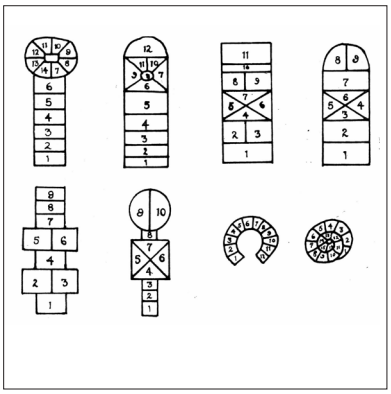

THE MIDDLE GROUND

Planning Landscapes of Uncertainty

P4 Reflection Report

AR3U100 Graduation LAB: Urban Transformations & Sustainability

(2016-2017 Q1)

Part of the P4 Graduation report
Supriya Krishnan (4479572)

May 2017

Graduation Studio Delta Interventions
Department of Urbanism
TU Delft, Faculty of Architecture and the Built Environment

fig 1: 'Submerged Potraits' (Source: http://gideonmendel.com/submerged-portraits/)

THE MIDDLE GROUND

Planning Landscapes of Uncertainty

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

P4 Reflection Report
AR3U100 Graduation LAB: Urban Transformations & Sustainability
(2016-2017 Q1)

Student number: 4479572

Graduation Studio 2016-2017
San Francisco Bay -Resilience by Design / Designing for uncertain delta-landscape futures

TU Delft/ Faculty of Architecture/ Department of Urbanism / Research Group Delta Urbanism

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Cover photo : Playing hopscotch (Source: http://www.amazeingacres.org/hopscotch.html)

D-i TU Delft

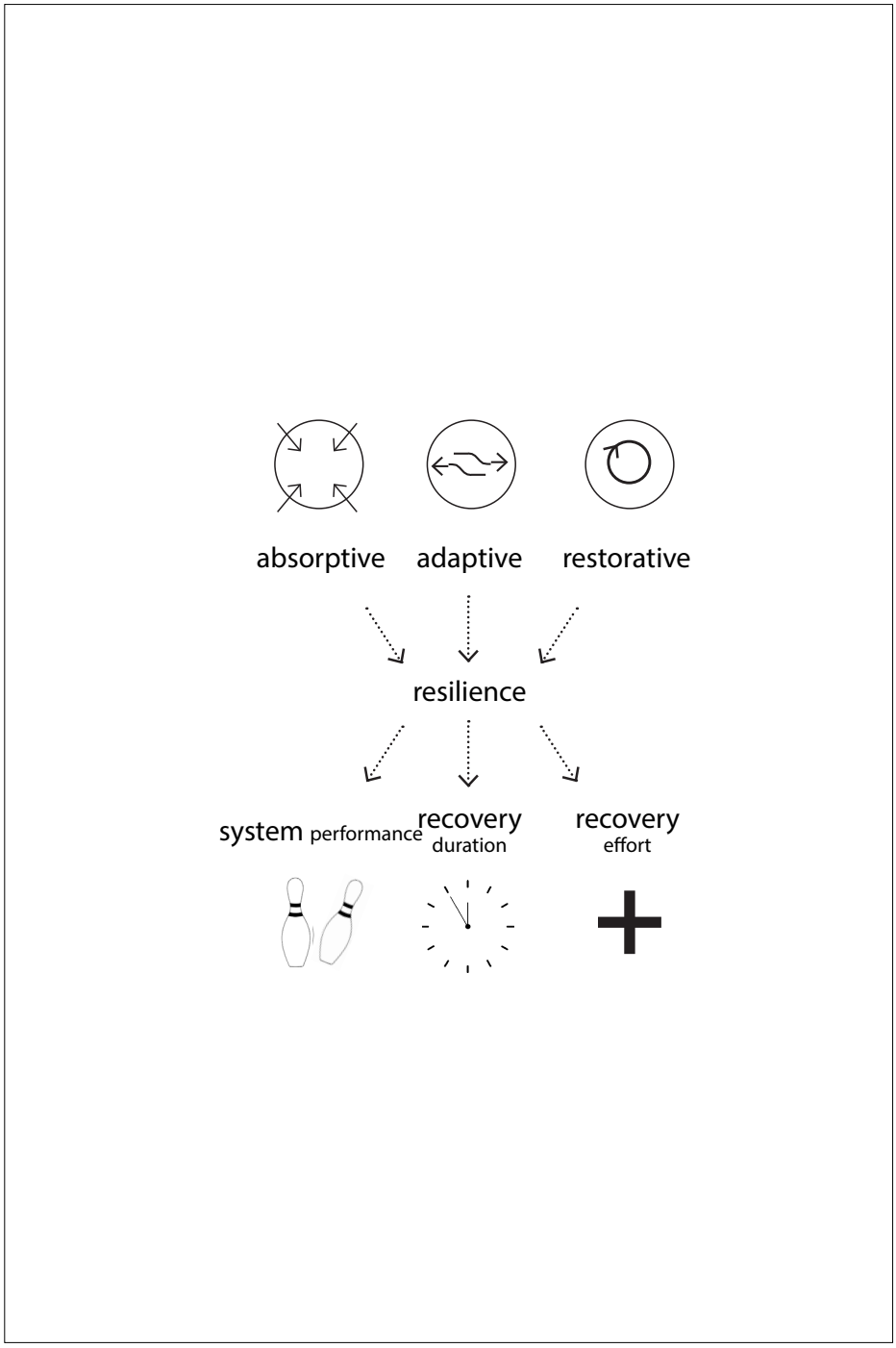


fig 2: Conceptual illustration of a resilience assessment framework (content from: Climate Change and Infrastructure (Wilbanks))

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.

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.
'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 3: The position of urbanism in planning for uncertainties (Source: Author)

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)

The role of urbanism

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).

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*** 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*** to include urban network vulnerabilities ,flexibility and accessibility during crisis
8. Produce a ***transferable spatial risk assessment framework*** that can be used in the context of the San Francisco Bay Area and to other geographies with relevant modifications 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.

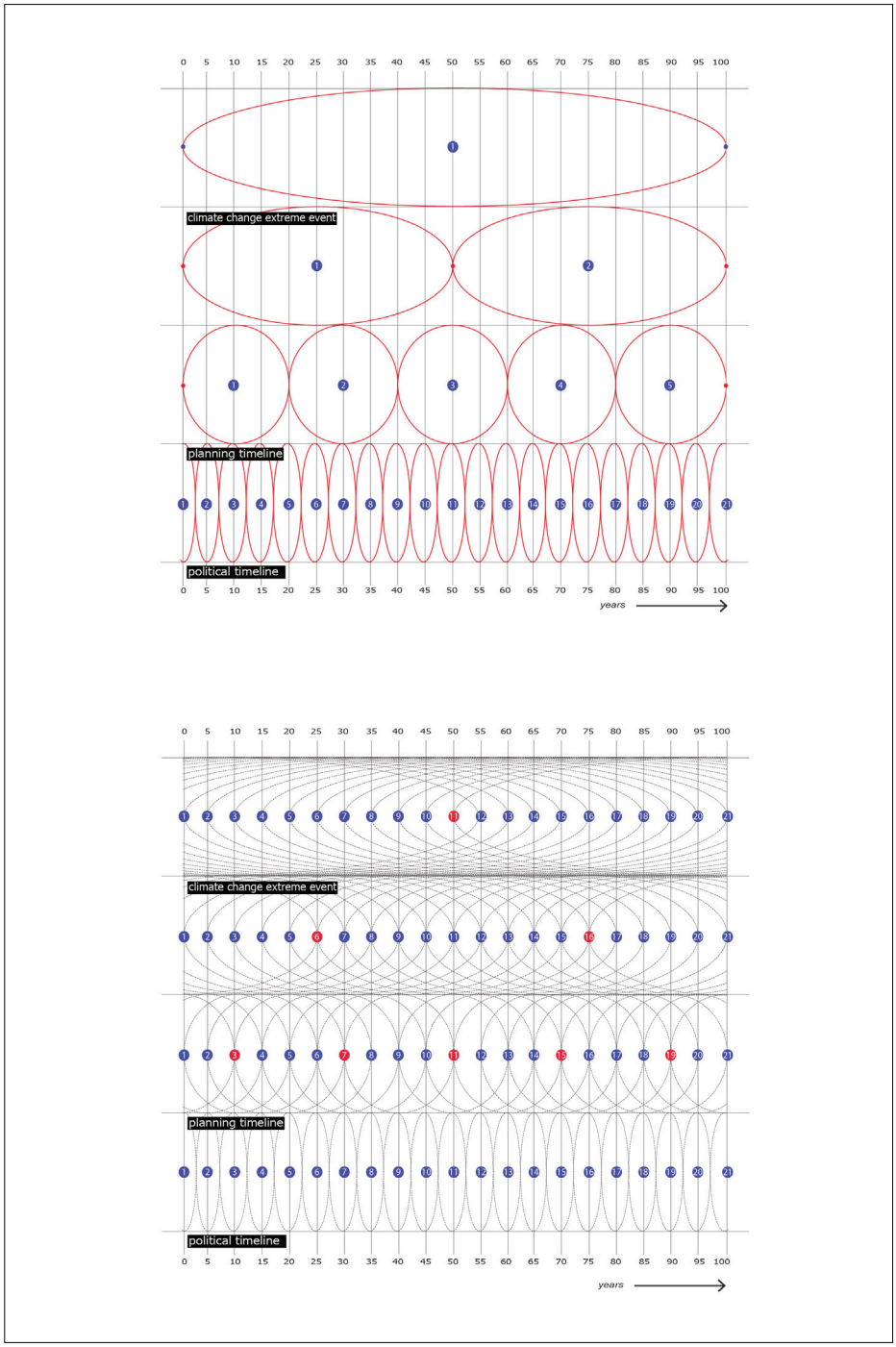


fig 4: 'typical timelines: Climate change manifestation v/s urban planning v/s political term. Each circle indicated possibilities of probabilistic design scenarios

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.

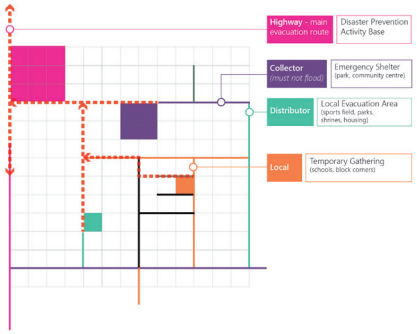


fig 5: Public space evacuation hierarchy related to road hierarchy (inspired from evacuation system of Tokyo metropolis) (Source: Author)

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.

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.

Lessons learnt

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

The 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

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-Understanding System variables (transport, energy, water)	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-Understanding Spatial variables	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
10	A	MESO	-mapping the 'Disruptive variables' from the 'Risk Assessment Framework'	ArcMap data+ Adobe suite	-finding deviations in the growth system to generate alternative ways of growing

RESEARCH-ANALYSIS-DESIGN DERIVATIONS

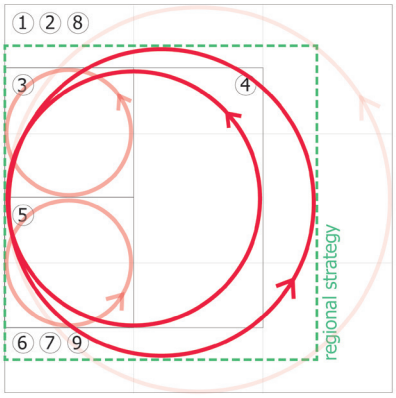
The analysis and strategy making process of the thesis is guided by design thinking style of urbanism that synthesis learnings from different domains. Three main scales - macro, meso and micro were the frames for analysis and design iterations. As an analysis that attempted to understand the behaviour 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.



(What + How = Outcome)

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

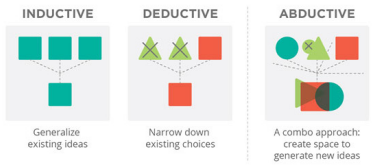


fig 6&7: Cycles of research and design with different ways of reasoning (Source: Author)

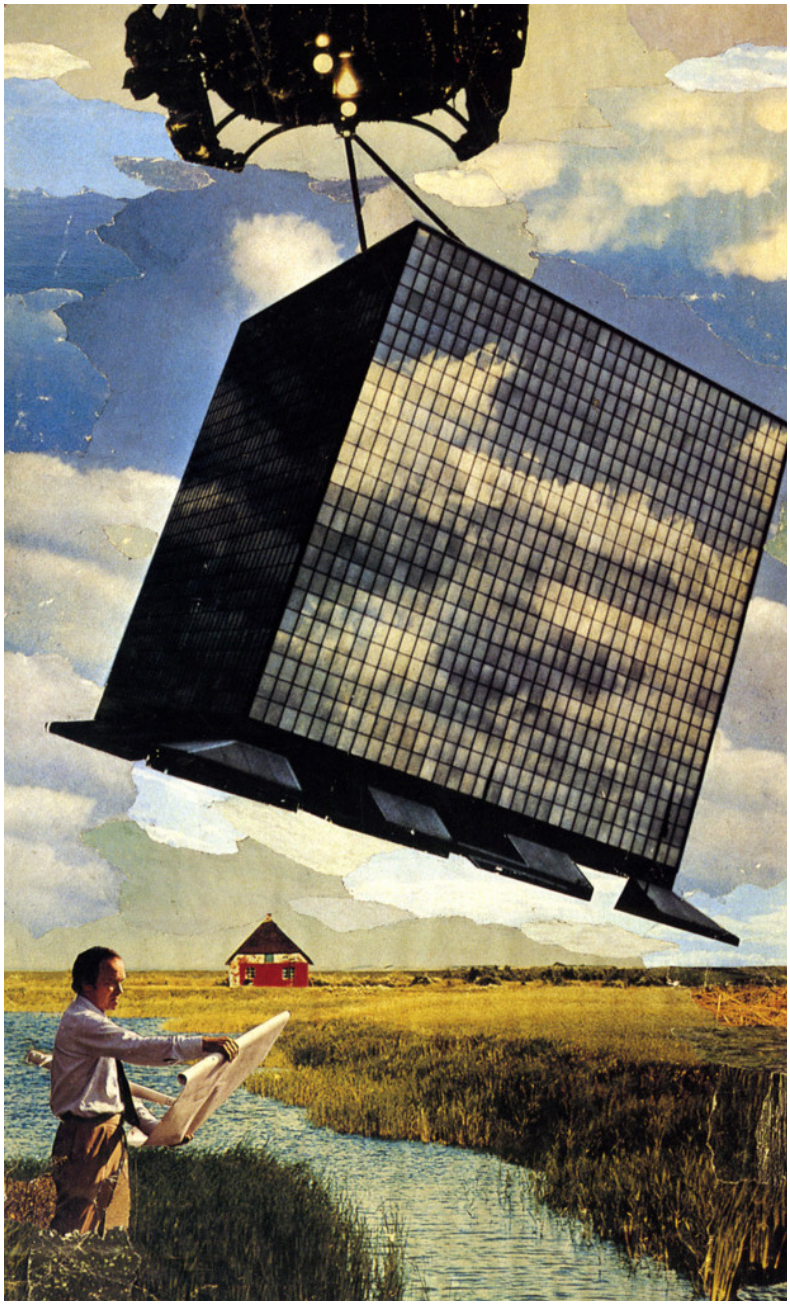


fig 8: First the building then the site
Nils-Ole Lund, 1982

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.

_lack of a concrete concept model

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.

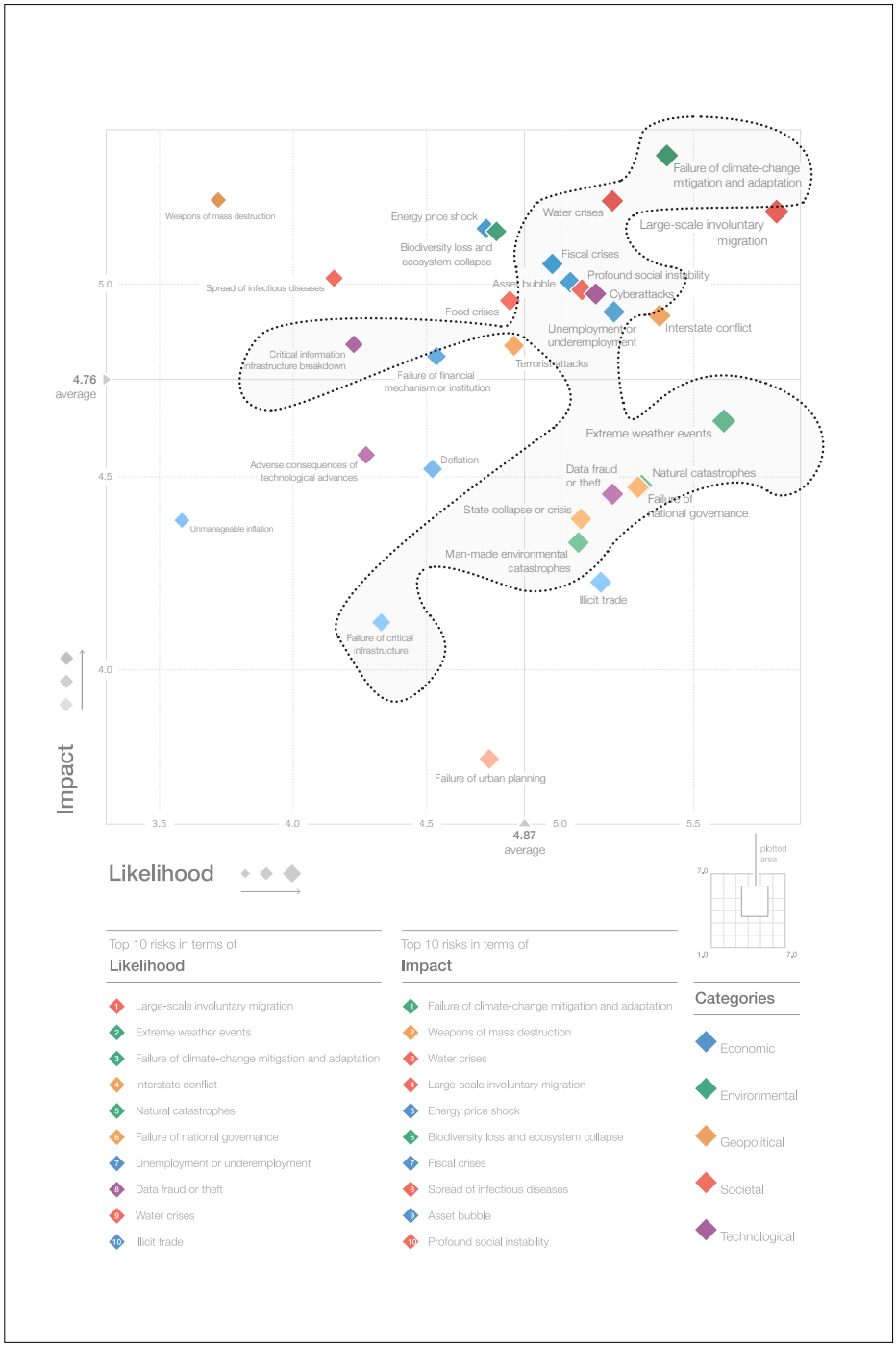


fig 9: Source: Global Risks Landscape 2016, Global Risk Report 2016 , World Economic Forum (www.weforum.org) with the cloud of knowledge domain for the thesis project highlighted by the author

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.

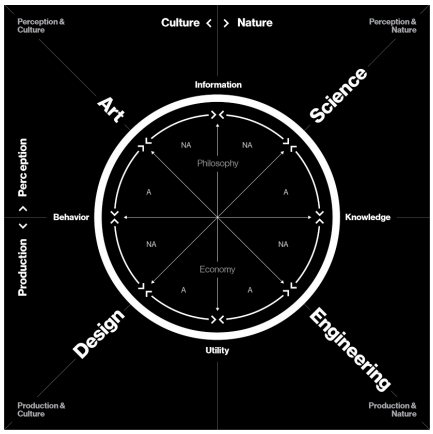
Scientific

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

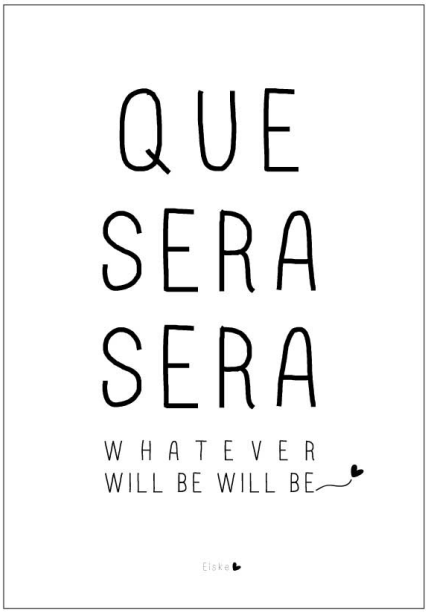


fig 10: living with uncertainties
(image source: MIT)

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.

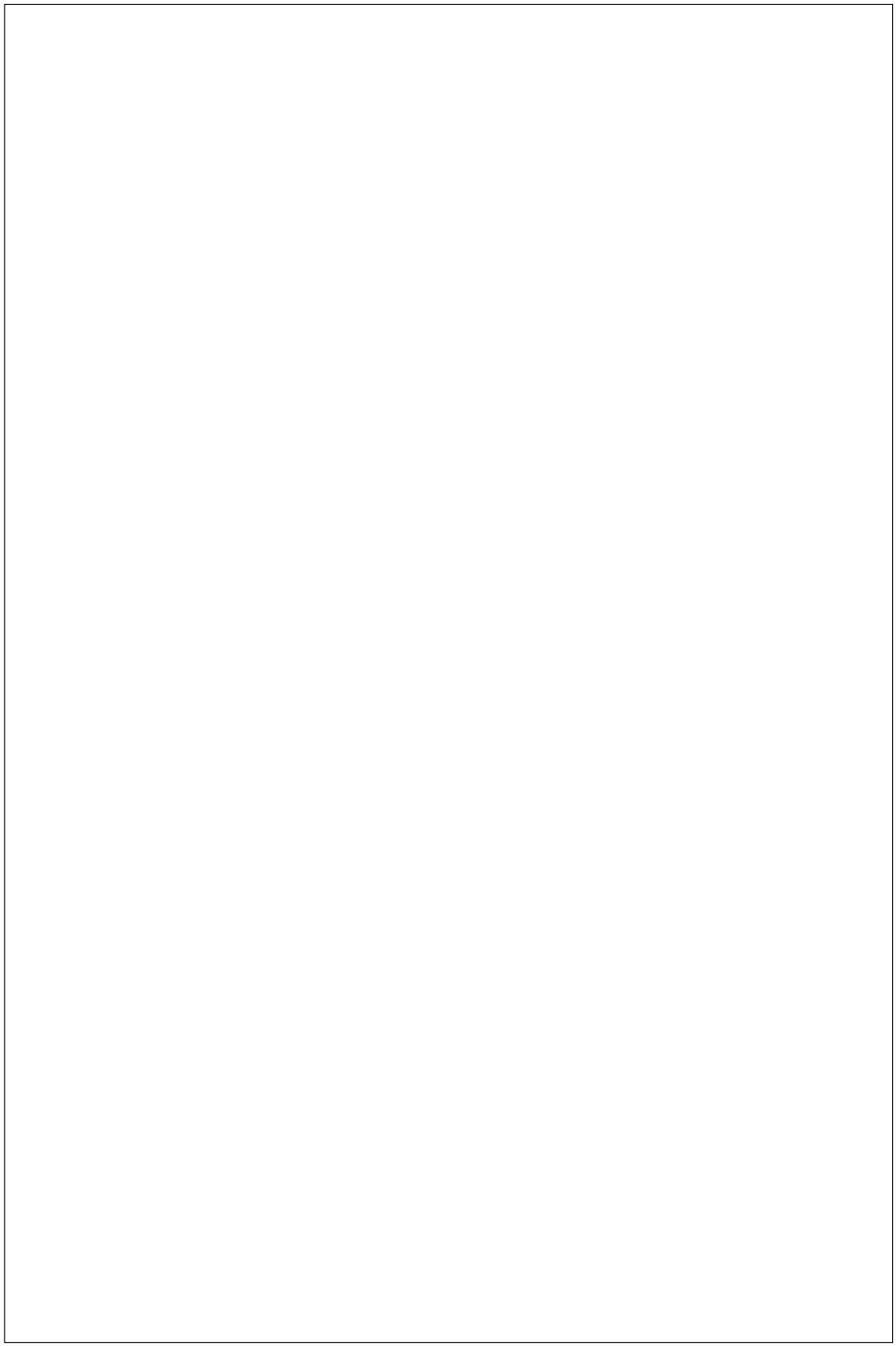
The thesis reflects on this rational, logic oriented approach to analysis that forms the basis of a design that answers one set of problems as a 'complete 'masterplan'. While urban analysis is a combination of quantitative and qualitative research, the 'design' output is not attributed the scientific 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.



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[3]http://cau.mit.edu/ [3]

[2] [5]Engineering resilience is drawn from environmental sciences where the resistance to disturbance and rate of return to an optimal equilibrium is paramount. It is predicated on understanding the componentry of a system, the universal applicability of resilience principles, and its 'efficiency, constancy and predictability' [3] – all attributes at the core of engineers' briefs for fail-safe design.

Ecological resilience (ex ecological sciences) is about the interrelatedness of a system's components and forces; how a system can undergo change and still retain function and structure; how it can self-organize; and how it can increase the capacity for learning and adaptation. (Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global environmental change, 16(3), pp.253-267.)

[6]The 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

Wamsler, C., 2006. Mainstreaming risk reduction in urban planning and housing: a challenge for international aid organisations. Disasters, 30(2)

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