

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:

Personal information	
Name	Ranee Leung
Student number	4750241
Telephone number	
Private e-mail address	

Studio	
Name / Theme	Transitional Territories Studio/North Sea: Landscapes of Coexistence
Teachers / tutors	Dr. ir. Taneha Kuzniecowa Bacchin/ Dr. Daniele Cannatella
Argumentation of choice of the studio	<p>The rationale for the selection of the Transitional Territories studio (TT) was due to my interest in the studio's methodology and with my previous experience with internships and research. TT tackles several issues that I am heavily fascinated in such as the focus on how nature can be altered based on extreme environments and the impacts it can have on livability. The emphasis on how extreme environments can deeply impact the performance socio-ecological systems is very intriguing.</p> <p>During the summer, as part of the Design in Process, Process in Design course (AR0069), I worked at Defacto, where emphasis was placed on regional design with water management and energy transition strategies in future scenarios. The combination of my internship and enrollment in the Honours Programme (HPM)–Infrastructure and Environment has continued to shape my interests and develop further knowledge into societal issues regarding the domain of water, infrastructure, energy and the environment. So far, the program has challenged me to work collaboratively with other interdisciplinary departments and I hope to continue to do so in the TT studio.</p> <p>The North Sea is historically seen as a 'multi-layered ecosystem' and is intrinsically tied as a source of food, energy, and life. As an ongoing contested area between</p>

	<p>different nations, it poses as an optimal research opportunity to see how nations can work together to combat future risks. I believe that the HPM and studio share a common ground on focusing on key issues regarding adverse effects of climate change affecting major societal challenges such as the availability of resources, livability, and water safety. I believe the studio will complement and continue to develop my fascination with the notion that delta cities are constantly challenged to become more adaptive and resilient to become more sustainable. Having the additional resources of the MVI North Sea Energy Lab, Ministry of Economic Affairs and Climate Policy are also exciting to have as a supplementary leverage.</p> <p>As part of the motivation section of the thesis, Canada has a long history of facing large climatic issues and geo hazards. Majority of the economic hubs and highly urbanized cities are situated along a waterfront and are subjected to flash flooding, droughts, food security issues or forest fires. There has been several cases where cascading risks and energy failures have spread across cities. The studio offers an insight into working with different scales while providing a method of exploring the complexity of these large scale issues (social, economic and ecological extremities).</p>
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Graduation project	
Title of the graduation project	Adapting to Uncertainty: Re-thinking Critical Infrastructural Systems
Goal	
Location:	Thames Estuary, London Greater Area, UK
The posed problem,	<p>There are prevailing issues regarding major altered states of extreme weather events. For instance; storm surges, sea-level rise, and droughts have all resulted in many regions left with critical systems and interdependencies exposed. The impact and risk of modern disasters have caused substantial adverse socio-economic impacts, by damaging and disrupting infrastructure services that modern societies have become heavily reliant upon. Further disruptions from winter storms between the years 2013-2016 have established long-lasting disruptions and have had impacts of complete losses of essential services such as water, energy supplies, and transportation and community networks. The frequency of these extremities is considered to be the new norm (Dawson et al., 2018). With that in mind, critical</p>

infrastructures play a crucial role in supporting society, and if major systems were to fail by a sudden shock, a ripple effect would be felt. A single failure in the system can easily cascade across a network of critical infrastructure (CI) that would render otherwise unaffected sectors inoperable. Presently, there are a myriad of issues in the UK governmental system, as there is little action being done to ensure service continuity and security of supply. No agency has an overall responsibility for defense against system failure.

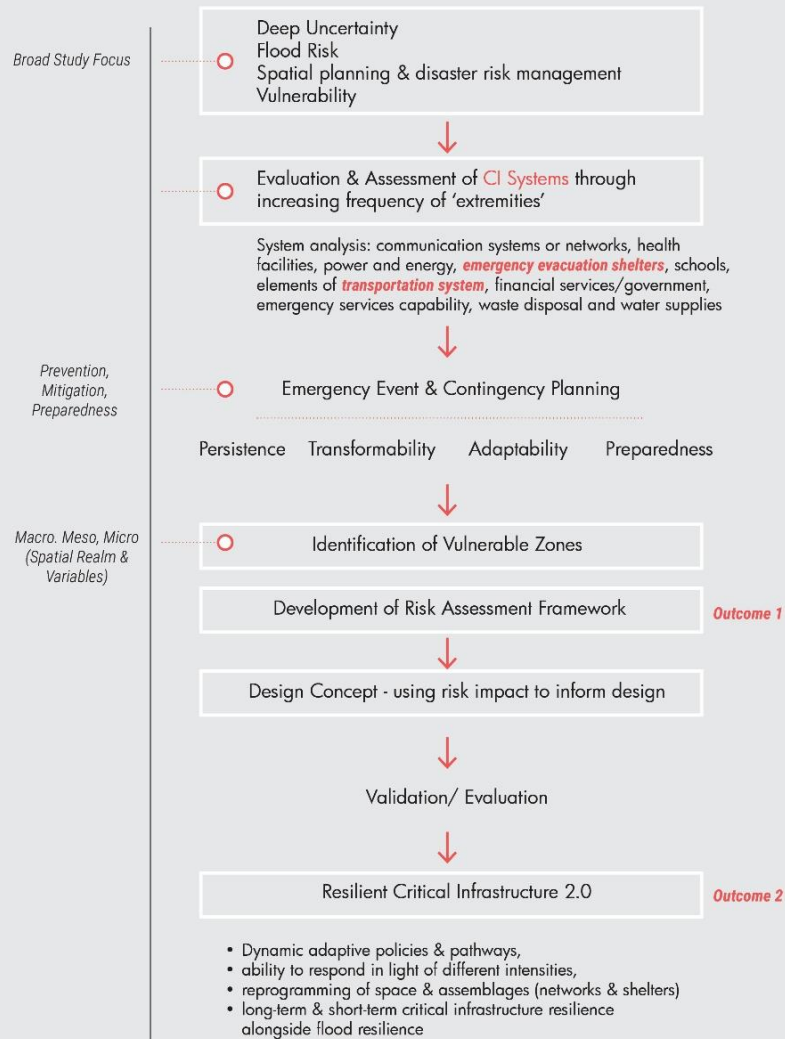
Recently, the UK government announced a six-year capital program from 2015-2021, to provide greater certainty and efficient planning in response to water defense infrastructure. However, the current model has no clear long-term objective for the level of flood resilience that the government is seeking to achieve. Although it will be impossible to prevent all types of flooding, the current planning system is too piecemeal, reactive and have been disjointed. Current levels of adaptation are also projected to be insufficient to avoid flooding and coastal erosion risk. In addition, it is projected that with 4°C of warming and population growth, a significant number of households will encounter the effects of flooding. It is predicted 860,000 to 1.9 million homes by 2050 could be affected. We need to ensure that our systems are able to cope with future shocks and threats especially in light of increasing interdependencies of infrastructure systems.

As a response, there is an urgency to develop a spatial risk assessment framework along with a set of dynamic and adaptive pathway strategies. To simplify, the integrated framework includes transient scenarios which represents a variety of relevant uncertainties and development over time (Haasnoot et al., 2013). The strength of the model comes from being able to handle vulnerabilities (how it might fail) and developing a series of actions to protect these weaknesses. This would assist decision-makers to identify potential vulnerabilities and to prioritize critical systems that require attention. The core of the project should implement a future long-term plan while accounting for deep uncertainty and to provide emergency capacities to endure disruptive changes. The reliability of infrastructural components and combinations should be able to operate no matter the hazard so that basic services such as shelter, water, evacuation and electricity are maintained. This would enable incremental planning strategies that would be

	flexible and adaptable which would translate into long-term resilient planning for regional growth and risk.
research questions and	<p>RQ: How to develop dynamic and adaptable strategies for vulnerable critical systems to address deep uncertainty and flood risk for the Thames Estuary Region?</p> <p>Sub-Research Questions: The following are a series of sub-research questions that are listed to compliment and help examine the main research question. In addition, they offer supplementary guidance in the construction of the provided frameworks. The frameworks and questions will be further elaborated in the following chart which outlines the intentions, rationale, processes, variables and tools per method.</p> <p><i>Conceptual & Theoretical Framework S.Qs</i></p> <ul style="list-style-type: none"> • What is critical infrastructure and what are the independencies in critical urban infrastructure systems? And how does the UK define essential services that need to be maintained during a disaster? What is the risk cycle and how does each factor influence one another? And how does flood risk impact critical infrastructure systems? • How does risk compound and cascade across critical infrastructure systems? • How are social and physical vulnerabilities distinguished? • What is the role of spatial planning on mitigating flood risks from hazards and designing for uncertainties? What is currently being done in the UK? • How can dynamic adaptive pathways assist in developing incremental strategies in light of deep uncertainty? <p><i>Analytical & Spatial Framework S.Qs</i></p> <ul style="list-style-type: none"> • How will a trans-scalar approach assist in understanding deep uncertainty and flood risk in the Thames Estuary? • What is the role and functionality of existing critical infrastructure (lifelines) during and after a crisis? • What are future urban expansions, climate trends and predictions that would exacerbate hazards and risks? • What are the current and future adaptation and spatial strategies to combat risk prevention and mitigation in the Thames Estuary? And do the strategies integrate both social and physical vulnerability? • Are there self-organizations set in place within the UK to combat unforeseen disruptions? • What are essential services that London wants to maintain during a disaster? • What are London's current emergency frameworks as a response to flood risk or service disruptions? <p><i>Strategic & Design Framework S.Qs</i></p> <ul style="list-style-type: none"> • How can the arrangement/hybridity of certain assemblages or combinations of critical systems be used to deal with different extremities of flood risk?

- How to improve the reliability of infrastructure components so they are able to operate under flood risk?
- Can the functionality of critical infrastructure operate differently depending on the intensity of the event? And if so, how to ensure service continuity and supply for the region?
- How can a systems approach assist in enhancing functionalities of urban elements to deal with short-term and long term impacts from natural hazards?
- How to provide emergency relief and response under deep uncertainty?
- What are London's current emergency frameworks as a response to flood risk or service disruptions?

OVERALL RESEARCH DOMAIN



Design assignment in which these result.

The thesis aims to produce an incremental and transformative strategy to deal with flood risk management in the Thames Estuary region through spatial interventions and re-programming of space. The primary focus would be to reconsider the use of a set of networks ie. road systems and position of shelters during the light of extreme events. There needs to be a shift in thinking of developing a standard for critical infrastructure resilience alongside flood resilience. With the use of the strategic and design framework, a method would be created to extract lessons learned from the analytical, spatial and theoretical frameworks in order to formulate the final deliverables which includes:

1. Producing a spatial risk assessment framework that could be used to understand the Thames Estuary Area with a modifiable set of variables. This would result in a product that exhibits a risk gradient in understanding the extent of risk from tidal and surface flooding.
2. Embedding resilient growth in the system by understanding priority development areas with a set of adaptation measures/spatial strategies in response to high flood risk areas and future urban intensifications which would be informed by the risk assessment framework
3. Developing a dynamic adaptive policy pathways strategy that would assist decision-makers with dealing with uncertainty

Research Aims

A large portion of the studio focused on examining uncertainties in the future and the impact of extreme unforeseen conditions from flood risk. "Projected sea level rises of 50-100 centimeters by 2100 will exacerbate flood risks and accelerate the process of coastal change for exposed communities" (Climate Change, p. 3, 2017). The direct climate-change related risks to the UK specifically have increased in frequency and have endangered UK wildlife, natural ecosystems and infrastructure. At the national level, efforts and approaches to adaptation could offset increases in annual flood damage if global warming is limited to 2°C projections but local impacts will vary substantially. In some cases, protection can be increased in some communities but others may face a prospect of increased risks. Risks towards the viability of communities and economies are closely linked to the resilience of local infrastructure. In particular, this points towards lifeline systems such as energy, transportation and communication systems.

The strengthening of infrastructure has been identified as an important field of disaster risk reduction. "However, CI and DRM terminologies have not been fully

integrated and results in inconsistent labeling, conceptualization and implementation of disaster risk-related CI activities and governance approaches”(Bach et al., 2016). The integration of flood risk management alongside spatial planning to transform urbanized landscapes are at utmost importance.

- There is an aim towards a shift in thinking of how critical infrastructure sectors is to be designed, delivered and operated (Mian et al., 2018). But in the limited scope of the thesis, the focus would be looking at the arrangement of primary transport networks and shelter as a priority in light of future disruptions. It is essential to think in this manner as vital as they provide key essential services, and should protect and connect us while amidst the deep uncertainty of the future. At the same time, there needs to be a recognition of the increasing complexity and interdependencies in these sectors.
- Examining the ability of critical infrastructure to accommodate both the expected and unexpected is a pre-requisite for ensuring the safety of life and property over the coming decades.
- The thesis also critically analyzes the existing paradigms of protecting vital urbanized landscapes and the adaptive measures taken. The approach of the thesis looks at the impact of flood risks on lifeline systems and how the system could be rendered obsolete. Drawing on the principles of resilience building (the aspects of transformability, adaptability, and preparedness) this will guide the thesis in the creation of a persistent and robust urban framework.

Process

Method description

In order to cover the scope of the thesis, the methodology chapter contains a defined set of frameworks were created as a backbone for the research. The chapter further elaborates the initial approaches, relational methods, techniques and analysis necessary to explore the research questions. In addition, the construction of the frameworks is essential as the design will be informed by a body of theory. The narrative of each framework will be further elaborated within the report and are divided into several frameworks:

- Theoretical Framework
- Conceptual Framework
- Spatial & Analytical Framework

The objective and synthesis of the frameworks will lead to the Strategic & Design Framework. Each framework will be advanced in parallel as a means to synthesize and critically analyze relationships.

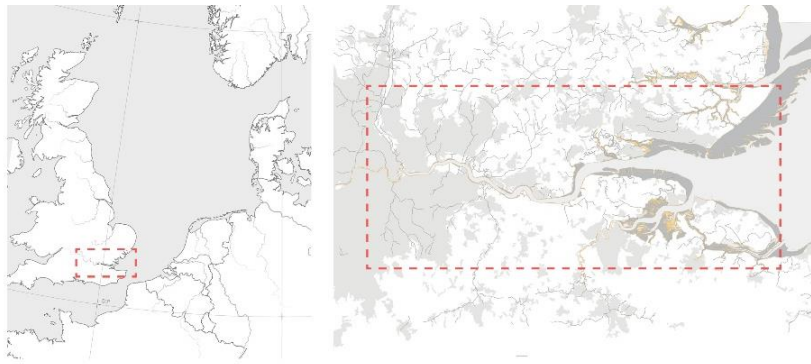
Below is a snippet of frameworks and questions that would be analyzed with a set of variables, methods, tools. For further elaboration, the P2 report identifies the rationales and aims of each. The principal tool used in the spatial framework is heavily reliant on mapping through GIS using open source data as a means to gather, manage and analyze data. Other means of analyzing and synthesizing data will be through literature review, case studies and reports.

Scales: (MI) Micro (ME) Meso (MA) Macro
 Frameworks: (CT) Conceptual & Theoretical Framework
 (AS) Analytical and Spatial Framework
 (SD) Strategic and Design Framework

Sub-Research Questions	Frameworks	Time	Scale	Method	Variables	Tools
What is critical infrastructure and what are the independencies in critical urban infrastructure systems? And how does the UK define essential services that need to be maintained during a disaster?	(CT) (AS)	Existing	(MI)	data analysis, literature review,	Critical infrastructure, systems and lifelines	GIS, online databases
What is the risk cycle and how does each factor influence one another? How does risk compound and cascade across sectors?	(CT) (AS)	Existing & Future	(MA)	literature review	risk cycle	online database
How are social and physical vulnerabilities distinguished?	(CT)	Existing	(MA)	literature review	Vulnerabilities	online database
What is the role of spatial planning on mitigating risks from hazards and designing for uncertainties? What is currently done in the UK?	(AS)	Existing	(ME) (MA)	literature review, case studies	spatial planning, hazards, risks	online database
How can dynamic adaptive pathways assist in developing incremental strategies in light of deep uncertainty?	(CT)	Future	(ME) (MA)	literature review, case studies	DAPP, deep uncertainty	journal articles, online database
How will a trans-scalar approach assist in understanding deep uncertainty and flood risk in the Thames Estuary?	(AS)	Existing & Future	(MI) (ME) (MA)	data analysis, systems method	uncertainty, trans-scalar	GIS, online database
What is the role and functionality of existing urban infrastructure during and after a crisis?	(CT) (AS)	Existing & Future	(MI) (ME)	data analysis	critical infrastructure, risks	online database & reports
What are future urban expansions, climate trends and predictions that would exacerbate hazards and risks?	(AS)	Future	(MI) (ME) (MA)	data analysis, literature review	climate trends & predictions, risks	online database & reports, GIS
What are the current and future adaptation and spatial strategies to combat risk prevention and mitigation? And do the strategies integrate both social and physical vulnerability?	(AS) (SD)	Existing & Future	(MI) (ME)	data analysis, literature review	adaptation, risk mitigation, vulnerabilities	online database & reports, GIS
What are London's current emergency frameworks as a response to flood risk or service disruptions?	(AS)	Existing	(MA)	literature review	risks, disruptions	online reports

Figure 11 Methods and processes chart with sub-questions

Sample of one of the frameworks and scales:



Territorial/North Sea

- Thematic studies: future projections on SLR
- Temperature increase
- Precipitation
- Urbanization trends

Regional Scale - Thames Estuary River Basin

- Flood risk levels
- Density of critical infrastructure
- Policy and frameworks
- Lack of standardized flood resilience
- Social vulnerabilities

City Scale - London

- Lack of defined spatial emergency routes and shelters
- Lack of foresight on maintaining essential services
- Impact on urban systems

Micro Scale - Vulnerable/High Risk Areas

- Test sites for increasing resiliency and preparedness plans + urban growth

SPATIAL ANALYSIS

Critical Infrastructure & Systems (Mapping/GIS)

In order to generate a spatial database in regards to critical lifeline systems, the following were divided into four main categories:

1. Mapping all the 'lines/systems': transportation systems (road networks, rail networks, tunnels), energy, water, communication lines
2. Mapping 'points': transportation (airport, ports, stations), energy (substations and towers), water treatment facilities, shelters (education facilities, leisure, sports center, places of worship), and emergency services (police, medical services, fire station)
3. Mapping 'polygons': boundaries: Thames River Basin District, census wards, open space, flood defenses
4. Mapping 'constraints': greenbelt, climate trends and projections, flood risk areas (zone 2 and 3), historic flood zones, flood alert areas, flood defenses, predicted urban growth

Objectives and aspects obtained from the reports are:

- Inform areas of critical infrastructure and the impacts of emerging risks, hazards and vulnerabilities
- Determine vulnerable neighbourhoods within the Thames Estuary that needs priority. This will then inform the strategic and design framework

Mapping out the 'lines' are essential as they can be seen as connection points and opportunities as escape routes. These need to be placed in high priority if a lifeline collapses. Using ArcMap with spatial analysis can determine the best routes.

Whereas the points analysis could address future shelters

Critical Infrastructure & Systems (Literature Review & Reports)

Objectives and aspects obtained from the reports are: to understand defined critical systems and lifeline systems at priority to map

Resources/Data Sources

- Flood risk assessments: climate change allowances
- Thames river basin district sea level rise boundaries and local authorities
- Thames Catchment Flood Management Plan
- London Data Store (data.london.gov.uk)
- UK CPNI
- EU Floods Directive
- Climatejust.org.uk
- OS OpenData: Ordnance Survey Mapping
- MAGIC Datastore
- Environment Agency GeoStore

Climate Trends & Projections (Mapping/GIS/Literature Review)

To gain a better understanding of deep uncertainty and the patterns of growing risks; the flood risk zones were mapped.

In addition reports of the following issues were explored:

- Sea level rise
- Annual precipitation increases (macro scale)
- Storm Frequency, intensity, duration analysis

Objectives and aspects obtained from the reports are:

- Trends will identify future risk and emergent risks, hazards and vulnerabilities (spatial and social contexts)

Understanding how future extreme climate events will impact vulnerable areas/populations and critical infrastructure. This will be further explored to create adaptive and flexible spatial strategies in the strategic and design framework.

Literature and general practical preference

In order to establish the theoretical narrative of the thesis as well as to identifying limitations of the project, the initial literature review seeks to explore the notions of critical and vulnerable systems. As per the problem statement, with the rising challenges of major altered states of extreme weather events, many regions left with critical systems and interdependencies are left exposed. The impact and risk of modern disasters have become more pronounced with extensive societal and economical damages. In the scope of the thesis, the following aspects need to be understood such as: critical infrastructure, interdependencies in the system and the causes of residual and cascading risk. As the thesis heavily focuses around designing around deep uncertainty, concepts of performance, functionality, adaptability and vulnerability within a systematic approach.

In the theoretical framework, it describes a set of definitions and models to give direction to the research and builds upon the different stages of the project. The construction of the framework includes scientific justification to the research investigation and offers a grounded perspective tied to scientific theory. To understand the problem statement and position of the research in detail, the initial discourse and literature review aims to establish and explore in detail several notions:

- Deep Uncertainty
- Evolutionary Resilience
- Dynamic Adaptive Systems
- Adaptive Capacity & Risk

Literature

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Reflection

Relevance

Societal Relevance

The frequency and intensity of major extreme weather events such as storm surge, sea-level rise, and droughts have resulted in many regions left with critical systems and interdependencies exposed. It is crucial to critically think and plan how the state of extremity could also disrupt flows of services, people, goods and way of life. Disasters can inherently reduce a community's resilience with the disruption of the operation of infrastructure ie. Electric power, transportation, water and are often referred to lifelines. As the dependency on these critical lifeline systems are increasing as well as these systems distributed over large geographic regions, they are often exposed to a broad amount of hazards. If there is a sudden impact on one of these networks or services, a large portion of society can become crippled. Malfunctions in the system at multiple locations can impede on the response and recovery of a community. Planning for resilience and recovery in these systems would prevent further disruptions and displacements of people or the compromise of social and economic losses. In the scope of the UK, failure and disruptions of services from floods have drastically affected electricity supplies, failure of bridges and disruption of communication networks. These adverse effects of extreme weather events and significant impacts are significant to regions of the world.

Establishing a study on critical infrastructure system performance can help better understand society needs during response and recovery. The main aim is also to help decision-makers in handling with deep uncertainty in making long-term decisions for urban planning. The emphasis is also to support short-term actions while being able to modify, extend or alter plans to the changing environment or future. This would also assist in identifying gaps between the desired and anticipated performance of key infrastructure and set priorities.

Scientific Relevance

The project aims to have a critical perspective on the role of critical infrastructure systems that can withstand extremities, and in particular, flood risks. Having an assessment of critical lifeline system performance and understanding societal needs during a disaster is a prevalent issue in present society. Gradual shifts in long-term trends and extreme weather events due to rises in average temperatures have also reduced the capacity and efficiency of certain infrastructure (Dawson et al., 2018). This would also increase in the frequency of disruptions. With this in mind, it is also relevant to consider the lifespan and design of critical systems. Referring to the UK, the National Infrastructure Plan allocates £300 billion of planned investment across all sectors by 2021 with large capital costs of 30-200 years. There are limited flexibility to the infrastructure once it is constructed. It is essential to put emphasis on new and existing infrastructure that can adapt to the context of flood risk.

The assessments in the thesis includes:

- Detailed analysis and consideration of vulnerable populations and systems at flood risk situations
- Lifeline assessments to review the performative criteria and standards for infrastructure such as transportation systems, water systems and shelter.
- Recommendations to identify needed development and support and reduce the likelihood of infrastructure component failure. Also to increase capacity and alternatives as an effective response and recovery from climate disruption

In most cases, the repercussions of a system failing includes prolonged recovery times, large investments on reconstruction efforts, managing housing and blackouts. It is vital to continue to build upon the technical knowledge that would reinforce to create resilient strategies. This would then inform and create a better understanding behind the complexity and subject matter of vulnerability, risk and climate change. Adaptation capacities and assessment frameworks will also be utilized to emphasize the importance of risk management.

Time planning

The following chart defines major deadlines and phases of the thesis. The frameworks defined in the methodology are the guiding points of the overall timeframe.

