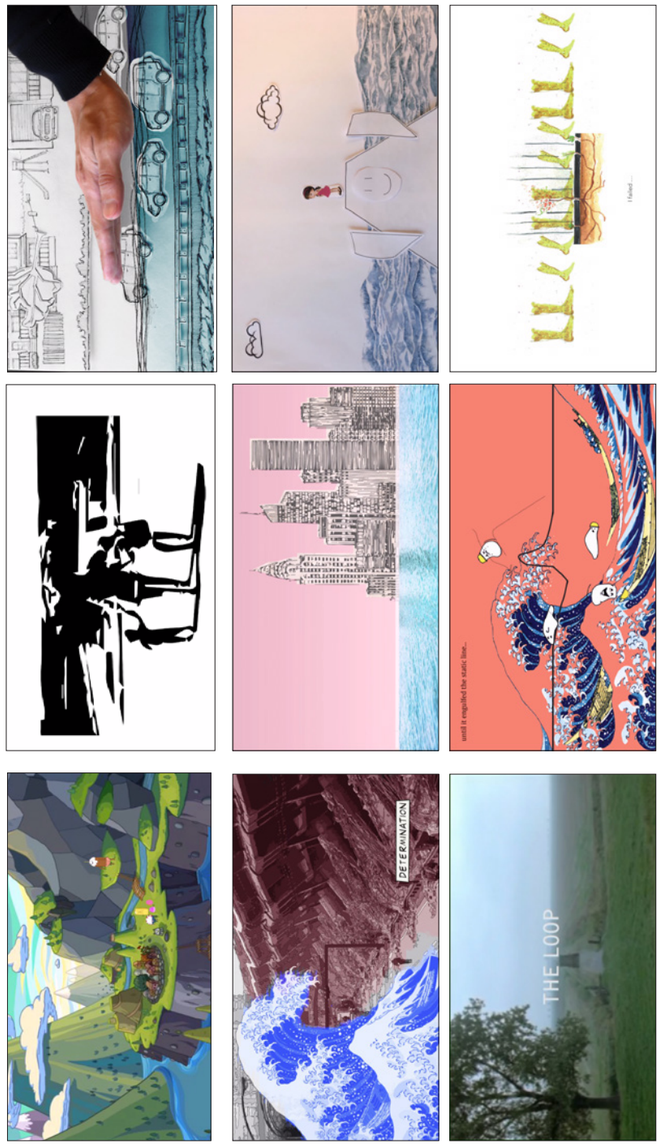


fig 149 Screenshots of the ten movie outcomes

Result
Over this week 10 MSc graduate students (5 Urbanism + 5 Landscape Architecture, including the organizing students) embraced the challenge of reframing their graduation project through a simple narrative. The outcomes are 10 'micro-movies' completely scripted, narrated and animated in very short days. The movie formats ranged from stop motion graphics, water colour illustrations, clay models and photo montages put together to produce a film.

Each film was presented to the jury composed of the founding members of Let's Talk About Water, speakers from UNESCO-IHE, Rijkswaterstraat and SMARTLAND- Intergrated Spatial Solutions for Sustainable Deltas. The movies were reviewed, appreciated and critiqued for their content and style of presentation.

An external panel of experts on cinema, visual learning, communication strategies and water governance is invited to reflect on the outcomes.
— Linda Lilienfield, Founder LTAW
— Jerome van Dam, LTAW
— Dr. Ir. Jeroen Rijke, Van Hall Larenstein University of Applied Science/ UNESCO-IHE ,Water Governance
— Dr. Loes Witteveen, Van Hall Larenstein/ Wageningen University, Visual Learning and Complex problems
— Jade Wising, Rijkswaterstaat / Communication strategy Room for the River

Screenings
Jeroen van Dam, the co-convener of LTAW and also one of the persons in charge of Filmhuis Lumen Delft was impressed by the outcome and proposed to screen all the movies as part of the Let's Talk About Water festival in an actual cinema hall. The screenings with an invited audience was conducted on Feb 18, 2017.

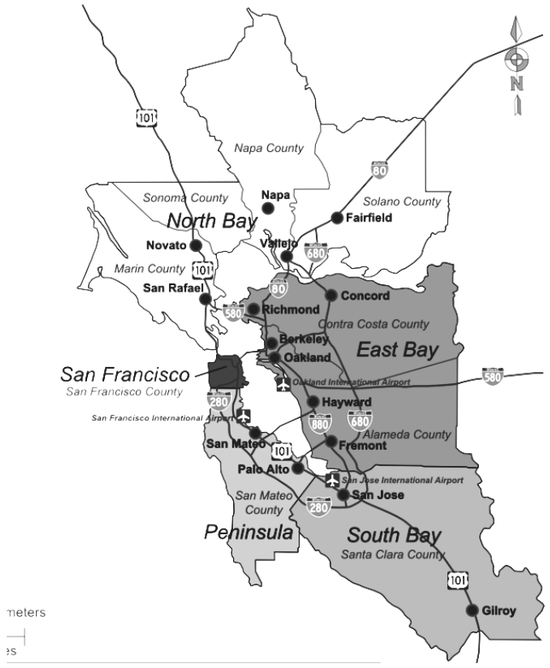


fig 150 *The San Francisco Bay and its counties , SWOT Analysis (By Author), Site Photographs (Sumanth Rao)*

APPENDIX IV: SITE VISIT LOG

Site Visit
The site visit was conducted as part of an extended excursion to San Francisco as collaboration between TU Delft's Department of Urbanism and the Masters of Urban Design Programme at the University of California, Berkeley. The trip involved excursions by bus to the North Bay and South Bay with several intervals along the way for observations and lectures by experts.

Seminar/ Discussion with experts
A seminar was organised in conjunction with UC Berkeley where an expert panel was invited consisting of crucial decision makers and stakeholders who shared their past and current research along with future projections for the region. The speakers included representatives from:

—University of California, Berkeley
—San Francisco Bay Conservation and Development Commission
—San Francisco Estuary Insitute
—Local design offices working on relevant projects in the Bay Area

Interviews
In addition to the formal seminar, interviews were also conducted with other insitutions such as Satnford University, Mumnicipality of East Palo Alto for further information about current projects and research.

Overview
SF Bay consistes of nine territorial counties / control units (NOT demographic units) across four directions:
EAST: Alameda, Contra Costa, (P) Port of Oakland is the largest seaport
NORTH: Marin, Napa, Solano, and Sonoma.(F) low density ,wealthy, undeveloped, no commuter rail service ,isolated, accessed by four bridges (Golden Gate Bridge leading to San Francisco, the Richmond-San Rafael and Carquinez Bridges leading to Richmond, and the Benicia-Martinez Bridge) (P) Residential, farmlands, vineyards,
PENINSULA: San Francisco, parts of San Mateo, Santa Clara
SOUTH: San Jose, Santa Clara, High tech suburbs/ Silicon Valley (P)High tech industries, automotive. Formerly agriculture, most millionaires

Observations: Land Use

— Most cities have their dumping sites near bays. Hence, landfills are also subsequently sited along the bay
— Tidal marshes visible along the bay. Water level fluctuates +/- 3 ft daily (high/low tide)
— Flatland that was oriented towards the bay used to build industries (most vulnerable land)
— Refineries cannot be raised to protect from rising water levels
— SF Bay Trail along the bay maintained as a regional park. SF Bay Ridge trail along the higher points of the bay being developed as a park (550 miles)
— Large gated communities act as water basins

Ownership and Revenue
— Federal government protects waterways and navigation
— Railroad companies in the US are privatised. The land is owned by the state but the utilities are not
— The Resilience by Design competition from the SF government will have one state in each county to cover the entire bay area
— Tax source >> impact/ used for
— Home ownership >> County
— Income tax >> State
— Industries >> City
— The city is autonomous. State cannot dictate terms or monitor decisions/ land use/ jurisdiction

Flood Risk
— UC Berkeley is simulating flood model for sea level rise of +0.4 / +1.0 / +1.5 m
— Berkeley model considers water from storm surge only (no fluvial. Pluvial flooding)
— Propagation v/s degradation
— Depositional v/s Dispersion
— Location of the coastline is permanently temporary
— San Francisco Government is designing to combat sea level rise of +3.0 m
— Western part of the Bay in greater danger than eastern (shallower) part of the bay
— San Francisco Bay Conservation and Development Commission oldest coastal zone management authority (jurisdiction 100 ft from high tide line)
— Part of the shoreline most resilient to sea level rise has no development at all

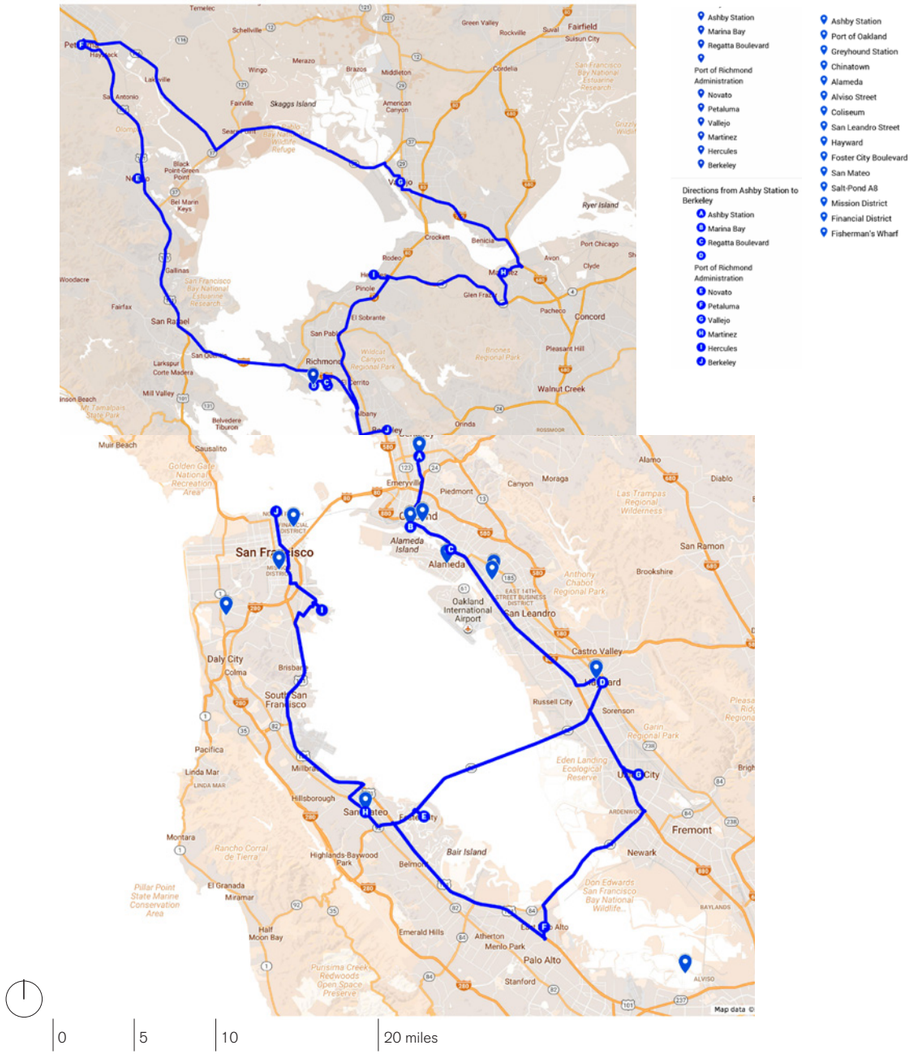


fig 152 Route of the site visit as plotted on Google Maps (maps.google.nl) (Graphics: Author)

fig 151 *Route of the site visit as plotted on Google Maps (maps.google.nl) (Graphics: Author)*

DAY 01
Starting point: Ashby BART Train Station (East side of the bay)
(1) Along the drive we pass Regatta Boulevard
(2)and Marina Bay County(3)

Ashby >> Richmond Harbour

STOP A: Richmond Port (4)
(P)INDUSTRIAL: Ford Assembly Plant
(P)INDUSTRIAL: Chevron Refineries across the Bay /Risk Substantial, embedded in the landscape (difficult to raise)
(P)RESIDENTIAL: Single family housing communities / low lying (population attracted to work at the harbour after World War 2)

>>Richmond >>San Rafael

Pass the Chevron Corporation Refineries. Tankers from Alaska unload Petroleum here
Piers sticking out: remnants of a ferry connection to Marin County across the bay before the bridge was built

>>Richmond /San Rafael Bridge (Pay Toll)

STOP B: San Rafael
(P)STATE UTILITY: San Quentin State Prison, San Rafael canal district residential
(P) Prominent: Autodesk, Marin Civic Centre, Sutter health care, George Lucas Studio (Star wars), Industries
(F)Bay marsh, Tidal Marsh, Larkspur: Low socio economic index, Industrial tax base
Social vulnerability (high % of hispanic, low income/property value)

San Rafael >> Novato
(P)rebuilt Passenger rail line extended to Santa Rosa, all grazing land
(F) Franciscan rock formation grey sandstone fracture due to seismic activity

STOP C: Petaluma river valley
(P)Agriculture, poultry (egg basket of the world)
(F)Eucalyptus trees used as wind breaks on slopes, non-native imported from Australia (solitary species, do not let other plants thrive, compete for water),
— low lying
— lot of scope for urbanisation and development, possible marketing as a 'canal city' due to open water streams, sewer system needs better organisation
— High navigation value, dredge value
— Contaminated sites along the bay
— Sewage treatment plant at a low lying spot
— Vineyards need water for irrigation
— Fertile soil, raodways need to be rethought
— San Pablo north: decommissioned military sites / dry docks

STOP D: Bridge over San Joaquim River
— Low lying delta
— Sedimentation regions
— Mouth of exchange of delta water
— Protected by tidal marshes
— Hercules: remediated land (previous explosive devices site)

DAY 02
STOP E: Oakland (Potential Competition site)
Bay Area Conservation and Development Corporation
(P)Port of Oakland (largest in Bay Area)
(F)Previously American shipping companies (State+Federal offices), Kaizer Shipyards+healthcare
— Old style Greyhound bus station
— Freeway built in 1970s
— BART : Undergound in Berkeley, Overground in Oakland
— LOFT Buildings (Commercial Buildings converted to residential by adding floors above)
— Inundation problem NOT severe

STOP F: Embarcadero Oakland, Oakland Chinatown
(P)Average Housing quality recently vacated plot
(F)Possibilities to create 'destinations' along the bay
— Landfill close to the bay. Land is capped by 5 ft filling
— Large Coliseum site to be reconfigured
— Oakland Airport built on landfill
— Lake Maritt part of the estuary
— San Leandro: Bedroom community
Alameda
— Largest watershed of the bay area
— 2 distributory channels
— Fair amount of discharge

STOP G : Alviso
High risk, bottom of the Bay
(F) Terrain Hills/ Marsh/ Water
(P) Light industries, Offices
(P) Edge: heavy industries, natural gas, Hayward recreation area

STOP H: Foster City
Low lying floodplain, lagoon living, boat houses, secured by series of levees

PASS BY: San Mateo
Wealthy county
(P) Close knit grid, fenced off plots
How the water connects to the sea must be rethought

STOP I : Hunters Point
Not much damage or risk
(P) Old shipping industry risk of being displaced, Real estate developer: Lennar

PASS BY : East Palo Alto
(P) Corporate Headquarters, Extended single family homes with upto 5 cars
{F)Low socio economic index of living populations
Big developers could likely take over to make room for employers displacing current population

STOP J: Financial District
(P) Densely structured prime office location, tourist and culture destination, high revenue generation
Piers with major recreational value projecting into the bay (will not sink in a 1.5m flood)

fig 153 *Simuation of an inundated Mission Bay District in the San Francisco Bay Area (Source: Google and http://drownyourtown.tumblr.com/tagged/san%20francisco)*

APPENDIX V : THEORY OF URBANISM ESSAY

The Anatomy of a Disaster

Analysing interdependencies of critical urban infrastructure networks in choreographing modern disasters

The planet of the 21st century survives under the veil of an impending disaster. Manifestations of climate change are becoming pronounced with increasing frequencies of acute disasters (floods, earthquakes) and chronically rising hazards (sea levels, global temperature). Hazards transform into disasters as a function of high vulnerability and lack of adaptation. Building resilience and improving recovery involve reinstating equilibrium by improving system performance but studies prove that investments in long-term risk mitigation are often few, poorly funded in comparison with post-disaster reconstruction (Fuente, World Bank).This indicates the general focus on reducing 'event risk' (probability) as opposed to 'outcome risk' (consequences). The lack of cohesiveness can be attributed to blind 'trust' on system security, fluctuating institutional terminology and uncertainty of event occurrence in one lifetime among other arguments.

While disasters in anthropogenic systems are considered a series of unfortunate coincidences, back casting the flow of a disaster illustrates how interdependencies in man-made systems aid in scaling up damages, decreasing recovery time and effort. Critical urban infrastructure (transport, water, power, communications) play a paramount role. While planning for resilience and adaptation are finding more listeners, the institutional frameworks essential to put the cogs into motion in a large way are still reluctant. Thus, dissecting the event chain of infrastructure behavior during and after a hazard is an essential exercise for informed decision making for resilience. Against the backdrop of a supporting theoretical framework, the paper analyses the causal event chains of three modern urban disasters. They analysis considers geographical context, 'cause and effect' relationships, primary and secondary disasters, complex adaptive systems (CAS), robustness, redundancies and cascading interdependencies. In doing so, it makes an argument for the shift in approach from a 'component' oriented to a 'system' oriented approach in planning for resilience and how that might be the sustainable way to inform urban contingency planning in the next decades.

Key words – critical infrastructure, climate change, risk reduction, urban planning, systems approach

1 Introduction

A United Nations prediction states that if current trends of development continue, the entire planet will be urbanized by the end of the 21st century. This prediction implies that effects of extreme events will have increasingly dramatic and intimate effects on the specific structure and dynamics of cities and urbanism (Juval Portugali 2012). Manifestations of climate change are intensifying with increasing frequencies of acute disasters (floods, earthquakes) and chronically rising hazards (sea levels, global temperature) (UNISDR, 2012).

Coping mechanisms for a disaster involve not only reinstating what has been damaged, but also coping with the associated socio-economic and environmental impact, thus building a resilient system. Catastrophe theory suggests that disasters may result from discontinuous transitions in response to gradual changes in parameters (climate change impacts, local disruptions). Hence, 'extreme events" can be a result of the way inherent system responds rather than unexpected external events (Helbing, 2013a). While planning for resilience and adaptation are finding more listeners, the institutional frameworks essential to put the cogs into motion are still reluctant. In order to critique this and veer towards better approaches, it is essential to understand the system, it variables, dependencies and associated perceptions.

2 Urban Networks

In an urban system, the flow of people inside a city depends the interactions between various networks including the electricity grid, railway network, roads, traffic lights, GPS systems and human control. The phenomenon can be extrapolated as a controlled system of input and outputs. Consider a chaos generated on a busy street due to a trigger extolling people to start escaping in different directions. If the people, who fall, do not manage to get back to their feet quickly, they are likely to get injured first, before causing others to trample over, thus increasing damage. This explains how one hazard can put the urban infrastructure system off equilibrium.

3 Global interconnectedness

Our society is entering a new era of 'globally networked society ('De Netwerkmaatschappi'j)' (Castells, 2011, Van Dijk, 2001), representing increasing interdependency, interconnectivity and complexity. A social media message on one side of the globe can cause an applause or unrest on the other side. Food and fuel shortages and rapid spread of diseases illustrate far-reaching impacts of network dependencies. The interconnectedness has scaled postitively across sectors for more accurate outputs like location data, brisk integration and response when public utilities data (eg water supply) is connected with emergency services data.

But this interconnectivity decreases the robustness of the system The chief reason as explained by (Pelzer and Hempel 2014) is that transfer of resources across physical spaces is related to communication of 'information' between organizations and individuals governing or using them .If this system falters, the entire system is at a risk of cascading to a collapse. This explains why networks have arrangements for redundancies, isolation and compartmentalization to protect them from indirect attacks.

As (systems) grow more interdependent, they become more vulnerable to large-scale cascading disruptions across sectorial boundaries (Amin 2002) characterized by nonlinear paths. Hence, traditional linear understanding of cascades may not yield effective resilience mechanisms. In 'Normal Accidents', organisational sociologist Charles Perrow explains that 'the "essence of the normal accident [is]: the interaction of multiple failures that are not in a direct operational sequence." (Perrow, 1984). In several cases the secondary disaster may cause more harm than the primary source of disturbance (Little 2002). In the Tohoku cascade of 2011 (as explained n fig 7.2.2), while the built environment was prepared to deal with the earthquake (primary cause), the loss of lives and property was much greater due to the nuclear meltdown (tertiary) that was caused by the tsunami (secondary) that followed the earthquake (primary).

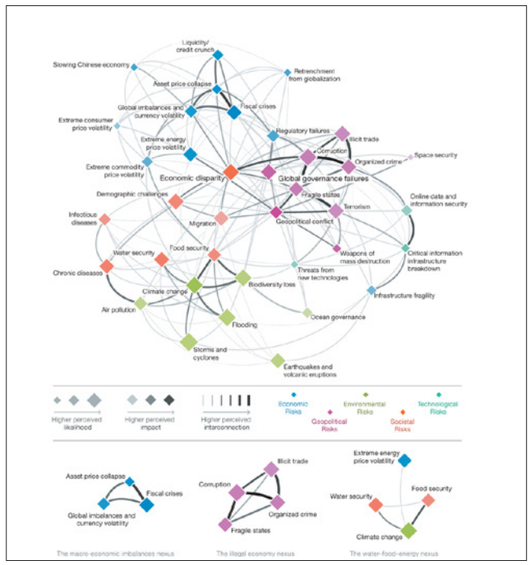


Fig 1: Risks Interconnection Map 2011 illustrating systemic interdependencies in the hyper-connected world we are living in (World Economic Forum 2015)

4 Risk and Disaster

In resilience planning, it is essential to understand the nature of risk and disasters. The United Nations Office for the Co-ordination of Humanitarian Affairs (UNOCHA 1992) defines disaster as "a serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of affected society to cope using only its own resources."

4.1 Risk

Scientifically, risk is defined as the product of 'event risk' (probability of a disaster occurrence) and 'outcome risk' (the ensuing damages) (Brooks, 2003). In global disaster mitigation practices, more attention and investment is focused more on reducing 'event risk' (reducing probability) than 'outcome risk' (reducing vulnerability) (Bank, 2003, Fuente, World Bank, Bank, 2013). If an urban infrastructure system can be analogised as a tree with several branches where each branch has its own characteristics, the potential of a branch to be affected by an event is directly related to its vulnerability. Hence, in an interconnected system, 'risk' is no longer just affected by the calamity, context or governance but it gets compounded due to interdependencies into a 'systemic risk 'and further to a 'hyper risk' (Helbing, 2013b).

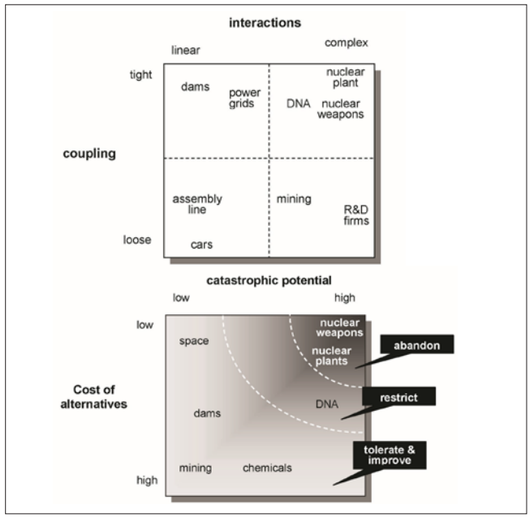


Fig 2: Perrow's taxonomy of system variables and policy (fig 3) recommendations (Perrow, 1984)

4.2 Characteristics of modern disasters

Based on literature studies, the following behaviour characterises disasters in modern society:

4.2.1 Not localised

Catastrophes in modern society tend to be less localized, with a significant impact on a larger hazard zone. In the case of Hurricane Katrina, the storm's entry point at the Gulf coast is significant because of the fact that nearly half of the gasoline consumed in the U.S. passes through refineries that were affected by the storm. The international impact was felt throughout the energy sector as oil prices escalated due to destroyed refineries (Elmerraji, 2016).

4.2.1 Highly interconnected

The effects of the Tohoku Tsunami and Indian Ocean Tsunami were felt across several countries. At the largest scale so far, floods in Thailand in 2010 led to a worldwide shortage

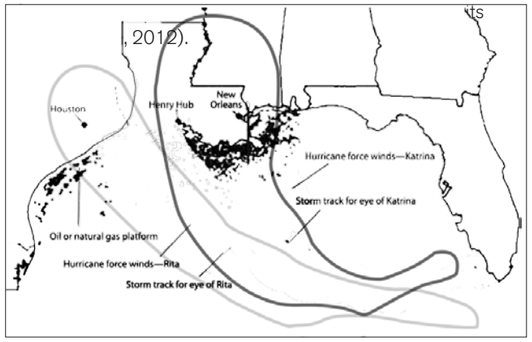


fig 3 : Path of the Hurricane Katrina (Wilbanks, 2012)

4.2.2 Scale Effects

The power outage in Italy (2003) illustrates scale effects in critical infrastructure cascades. A short circuit caused by a branch of a tree on one transmission line led to a series of blackouts on the Swiss–Italian border affecting 56 million people through disrupted trains, civil aviation and food networks. Cascades were being transmitted to each other through the nodes of contact in the power and communication system (Buldyrev, 2010).

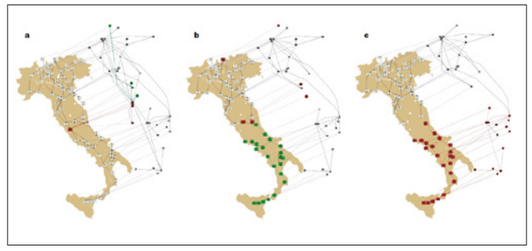


Fig 4: Illustration of an iterative process of a cascade of failures using real-world data from a power network (located on the map of Italy) and an Internet network (shifted above the map) that were implicated in an electrical blackout that occurred in Italy in September 2003 (Helbing, 2013b, Helbing, 2013a)

5 Critical Infrastructure

Infrastructure is defined as "a network of independent, mostly privately-owned, man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services" (President's Commission on Critical Infrastructure Protection -www.ciao.gov). This includes transport, power supply, fuel, water supply, wastewater treatment, telecommunication networks among other 'lifelines' that support city functions. Disruption of any one can disturb the balance of the urban ecosystem. Studies dating back as far as 1982 (Lovins and Lovins, Brittle Power) have, however, pointed to the vulnerability of large, complex infrastructures to large-scale failures, and this underlying concern has grown in recent years (Villasenor, 2011)

Resilience of the physical infrastructure is critical for both biophysical and social recovery. The impact of critical infrastructure has two aspects:

5.1 The physical (structural) network

Besides loss of life, infrastructure destruction is an obvious damage when we think about natural disasters. The economic consequences are rarely considered beyond the rebuilding cost, since a lot of current infrastructure are not designed to withstand (external) hydrostatic load (Elmerraji, 2016) . In a climate catastrophe, the resources for rebuilding also get scarce due to loss of critical networks, inactive working population and general decay of market value making recovery more difficult.

5.2 The service (non-structural) network

Movement is essential for recovering an ecosystem back to normalcy. The 'outcome risk' is manifested more when networks fail and hamper this movement of people, vehicles, supplies and water. It is perhaps safe to say that the recovery period after a crisis is inversely proportional to the redundancy of critical infrastructure networks that keep 'movement' alive

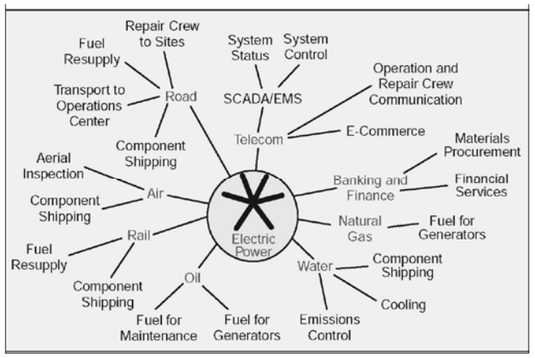


Fig 5: example of electric power infrastructure dependencies (Steven M. Rinaldi, 2001)

5.4 Causal Chains

"Cities are no longer regarded as being disordered systems. Beneath the apparent chaos and diversity of physical form, there is strong order and a pattern that emerges from the myriad of decisions and processes required for a city to develop and expand physically." (Batty, Science 8 February 2008:Vol. 319. no. 5864). Analysing interdependencies between networks and their impacts on space could reveal underlying behavioural patterns to generate an inventory that can inform better optimised decicions for contingency plans. In conclusion, it becomes important to 'backcast' the behaviour of infrastructure to construct the causal chain of events and understand how a system can be pieced back together. In order to understand the causal chain of a hazard (the path of a cascade), three contributing factors must be taken into account: the interactions in the system, the context (such as institutional or boundary conditions), and a triggering event (Helbing 2013, p.54).

6 Characterizing causes of disruptions

6.1 Critical Infrastructures as Complex Adaptive Systems (CAS)

According to (Steven M. Rinaldi, 2001), critical infrastructures are characterized as 'Complex Adaptive Systems' (CAS). The various components function as agents that interact according to their location in geographical space, capabilities (eg. pumping capacity) and memory (as result of experiences such as degradation by overuse). If networks…are connected at one or more points, disturbances in one network affect the networks connected to it. This phenomenon is called a cascade. FEMA's (Federal Emergency Management Agency) Facilitator Guide (2011) describes" cascading" as a general dynamic that may multiply the effects of a combination of different hazards, such as an earthquake that produces a breakdown in infrastructure, whose failure contaminates water and causes disease to spread, which disrupts the local economy.

Luiijf et al. (2009) analysed a data set of 1749 critical infrastructure failures in 29 European nations (most disasters timed after the year 2000), where the authors found that cascades were fairly common .The energy sector accounts for 60% of all cascades followed by telecommunication (28%), transportation (5%) and water (3%). Faltering energy supply generates consequences for irreplaceable services such as telecommunications, fuel, water that spiral to reinforce damages, thus increasing recovery effort.

6.2 Interdependency

The extent to which a system can be affected is determined by 'coupling' (how strongly are they dependent, tightly or loosely) and 'interdependency' (what all are they impacted by) between the two. Owing to this coupling, interdependent networks are extremely sensitive to random failure, such that a random removal of a small fraction of nodes from one network can produce an iterative cascade of failures in several interdependent networks (Buldyrev, 2010).

For examples, in a bidirectional interdependency both systems depend on each other and the failure of one will lead to the failure of both. For example, faltering supply of natural gas may impact the functioning of a power plant which may in turn hamper the functioning of the natural gas extraction. From various studies it can be observed that, interdependencies could be physical, logistical, cyber, geographical, institutional, temporal or operational.

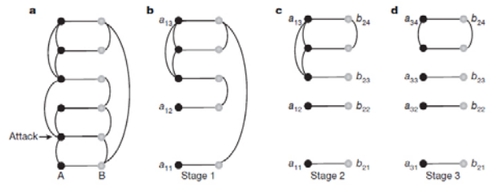


Fig 6: Modeling an iterative process of a cascade of failures in an interconnected system (Buldyrev, 2010).

7 Modelling and Simulation

A perfect model of risk would identify the likelihood of all possible hazardous events, map out what would be exposed to risk for each of those events; and quantify the extent to which those people and infrastructure would be harmed (2015). 'Causal loops' (fig 8) and 'network analysis' are conventionally employed for enumerating these flows and impacts manually. The same flow can be simulated digitally for more complex models. The traditional approach to risk management also simulates future risk (eg extent of inundation) followed by strategies to 'protect' the landscape against it. With more sophisticated softwares, modelling and simulation (M&S) of individual networks has seen excellent advancement (K. Peters, 2008, Rosato, 2008, Cutter, 2010). Simulations process large amounts of data to generate results .

The increasing availability of 'big data' has raised the expectation that we could make the world more predictable and controllable. Current modeling softwares that can model multiple interdependencies include 'aggregate supply and demand tools, dynamic simulation, agent based models, physics based models, population mobility models and Leontief input-output model.'

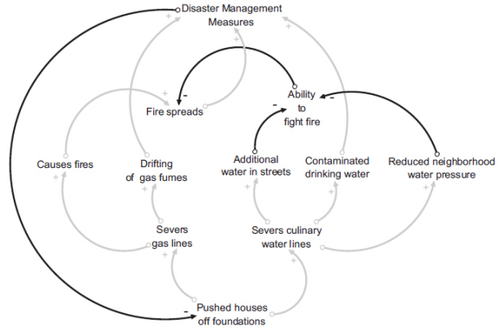


Fig 8:' Causal Loop Diagram ' F.May, Cascading disaster models in post burn flash flood, in:Butler,W.Bret, Cook,Wayne(Eds.),The Fire Environment Innovations,Management,and Policy ,Conference Proceedings,U.S Department of Agriculture,Forest Service, Rocky Mountain Research Station,

7.1 The problems of modeling risk

Indeed, processing volumes of data and real-time management may overcome instabilities and time in processing information manually. The FuturICT community (http://www.futurict.eu) is also working towards a Global Systems Science to make the theory of complex systems applicable to the solution of global-scale problems. It will take a data-driven approach to collaborate between the natural, engineering and social sciences…to enable response strategies for risk mitigation among other domains (Helbing, 2013b). This is perhaps at the forefront of risk management today, but comes with its perils. Projected failures can include risk of system failure, lack of data, small errors cascading to wrong assumptions, changing dynamics, security concerns, degree of fidelity of data, classes of data and more importantly the system's lack of ability to keep up with dynamic inputs from several interconnected sectors.

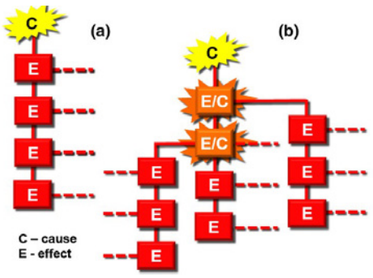


Fig. 7: Visual representation of cascading disasters (Pescaroli and Alexander 2015): a linear path of events in disasters and b nonlinear path of cascading, including amplification and subsidiary events (K. Peters, 2008)

7.2 Cascade Plotting

Inspired by 'causal loop diagrams' , the following is a series of studies in analysing three disasters and their paths of cascades. The primary, secondary and tertiary (if applicable) disasters are analysed for their implications on human life and economy .Th focus is on the behaviour of critical infrastructure networks (transportation, water, energy) and have been plotted to visualise the pattern of a disaster flow. The disasters were curated based on the differences in geography, cause of the disaster, relevance of 'cascade' effect in larger disruptions. The source of damages and the point of amplification of damages have been assessed through the documentation referred to for the analysis. In all three examples transportation, water and communications, in addition to fuel supplies played a crucial role in amplifying damage and recovery efforts (money, time and human resources)

Diagrams built with inputs from (Wilbanks, 2012, Marvin Phaup 2010, Chatterjee, 2011) , D'Ercole and Metzger (2009, (Dirk Helbing, 2012) (Helbing, 2013a), D'Ercole and Metzger, (2009,CBS News articles, CNN,OECD, The Guardian, Japan Times 2011 ,wikipedia, FEMA's Facilitator Guide 2011, http://www.slideshare.net/Ruth1618/tohoku-earthquake-case-study, http://exploregeography.net/case-study-the-tohoku-tsunami-japan-2011/, http://joeblakey.com/geography/case-study-japan-earthquake-tsunami-110311/

7.2.1 Hurricane Katrina

Hurricane Katrina illustrates the case of a primary hazard (hurricane) cascading to several secondary and tertiary hazard that are diffused through a larger span of time. These include power outages, damages to oil grids and petroleum hubs, fires, loss of production, damaged houses, displaced population that conclude into severe disruption of human life and damages to physical and economic infrastructure. Rising global oil prices and shut down of the New York stock exchange are the crucial economic terminal nodes of the cascade.

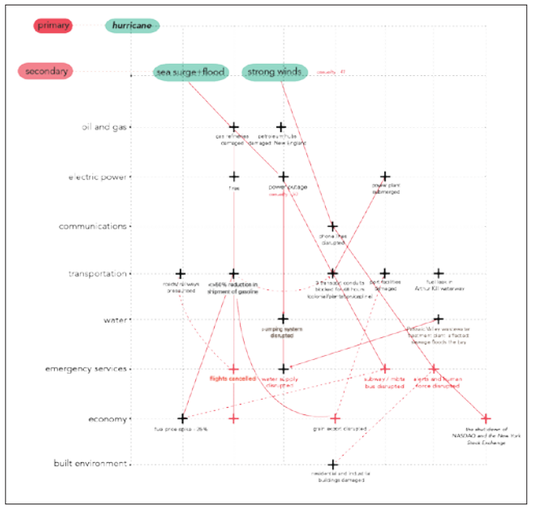


fig 7.2.1: Causal Cascade diagram: Hurricane Katrina 2005 (made by author)

7.2.2 The Tohoku Earthquake of 2011

The Tohoku Earthquake of 2011 shows how impacts of a secondary and tertiary disasters are each more complex to respond to than the previous. The primary trigger ,the earthquake, was an 'expected' disaster which the populations and authorities were equipped to deal with through planned long term mitigation and evacuation measures. Th ensuing tsunami took 1500 times of the lives claimed by the earthquake in addition to severe damages to critical infrastructure and the economy. The terminal node 'radioactive contamination' caused the largest disaster based mass migration and stirred a raging global debate against nuclear power.

7.2.3 Volcanic eruption in Iceland (2010)

The eruption of the Icelandic volcano Eyjafjallajokull is the case in which the primary trigger affected a functioning global network. Paralysing critical civial aviation even for a week cascaded to disrupted logistics, fuel supply and disrupted social/ business events that cascaded to irreversible economic losses.

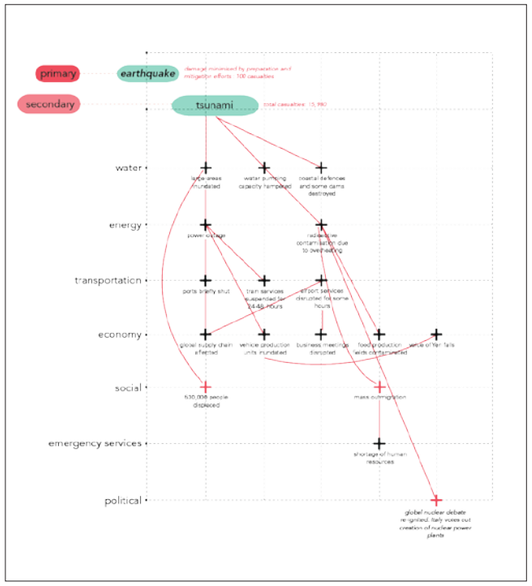


fig 7.2.2: Causal Cascade diagram: Tohoku Cascade 2011 (made by author)

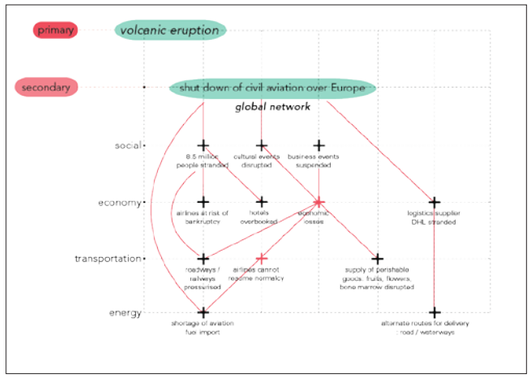


Fig 7.2.3 : Causal Cascade diagram: Hurricane Katrina 2005 (made by author)

8 Reasons for lack of integrated approaches in risk reduction strategies

8.1 Uncertainty: Systems involving uncertainty, where the probability of particular events cannot be specified, are probably the least understood. Hence, most risk mitigation strategies, even the empirical kinds, remain qualitative.

8.2 Means-end: Physically, cities are stocks of buildings linked by space and infrastructure. In effect, they are means-ends systems in which the means are physical and the ends functional (Hillier, 2007). The current focus on improving resilience of the 'end- components' as opposed to the 'means – networks' is an important indicator of the essential shift required in planning for risk reduction. That is focus on the systems of movement.

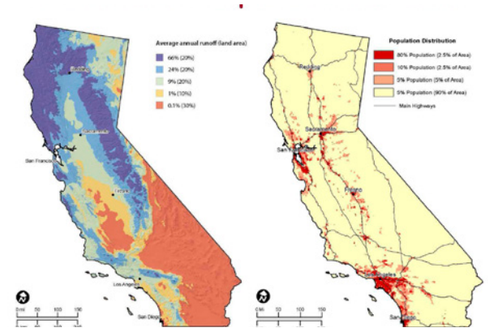


Fig 9: In California, says engineer Mr Lund, "all of our water is in the north, in the mountains, in the winter, and where we want the water is in the south, in the summer. This is a system made for engineers. "The south, where most of the population is concentrated barely produces any water (California Water Policy Seminar Series: Jay Lund: Insurmountable Opportunities:www.mavensnotebook.com).

8.3 Larger geographical system sizes: Water, power and data are often delivered from outer limits of the political region (eg San Francisco receives it supply from the Hetchy Hetchy reservoir way beyond city limits). Hence a fault in the system up north could potentially and majorly impact supply in the south for no fault of maintenance or administration of authorities in the south.

8.4 Reduced redundancies (Maximization over Optimization): Most systems are designed for maximizing output with minimized safety margins as opposed to optimization for robustness. This 'just-in-time1' economic ideology keeps systems functioning at 'tipping points' ready to crumble at a nudge. This is the result of a good theory taken too far such that it is not sustainable anymore. Systems maintenance also prioritizes reassurance of output efficiency as opposed to external vulnerability to the system.

8.5 Innovation: The high pace of innovation especially where most innovations are related to increased data dependencies over denser, more interdependent networks produce latent uncertainties that are usually not predictable.

8.6 Security Assurance: The security of critical systems is generally taken for granted until after a disaster strikes. Citizens place blind faith on the state to uninterrupted and safe supplies.

8.7 Governance: Governments, donors and development agencies have acknowledged the need to shift gears in disaster management planning and finance from relief and response towards prevention (UNISDR, 2005). But any political decision has to bargain investments based on return value which is hard to fathom for mostly unpredictable climate occurrences.

8.8 Institutional Grammar: In the debate to find a common ground between 'risk reduction' and 'urban development' , the historical separation results in different working priorities, concepts and terminologies that further foster the gulf between different professionals (Wamsler, 2006). The interviews and literature, such as Bull-Kamanga et al. (2003), reveal that development people focus more on life, health or livelihood threatening everyday hazards, while disaster people look at life threatening situations of occasional large-scale disasters. Furthermore, disaster people use concepts and terms like 'risk', 'mitigation', 'preparedness' and 'prevention', whereas development people tend to employ terminology like 'security' and 'security measures'. (Geis 2000) argued that the term disaster resistant is both more fitting and more marketable than disaster resilient.

8.9 Investment: The incoherent institutional grammar has also aided imbalanced resource allocation for disaster management that focuses on repairing post disaster rehabilitation as opposed to reducing the damage through better urban development strategies (Fuente, World Bank).

9 Possible Solutions and obstacles

Resilience is defined as the capacity to anticipate, prepare for, respond to, and recover from significant disruptions (Wilbanks, 2012). Numerous factors contribute to a system's adaptability, including availability and number of substitutes…workarounds and contingency plans, backup systems, training and educational programs for operational personnel and even human ingenuity in the face of disaster.(Steven M. Rinaldi 2001).

Conventional thinking will lead to repetition of mistakes. This calls for a paradigm shift in thinking. Systemic instabilities can be understood by a change in perspective from a component-oriented to an interaction- and network-oriented view.(Helbing, 2013b) . A systems approach can be adopted by observing behavioral changes at the level of the landscape. Hence, it is essential to find common space in the intersection of 'urban planning with 'risk reduction'.

In a paper by (Wamsler, 2006) that argues for the cause of 'Mainstreaming risk reduction in urban planning', some interviewees suggested that the easiest way to integrate risk reduction and urban planning is 'to wait for the next earthquake, let the city fall down and start again' (Maskrey, UNDP–BCPR Ironically, the Global Risks Perception Survey by the World Economic forum also ranks 'failure of urban planning' as having the least impact in the global risk landscape (WEF, 2016). Perceptions such as these on global platforms are important indicators to critically analyse the reasons that encourage current attitudes. While adaptive, resilient systems are ambitions of future cities, there needs to be a fundamental shift in the approach to envision integrated growth patterns.

\

10 Approaches

While this process appears to argue for physical and organizational elements in the landscape, the bottom line is that these are all systems in space. The functional aspects must interact with the other equally important drivers such as the environment, socio-economic demographics and politics. New development models may be envisioned utilising the following concepts:

(1) Adopt a systems approach to understand macro behaviour. Re-territorialise political boundaries for landscape level assessment. Studies indicate that climate risk related impact can be tackled better and are more viable on a regional scale.

(2) Establish a uniform grammar to explain infrastructure dependencies and risk More coherent models will attract better investment of time and money

(3) Planning for resilience requires scientific autonomy like 'national security'. It needs to be directly under the head of the state. Focus on incremental development that fits within a political term, but is part of a longer undisputable national agenda.

(4) Maintain a 'clean energy' contingency as a backup: The occurrence of a calamity is followed by practical issues like rolling power blackouts and serious water contaminations. Solar powered lights, potable water filters are currently utilized. None of Japan›s commercial wind turbines (including the Kamisu offshore wind farm directly hit by the tsunami), totalling over 2300 MW…, failed as a result of the Tohoku Cascade 2011, (Pescaroli Gianluca, 2015). A 'non-networked' way of problem solving must be deployed at larger, more integrated scales for reducing risks.

(5) Evaluate the contingency plans for interscalar, temporal development. Reprogramming the landscape compositions and land use. It is essential to understand layers of interdependencies at a macro scale and its impact on a micro scale to generate possible outcomes that can inform better regional strategies for risk reduction.

11 Conclusions

Urban planning is a complex game given the diverse parameters and unforeseen outcomes. Making decisions in complex systems for something one may never see in a lifetime involve both the acumen and technical support to foresee uncertainties. As Charles Perrow mentions 'normal accidents are an inherent property of complex systems. This means that engineers, operations process designers, human factors and the like are completely helpless in preventing normal accidents.' Understanding system behavior and 'knowing' ways in which things could go wrong is perhaps one way of preparing for the future as opposed to being taken unaware (Perrow, 1984). (Pescaroli Gianluca, 2015) suggests that interdependencies, vulnerability, amplification, secondary disasters and critical infrastructure are important factors that need to be addressed in risk reduction practices in order to limit cascading during disasters.

might be the sustainable way to inform urban contingency planning in the next decades. Behavioral models, reinforcement plans and multifunctional design strategies around critical urban infrastructure systems are perhaps an impactful strategy in dealing with dynamic changes in the built environment in the next century.

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1 Just in time: When first developed in Japan in the 1970s, the idea of just-in-time (JIT) marked a radical new approach to the manufacturing process. It cut waste by supplying parts only as and when the process required them. The old system became known (by contrast) as just-in-case; inventory was held for every possible eventuality, just in case it came about. JIT eliminated the need for each stage in the production process to hold buffer stocks, which resulted in huge savings (http://www.economist.com/node/13976392)

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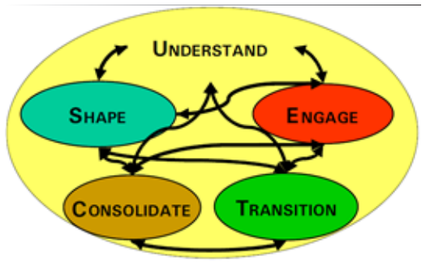

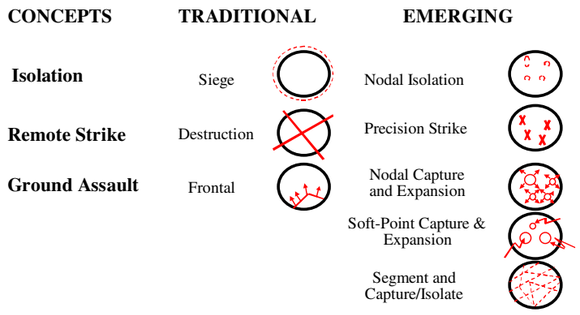

fig 154 *The USECT Construct , Some Types of Operational Concepts: Capture the Urban Area*

APPENDIX VI : RISK ASSESSMENT FRAMEWORK CASE

An additional study that contributed to understanding risk impact in urban space was the Military assessment - NATO Urban Operations 2020 (NORTH ATLANTIC TREATY ORGANISATION / RTO Studies 2003). As a thesis that is utilizing 'recovery' and 'failure' as learning processes for resilience planning, the NATO reports provides an essential insight to understanding how a military strategy is utilized to safeguard or capture an urban territory from the enemy.

— The report focuses on the USECT approach that is utilized to maneouver into urban space to combat disruption, protect critical services, set up emergency evacuation measures
— In conclusion, the report highlights the importance of critical segments (roads), isolation techniques and the importance of nodes in the operational phase to 'paralyse' a city.
—
It outlines the centres of
gravity and identification of his decisive points of a city system for successful emergency operations
— Isolation is aimed at denying an opponent any advantages of occupying the urban area. Dependent upon the level of the operation this can include isolating him physically, politically, electronically or psychologically.
—
Nodal Isolation is an emerging concept that denies an occupying force access to, or use of, critical facilities within the urban areas. Elements of this approach may include: information operations to control facilities such as power stations, or communication networks; the creation of "keep-out" zones using remote surveillance, remote generation of precision, non-lethal effects, or deployed robotic sentries; or the similar control of transportation routes and facilities. Again, the idea is to deny the utility of the urban area to an opponent's forces with a minimum of civilian casualties or collateral damage.
— Segments that are critical to the opponent may then become the focal points of subsequent military action while sparing less critical areas.

The USECT Construct

Understand:
— The requirement to understand the battle space includes evaluation of physical terrain, buildings, cultural centres and critical infrastructure such as utilities, transportation systems and hospitals.
— evaluate all relevant forces, groupings, cultural and religious factors and to identify critical nodal points in the urban area not all of which are physical.

Shape:
— The term 'Shaping' includes all actions taken to set favourable conditions for the subsequent phases of Engagement, Consolidation and Transition activities. One aspect of Shaping is the strategic movement of forces into theatre and their positioning forces for operations.
— Shaping also includes actions to maximise mobility, force protection and establishing air and maritime superiority. At the same time, establishing refugee camps or sanctuaries for non-combatants, providing safe passage for them, and arranging emergency services, which as shaping activities at the highest level may be the early focus of tactical military activity.
Shaping will involve activity to isolate portions of the battle space. Isolation has both an external aspect (i.e. of cutting off outside support), and an internal aspect (i.e. of cutting off mutual support). Isolating the adversary may also preclude his withdrawal. The physical isolation of a large urban area could have serious implications for the identification and control of the movement of personnel, equipment and non-combatants.
At the operational level, shaping a campaign often requires the seizure, disruption, control or destruction of critical nodes (power grids, communication centres, etc) which have been previously identified during the IPB process in line with the requirements of International law. This may involve controlling key terrain, critical infrastructure and cultural centres unhinging an adversary's decision cycle process, cutting or controlling inter-city and intra-city mobility links and communications, deliberately triggering an adversarial response or positioning forces to accomplish yet further phases of the operation.

Engage:
— Engagement can range from large-scale combat operations in war to humanitarian assistance and disaster relief in military operations other than war. In all cases where an enemy is confronted, recognition of his centres of gravity and identification of his decisive points will be critical to the success of one's own operations.

Consolidate:
— The focus of consolidation is on protecting what has been gained and retaining the initiative to continue to disorganize the adversary. Civil affairs, public affairs and

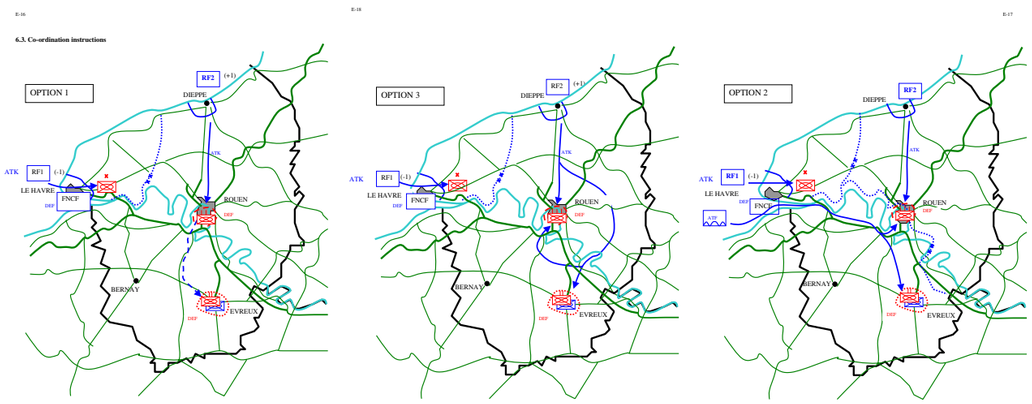

fig 155 The USECT Construct , Co-ordination instructions: Scenarios

Consolidate:

— The focus of consolidation is on protecting what has been gained and retaining the initiative to continue to disorganize the adversary. Civil affairs, public affairs and psychological operations activities will continue to be especially critical in this phase of the operation, as will engineering efforts which could range from demolition, repairs, clearing routes, bridge construction and water supply.

Transition:

— The strategic objective for a military commander in urban areas is to transfer control of the urban area to the local civilian authorities or perhaps an international organisation. The resettlement of displaced civilians and the reconstitution of national military forces if appropriate are central to a transition process.

The aim of the manoeuvrist approach to operations in urban areas, as described in this Chapter, is to achieve objectives with fewer casualties, less collateral damage to urban infrastructure, and reduced harm to the noncombatant population.

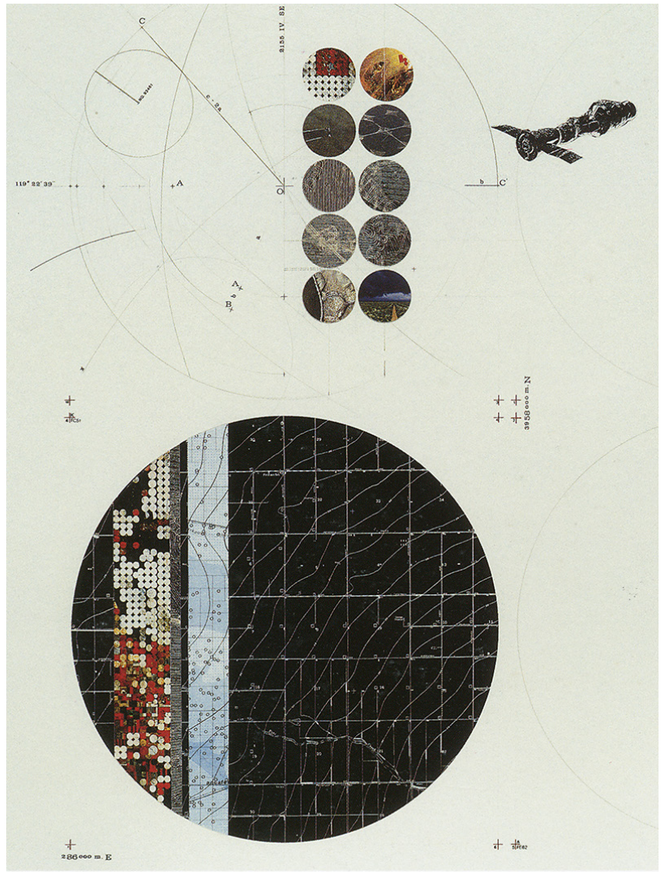

fig 156 *James Corner, Hoover Dam and the Colorado River, Nevada, map-drawing from Taking Measures Across the American Landscape, 1996.*

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6The study differentiates between people working in the field of development ('development people') and those employed in the area of disasters ('disaster people').9 Urban specialists form part of the group of development people, and in turn, urban planners make up part of the group of urban specialists

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