Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
**Graduation Plan: All tracks**

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

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<th><strong>Personal information</strong></th>
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<td>Student number</td>
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<th><strong>Studio</strong></th>
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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) programme that specifically studies the water risk infrastructure systems in Sao Paulo and Tokyo; is aiding observations and 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 dynamic risks offers an important testing site for experimental research.
<table>
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<td>Title of the graduation project</td>
<td>Spatial Planning under uncertainties /Evaluating the effects of natural hazards on critical urban infrastructure networks towards a spatial strategy for risk reduction</td>
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![Conceptual illustration of a resilience assessment framework (content from: Climate Change and Infrastructure (Wilbanks))](image)

Several global risk reports prove that the manifestations of climate related events (both chronic and acute) has been steadily rising (UNEP). The process of climate change is gradual, which is why the urgency to invest and act at a holistic, systems scale is sidelined. Currently, the process of planning for risks in urban areas focuses on simulating or foreseeing the impact of hazardous scenarios (like inundation maps, potential economic damage maps) and making strategies to ‘protect’ the terrain.
Studies to analyse the chain of events that lead to delayed recovery see a roadblock due to the uncertainty of the event occurrence in one lifetime or one political term.

Resource allocation (both planning and investment) focuses heavily on post disaster rehabilitation as opposed to preparing to reduce the damage at the source through better modulation of the urban terrain and the built environment. While planning for better climate resilience and adaptation are finding listeners, the institutional frameworks essential to put cogs into motion in a large way are still reluctant. A fundamental issue is the lack of integration between the domains of urban planning and risk reduction. A more mainstreamed, integrated planning strategy for disaster risk reduction is essential and perhaps a necessity.

Hence, it is essential to adopt a ‘systems approach’ to understand layers of interdependencies at a macro scale and its impact on a micro scale to understand the behavior of the system that can inform better regional contingency strategies for risk reduction.

[Hypothesis]

The proposal works on the hypothesis 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.

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). A shift from post disaster planning to pre disaster resiliency will help develop better adaptive urban environments.

[Problem Statement]

Planning to prevent the negative consequences of a flood related event can be tackled better if we understand the response ecosystem of critical infrastructure networks in the urban fabric, thus helping prioritize development and investment models.

<table>
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<th>Hypothesis</th>
<th>How can understanding the effects of flooding and earthquake risk on critical urban systems (networks and space) inform incremental spatial strategies towards risk reduction?</th>
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<td>Sub Research Questions:</td>
<td>— Sub Research Questions:</td>
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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 determine 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.
| Design assignment in which these result. | The objective of the thesis is to approach resilience through risk reduction through better adaptation and robust connectivity. 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 changes gracefully and without catastrophic failure—is critical in times of disaster (Foster 1997). The analysis of the repercussions of an unforeseen event will help better informed priorities for urban development. The thesis aims to formulate a framework to explicitly understand the interdependencies of critical urban infrastructure systems in functioning for better response and recovery during and after a natural calamity. The objective of the project is urban design strategies for risk reduction for the San Francisco Bay area with focused illustrations on the city scale. Risk=Probability (event risk) x Consequences (outcome risk) Risk reduction is attempted through reduction of ‘outcome risk’ in the event of a gradual or acute climate related disaster. |
preparedness of system behavior and inform regional contingency plans.

*Key words: landscape urbanism, systems approach, scenarios, structural change, new spatial cohesion, territorialism*

**Process**

**Method description**

Climate related risks are never static. But the response frameworks have largely been monofocal about wanting to ‘mitigate’ the effect of a flood. In order to design for a dynamic process (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. The nature of the graduation project is exploratory attempting to understand scenarios and inventories. 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.
**Site Visit, Seminar, Expert Input**
San Francisco Earthquake Institute, San Francisco Bay Conservation and Development Commission, San Francisco Bay Area Planning and Urban Research Association, UC Berkeley

**Desk Analysis**
Scholl analysis; multi-hazard (flood, wild fire, earthquake), socio-economic demography.

**Report Analysis 1**

- **METHODOLOGY**
  - Systematic planning & design introduction
  - Protection
  - Adaptation
  - Emergency
  - Recovery to resilience - using critical urban infrastructure networks

**Report Analysis 2**

- **MACHO**
  - (1st level) analysis
  - Identifies vulnerable zones (A and B)

- **MICRO**
  - (2nd level) impact assessment
  - Spatial variables
  - Spatio-temporal impact on urban components

**MESO**
- (3rd level) spatial scheme
- Spatial Risk Assessment Framework
- Design concepts: Utilizing risk impact to inform urban design

**VALIDATION**
- Projecting risk from 100 year sea level rise and earthquake liquefaction and transport database to simulate damage and derive redundancies

**CRITICAL REGIONAL PATCH MATRIX**
- Incremental
- Transitional
- Transformational

**NEW RESILIENT REGIONAL BACKBONE**
- Based on risk gradient and ability to respond

**LAND REPROGRAMMING**

*Fig 2: Project methodology framework (by author)*
**Process:**

While a perfect study would utilize a comprehensive study of all the above networks, the purpose of this exercise is to device a tangible urban strategy by identifying what is most important to mitigate risks and damages. 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. The authors found that the energy sector accounts for 60% of all cascades followed by telecommunication (28%), transportation (5%) and water(3%) Luiijf et al. (2009). In addition, a case analysis of three modern disasters was generated utilizing the ‘Causal Loop Diagram’. 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)

Hence, the scope of the thesis will be assessment of impacts due to risks on the interdependencies of three infrastructure networks – transport, water and communication on the urban landscape

--- **Parameterization**

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. 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:

- Finding guidelines for more intensive study as opposed to broad readings and abstractions
- 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
- 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 any 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. This exercise was carried out by specifically studying parameters and evaluation frameworks devised by relevant agencies through the following steps:

- Observations on site
- 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
- Study of National Assessment reports for disaster management (FEMA, National Security Agency)
- Independent agency report for disaster resilience (100 Resilient cities)
- Papers on modelling behaviour of critical infrastructure and ‘complexity theory’
- Papers on formulating ‘indicators’ of infrastructure performance.
- Utilizing ‘Causal Loop Diagrams’ (CLD) to manually model the cascade impact of disruption to one system to another

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 answers 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.

The Analysis to design methodology follows a nonlinear interscalar approach. The first level analysis is done at the macro scale

**MACRO**

The Central and South Bay of San Francisco are the boundary conditions for the ‘macro scale’ and in the case of this project the ‘system scale’. A detailed 3X3X3 analysis (first level analysis) of the entire bay was carries out to evaluate the natural, artificial and human occupation networks on the site. Historical maps were studied to understand the
urban development pattern, growth of infrastructure networks and the events leading to
it.

---Objective: To understand the large system structure and vulnerable nodes that can
impact the system

The projected risk zones for earthquakes and sea level rise were mapped utilising
information from 'US National Topo Maps' and FEMA. The impacts of the risks were
overlaid on the each network 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'.

**MICRO**

The urban district, in the case of the project the 'spatial scale'

---Objective: To assess the direct physical impact of risk manifestation flooding event,
earthquake of failure of a 'system variable' at the macro scale) on a tangible urban block.

The ‘second level analysis’ analysis was zoomed to the micro scale of the ‘high impact risk
zones’. The characteristic of the micro scale were assessed based on three characteristics
from Paola Vigano’s theory on Territorialism (Viganò, 2014)- Porosity, Permeability and
Correspondence. Porosity refers to the importance of water and permeability but also of
infiltration and connectivity into the city’s contemporary condition of
enslavement, permeating all aspects of the city, from vegetation, to buildings,
populations, and uses.

This was supported by mapping of the land cover acted as a base indicating land cover
types and the landscape patch-matrix. 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 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.

A ‘research by design’ philosophy undermines the flexibility of this method where
variations in the planning guidelines at the municipal scale can be developed for better
local engagement. As part of a larger resilience guideline, the scale helps identify
fundamental ‘gaps’ (spatial, functional, administrative) in reaching desired resilience goals.

The analysis concluded in a ‘critical map’ which is the infrastructure backbone of the
region whose security must be assured to avoid large scale damages.

**MESO**

The 'city or county’, in the case of the project the 'regional strategy scale’.

---Objective: 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.

The ‘critical map’ derived from the micro scale is expanded to the meso scale for larger implications, damages and emergency services. At the scale of the county and an agglomeration of several municipalities, it gives the urban designer a tangible scale to redefine spatial structure and vision. As a subsystem of the larger bay, the spatial impact or acute shocks (flash floods, earthquakes) can be better evaluated since risk zones / soil liquefaction zones often cover more than one urban district. They also accommodate more critical services, land use planning, waste water treatment plants, pumping station, fire stations, ferry terminal, lakes and intermodal transit terminals.

The meso scale hence is the crucial ‘outcome’ scale for the project. The aim of the exercise of planning under uncertainties of critical infrastructure behavioral impact by default implies multiple responses of varying degrees of resilience. The meso scale enables a ‘network’ behavior inventory on a more tangible scale as opposed to a schematic on a macro scale. This inventory becomes a basis for system analysis to inform a refined regional restructuring, attenuation measures, rerouting and land reprogramming for risk reduction.
The intent of the interscalar exercise is to derive a ‘backbone’ map for the region. The research by design is utilized to develop a new resiliency vocabulary at three stages: bay (system), city (space) and county (territory) in conjunction with landscape ecology. A time series analysis will be derived for an implementation plan that could adhere to this sequence. This could involve stakeholder analysis, growth models, plan critique for a realistic plan.

**Literature and general practical preference**

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.
As a confluence of diverse fields of studies synthesized for a common problem, 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.

References:


(UN, 1999)


HELBING, S. B., J. PORTUGALI 2011. The two messages of complexity theories and their implications to

GERSONIUS, B. 2012. The resilience approach to climate adaptation applied for flood risk. UNESCO-IHE, Institute for Water Education.


UNISDR (2012). “Making Cities Resilient – My City is Getting Ready!”


(2015). ”Delta cities, wealthy or not, face rising risk from sinking land “.

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

— The interdependencies of networks are being studied 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).

2.1 Landscape Urbanism (LU)


2.2 Complexity Theory (CT)


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.


Others:
GERSONIUS, B. 2012. The resilience approach to climate adaptation applied for flood risk. UNESCO-IHE, Institute for Water Education.
Reflection

Relevance

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, pp. 769 – 771).

The Delta Interventions Graduation Studio is an inter-disciplinary studio which, on a wide variety of scales, deals with the necessary transformation of the delta. One of the goals is integration of different socio-technical disciplines to inform better decisions about envisioning future water landscapes. The thesis looks towards adopting a ‘systems approach’ on the behavior of three critical infrastructure systems (Water, Transport, Communication) of the San Francisco Bay Area to guide to build an inventory of risks for a better contingency plan to deal with future risks.

Context

As a developed context and in spite of being a ‘moderate risk’ zone, the San Francisco Bay Area already sees several studies being conducted for risk assessment, restoration and rehabilitation. What it lacks, by admission of its own administrators, is integration and co-benefit models. As the project is being conducted in parallel to an honours research that also deals with flood risk infrastructure if vastly different geographical contexts that inform a richer decision making process

Process

The process and outcome of this project could be a starting point in mainstreaming the importance of urban planning in integrating risk reduction measures on a regional scale. One of the biggest issues with dealing with risks is the assumption that ‘it cannot get worse than this’. Knowledge is empowering, hence, understanding future trajectories and inventories that describes ways in which a system can respond can help refined decision making

Agencies

The thesis document could be useful reference to organisations 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 and Federal Emergency Management Agency. It can be treated as one possible outcome that could result in as part of the institutional framework of the Bay Area. It could be relevant in different proportions to the ‘lifeline’ operators of the Bay area that deal with critical systems such as:
--- 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

The research domain of urbanism has diffused edges. The process of identifying, understanding interdependencies in dynamic interaction can lead to several answers. Currently, there is no satisfactory set of metrics or models that articulates the risk of failures, either naturally caused or human induced for highly interdependent infrastructure (Steven M. Rinaldi 2001). Since the urban domain has no one right answer, generating a set of possibilities is an important exercise. Complexity theories offer us a different lesson – 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. One thus has to find solutions not only in stronger machines/models but in the qualitative messages of complexity theories and their potential to suggest new forms of human behavior, communication, governance and planning (D. Helbing 2011). This is also a legitimate opportunities to identify potential areas for cohesive development models. Integration is the key. Diverse components make for richer outcomes. By integrating theories of ‘Landscape Urbanism’ with ‘Complexity Theory’, the thesis aims to spatialise crucial network concepts that have been theorized over the last decades. Much has been written about cascading, interdependent critical infrastructure systems and their impact of aggravating a disaster. By using causal loops and layer analysis, the project attempts to contribute towards relooking at the way our cities prepare for disasters.

Time planning
Possible Outcome

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 model, phasing the resilience investment for a region based on the probability of flooding event. Each phase (P1, P2, P3, P4) has associated spatial actions based characteristic of the plot and exposure to risk.

In conclusion, the project attempts to synthesize 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 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.