URBAN RESILIENCE BUILDING FOR SEA-LEVEL-RISE ADAPTATION AND WHAT IS THE RELATIONSHIP BETWEEN RESILIENCE AND SUSTAINABLE DEVELOPMENT? CASE STUDIES OF ROTTERDAM, THE NETHERLANDS AND YOKOHAMA, JAPAN

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Abstract

As a consequence of climate change, the rise of sea level is disrupting particularly vulnerable delta cities. Nowadays, resilience-building has been put on the agenda in many cities; however, to establish a context-specific “sea-level-rise resilience”, the knowledge about which mechanisms and narratives should be introduced is still limited. Besides, many cities have taken the idea of resilience-building for granted as an element facilitating sustainable development. Whereas the relationship between resilience and sustainability is complicated, with enormous similarities in concepts and overlaps in implementations, which may hinder long-term development. To address these problems, the research 1) adopts a PARA (protect-accommodate-retreat-avoid) risk-reduction framework, shedding light on effective adaptative solutions for sea-level-rise impacts, and 2) develops a diagnostic tool, precisely assessing these strategies in terms of resilience building. The PARA framework and resilience diagnosis are carried out in two case studies: Rotterdam in The Netherlands and Yokohama in Japan. The relationships between resilience and sustainability are also elaborated in both cities. Overall, the objective of the research is to 1) identify all strategies for sea-level-rise adaptation in a systematic way; 2) demystify resilience-building by providing a performance evaluation model; 3) analyze the extent of sustainability and resilience affecting each other for ameliorating future development plans; 4) promote new international cooperation in the specific field for worldwide delta cities.

Come conseguenza del cambiamento climatico, l'innalzamento del livello del mare sta sconvolgendo le città del delta particolarmente vulnerabili. Al giorno d'oggi, la costruzione della resilienza è stata messa all'ordine del giorno in molte città; tuttavia, per stabilire una "resilienza all'innalzamento del livello del mare" specifica del contesto, la conoscenza di quali meccanismi e narrazioni dovrebbero essere introdotti è ancora limitata. Inoltre, molte città hanno dato per scontata l'idea della costruzione della resilienza come elemento che facilita lo sviluppo sostenibile. Mentre il rapporto tra resilienza e sostenibilità è complicato, con enormi somiglianze nei concetti e sovrapposizioni nelle implementazioni, che possono ostacolare lo sviluppo a lungo termine. Per affrontare questi problemi, la ricerca 1) adotta un quadro di riferimento PARA (proteggi-alloggio-ritrattamento-evitamento), facendo luce su soluzioni adattive efficaci per i fili di innalzamento del livello del mare, e 2) sviluppa uno strumento diagnostico, valutando con precisione queste strategie in termini di costruzione della resilienza. La struttura PARA e la diagnosi di resilienza sono applicate in due casi studio: Rotterdam in Olanda e Yokohama in Giappone. Anche le relazioni tra resilienza e sostenibilità sono elaborate in entrambe le città. In generale, l'obiettivo della ricerca è di 1) identificare tutte le strategie per l'adattamento all'innalzamento del livello del mare in modo sistematico; 2) demistificare la costruzione della resilienza fornendo un modello di valutazione delle prestazioni; 3) analizzare l'entità della sostenibilità e della resilienza che si influenzano a vicenda per migliorare i piani di sviluppo futuri; 4) promuovere una nuova cooperazione internazionale nel campo specifico per le città del delta mondiali.

Keywords
Urban resilience, sustainability, sustainable development, sea-level rise, climate adaptation.

Introduction

Preparing for and striving against the effects of climate change is regarded as one of the essential and urgent challenges in the 21st century. This research focuses on sea-level rise. With continuously increasing global temperatures, sea levels have risen at an accelerating rate (The World Economic Forum, 2019). According to the Intergovernmental Panel on Climate Change (Ipcc), owing to increased oceanic warming and loss of glaciers and ice sheets, global sea levels will continue to rise through the 21st century and beyond. Furthermore, a 2°C increase will cause sea levels to rise between 0.30 meters and 0.93 meters by 2100.

Sea-level rise threatens significant property damage—not only homes and businesses but also public assets and critical infrastructure, which adds significant contingent liabilities to the taxpayer (The World Economic Forum, 2019). Various forms of infrastructure and economic activity are at risk from rising sea levels, including roads, railways, ports, internet, sanitation, drinking water, energy, tourism, agriculture. Delta cities, home to more than two-thirds of the world's largest cities and 340 million people (Dircke et al., 2010), are particularly vulnerable to the consequences of climate change such as floods (Francesch-Huidobro et al., 2017). As urban infrastructures such as drainage systems, dikes and dams, together with accelerated land reclamation processes and the training of rivers have disrupted the natural process of land-making, decreasing the capacity of delta cities to cope with excessive water (Meyer et al., 2017). To make the city more resilient to sea-level rise, the idea of adaptation is set to be a priority for delta cities' plans worldwide. From a global perspective, not all countries are equally vulnerable to sea-level-rise impacts. Small Island Developing Nations (Sids) are on the frontline not only due to their low-lying lands but also the lack of technology and development. While Oecd (Organisation for Economic Co-operation and Development) countries use and share efficient, effective and equitable responses for coastal risk management (Oecd, 2019), many Sids can only build higher or expensive sea walls to buttress their islands from escalating tides. Therefore, diverse support and cooperative efforts from developed countries that undermine their roles as leaders are urgently required. On the other hand, the corresponding responses also provide links between resilience building and sustainable development. For instance, investments in disaster risk prevention and reduction, as resilience-building to climate change, can also be drivers of innovation, growth, and job creation (Zurich Insurance, 2018), simultaneously achieving long-term sustainable development.

Rotterdam and Yokohama are two famous delta cities facing with sea-level-rise threads in Europe and Asia. Both cities host numbers of adaptive attempts and have committed to full-scale resilience building. Rotterdam is located at the mouth of the Nieuwe Maas channel leading into the Rhine–Meuse–Scheldt delta at the North Sea, with an elevation of 0 m above sea level (estimated 2019), and Yokohama is in the south of Tokyo Bay, which is connected to the Pacific Ocean by the Uraga Channel, and in the Kanto plain, with the elevation of 10 m above sea level (estimated 2019). Involving in the global100 Resilient cities (100Rc) network and being faced with the severe threat of sea-level rise, Municipality Rotterdam is actively responding to and preparing for the crisis in urban planning. Corresponding programs include Rotterdam Climate Initiative[1], Rotterdam Resilience Strategy[2], etc.; being selected as "FutureCity" in Japan, Yokohama is also committed for a sustainable future. The Climate Change Policy Headquarters in City of Yokohama, issued the Yokohama City Climate Change Adaptation Strategy in June 2017, promoting "Zero Carbon Yokohama", one of which strategies clearly address the improvement of "city resilience". By holding the 2019 Asia Smart City Conference (Ascc), Yokohama has a close relationship working with the Association of Southeast Asian Nations (Asean) countries. However, in terms of resilience building to sea-level-rise impacts, comprehensive international cooperation remains extraneous for Rotterdam and Yokohama.

Theoretical framework

Resilience

The word resilience, together with its various derivatives, has a long history (Alexander, 2013). It stems from "resilire" and "resilio", Latin for "bounce". The adoption of the scientific concept of resilience outside mechanics owes much to the theoretical work of a US-Canadian ecologist Crawford Stanley Holling (Alexander, 2013), with the backdrop of "the recognition of our ignorance" and "unexpected future events" (Holling, 1973). Originated from ecology, the concept of resilience gradually applied to other fields.

As the earliest concept of resilience, engineering resilience described a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (Holling, 1973). Since the level of a system's resilience depends on how quickly it can recover to the initial state after being disturbed, engineering resilience could be hereby estimated by a return time, the amount of time taken for the displacement to decay to some specified fraction of its initial value (Pimm, 1991). However, total recovering to the initial state is impossible in many cases; instead, in conditions far from any equilibrium steady state, where instabilities can flip a system into another region of behavior – that is, to another stability domain (Holling, 1973), ecological resilience is therefore defined as the

[1] A partnership launched in 2006 with the objective of reducing CO2 emissions by 50% and climate proofing the city.

[2] Releasing in 2016, drafted by Resilience Office in Rotterdam. The Resilience office, supporting by 5 staff members, was created in 2014. The Resilience Strategy soon becomes one of the City's top strategic programs.

capacity of a system to absorb disturbance and re-organize while changing to retain essentially still the same function, structure, identity and feedbacks (Walker et al., 2004). In engineering resilience, a single stability domain is implicit, whereas in the ecological resilience concept, multiple steady-states are possible (Gunderson, 2002).

Further, the approach to view resilience and the evolutionary perspective in economic geography is called evolutionary resilience (Davoudi et al., 2012). Evolutionary resilience was interpreted as the ability of complex social-ecological systems to change, adapt or transform in response to stresses and strains (Carpenter et al., 2005). The evolutionary resilience derives from an adaptation thought (Holling and Gunderson, 2002); it requires the understanding of how system's dynamics behave and evolved, and how in that process the current system has shaped (Teigão dos Santos and Partidário, 2011). The evolution of three resilience concepts (engineering, ecological, evolutionary) (Table 1) reflects a significant leap in resilience's academic explanations.

Concept	Characteristics	Focus on	Status
Engineering resilience	Return time, efficiency	Recovery, constancy	A single Equilibrium
Ecological resilience	Buffer capacity, withstand shock, the existence of the function	Persistence, robustness	Multiple Equilibria
Evolutionary resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity transformability, learning, innovation	Beyond Equilibrium

Table 1. Comparison of three resilience concepts, created based on Folke, 2006.

Today, numerous cities face acute challenges in managing rapid urbanization — from ensuring adequate housing and infrastructure to support growing populations, to confronting the environmental impact of urban sprawl, to reducing vulnerability to disasters (Un-desa, 2018). Therefore, resilience thinking requires a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take (Holling, 1973), is gradually situated in the urban context and provides a benchmark of resilience building for urban planners. However, due to the fuzziness of the terminology "resilience", resilience principles, including traits, attributes, actions, and behaviors that describe specific mechanisms that make a system resilient (Wardekker, 2018), are utilized as design guidelines to help policies and practices enhance resilience. These principles support resilience-thinking in relation to urban adaptation and develop a diagnostic tool in the following research.

Relationships between resilience and sustainability

As the No. 11 Sustainable Development Goals (Sdg) combine resilience and sustainability – make cities and human settlements inclusive, safe, resilient, and sustainable; the relationships between resilience and sustainability have been discussed in various dimensions. However, due to enormous similarities between the concepts of sustainability and resilience, they are often used without a clear distinction in meaning and purpose for a variety of applications (Marchese et al., 2018).

Firstly, resilience has been seen as a necessary precondition for sustainability; strengthening the capacity of societies to manage resilience is critical to effectively pursue sustainable development (Lebel et al., 2006). Given the fundamental uncertainties of ecological and social dynamics, ensuring the resilience of ecological systems on which our economies depend is obligatory for (Arrow et al., 1996). In recent years, resilience is found to become a component of sustainability as the dominant organizing frame in urban planning (Davidson et al., 2019). Another perspective regards resilience as the "final objective of the system", with sustainability as a contributing factor to resilience (Marchese et al., 2018). This relationship implies that increasing the sustainability of a system makes that system more resilient, but increasing the system's resilience does not necessarily make that system more sustainable (Marchese et al., 2018). However, there are substantial conflicts between the two concepts. Sustainable development at many times maximizes efficiency, in the meantime reducing redundancy. Redundancy, a reserve of flexible fall-back positions and diversity of actions that can be used to meet the exigencies of novel disturbances (Holling, 1973), is one of the hallmarks of a resilience system (Tarhan et al., 2016). So if greater efficiency means less resilience, conversely, greater resilience means less efficiency (Goerner et al., 2009), and less sustainability. Another viewpoint states that resilience and sustainability have separate objectives that lack a hierarchical structure, complementing or competing with each other (Marchese et al., 2018). Global and local policy processes often use vague or narrow definitions of the concepts of urban sustainability and urban resilience, leading to profound confusion and vagueness, which slow down the needed urban transformation processes (Elmqvist et al., 2019). Problems often emerge in the combination in urban planning of both sustainability and resilience building.

While resilience is becoming a planning and managing priority for cities is on a quick rise with governments, planners, architects, social scientists, ecologists, and engineers taking up the resilience agenda (Tarhan et al., 2016), it needs to be linked to sustainability so that the resilience planning could help move towards a desired, sustainable future.

PARA strategies and resilience diagnosis framework

Initially, Protect-Accommodate-Retreat-Avoid (PARA) strategies were proposed as a practical approach for comprehensive flood risk reduction (Doberstein et al., 2018): *Protect* – ensuring the land being protected from the sea so that existing land uses can continue (Czms, 1990), engineering structures have so far proven to be the most common sea level rise response (Harman et al., 2013), either hard (e.g., sea walls, levees, surge barriers, water pumps, overflow chambers) or soft (e.g., nourished beaches, dunes, restored wetlands, mangroves) (Bello, 2016). *Accommodate* implies that people continue to use the land at risk (hazard-prone areas) with reduced sensitivity or exposure or both to sea-level rise (Harman et al., 2013). Natural system effects are allowed to occur, and impacts on humans are minimized by adjusting human use of the coastal zones via flood-resilience measures (Nicholls, 2011). *Retreat* means no effort to protect the land from the sea – the coastal zone is abandoned and seeks refuge behind natural ecological defenses (Abel et al., 2011). In extreme cases, an entire area may be abandoned (Czms, 1990) – *avoid*. Ideally, the avoid approach should be implemented before significant disasters, but in reality, the new or strengthened avoid approaches are often implemented after the disaster (Doberstein et al., 2018). In this research, PARA strategies are used to present sea-level-rise adaptation.

For cities, climate change impacts are acknowledged as a few out of a multitude of potential disturbances and can be discerned into sudden shocks and disasters (e.g., extreme weather events, heat stress) and gradual, disturbing trends (i.e., sea-level rise) (Walker et al., 2004; Wardekker et al., 2010). Thus, both resilience-building and climate-adaptation, though with different intensities, look at climate change-related impacts and seek ways to mitigate and moderate these impacts (Wilk, 2016). Therefore, the implementation of PARA strategies also contributes to enhancing urban resilience.

By measuring the level of each PARA strategy fulfilling resilience principles, a diagnosis makes resilience sufficiently operational for local actors to explore policy options (Wardekker et al., 2010) for sea-level-rise adaptation. Resilience principles were first proposed as strategies of risk reduction and principles of ecological stability for cities: homeostasis, high flux, omnivory, flatness, buffering, and redundancy (Wildavsky, 1988), which theoretically supported resilience-thinking in urban planning. Then resilience principles started to be indicative guidelines. The 100 Resilient Cities (100Rc)[3] propose the City Resilience Framework, identifying seven characteristics that urban resilience-building needs to follow: reflective, resourceful, inclusive, integrated, robust, redundant, flexible. In 2016, under severe climate change, an urban climate resilience framework (Wilk, 2016) was established. This framework thereby advanced conceptual clarity of resilience in the context of climate change and assessed the practicality of resilience principles to improve their functionality for policy-makers (Wilk, 2016). Based on the work done by (Wilk, 2016), this research furtherly

[3] Pioneered by The Rockefeller Foundation in 2013. Cities in 100RC network are provided with the resources to establish a Chief Resilience Officer and to draft a Resilience Strategy.

develops this framework (Table 2) with 4 phases (planning and preparation; absorb; quick response; adaptation) and 11 principles (anticipation and foresight; planning ahead; homeostasis, compartmentalization; robustness and buffering; omnivory; redundancy; flatness; high flux; flexibility; learning and reflectivity) as a holistic evaluation tool. Each principle has several indicators.

Phase	Principle	Definition	Indicators
Phase 1. Planning and preparation	Anticipation and foresight	They originate from the human capacity to anticipate disturbances, imagine different futures and thus, consider possible outcomes and to implement preparatory interventions. It should create relevant knowledge about the disturbances, and the knowledge should be shared with the wider population to create awareness.	Amount of research/reports Knowledge exchange Projections, forecasts, and scenarios Connection with stakeholders Public awareness Monitoring system Mapping of critical functions in flood-prone areas Water storage, drainage and infiltration capacity
	Planning ahead	This aims at strengthening a city's coping responses before a disaster occurs. It enhances the chances of absorbing impacts and quicker recovery.	Emergency plan Response management Platforms for risk communication or/and knowledge generation Resources for planning Training/educational measures Involvement of stakeholders Networks for exchange practice Preparation of business Early warning system
	Homeostasis	Homeostasis refers to multiple feedback loops within the coastal system that counteract disturbances (dampening feedback) and stabilize the system.	Water management/governance Integration of sea-level-rise adaption in policies, regulations, laws, and spatial planning Flexible budget mechanisms Insurability of flood loss Use of technology
	Compartmentalization	Mechanisms to locally contain flood impacts and prevent cascading effects on a modular network structure.	Compartmentalization of engineering protection (e.g., dike rings, polders, temporary dams.) Transportation networks Exchange among actors across institutional boundaries (e.g., policy officials, municipality representatives, project coordinators.) Public disclosure

Phase 2. Absorb	Robustness and buffering	The inherent strength of a city, referred to as robustness and buffering mechanisms based on over-dimensioning systems, determines whether a city can endure, cope with a hazard, and maintain function during adverse circumstances.	Scale and robustness of flood protection (e.g., storm barriers, dams, dikes, water storage capacity) Assessment and improvement of flood-protective infrastructure Pre-emptive planning practices Flood-sensitive building Existence of the buffer zone
	Omnivory	The capacity to recover is increased by diversification of resources and means that may be mobilized in the event of a shock.	Diversification of power generation and transportation network Cultural and spatial diversity Multi-functional spaces and buildings Multi-skilled planning teams
	Redundancy	Redundancy describes the presence of multiple elements or replication of components or pathways in order to have multiple instances available that perform the same function. These can fully substitute each other and therefore prevent system failure in case one component fails.	Technological (e.g., power grid, infrastructure, transportation) redundancy Social networks that offer different problem-solving options The accountability Strategic creation of system's redundancy
Phase 3. Quick response	Flatness	The hierarchical levels relative to the base should not be top heavy because overly hierarchical systems with no local formal competence to act are too inflexible and too slow (1) to cope with surprise and (2) to implement non-standard highly local responses rapidly.	Citizen/community empowerment Social cohesion Public participation Social cohesion The ability of populations to self-respond to disturbances The autonomy of municipal authorities to authorize plans and to legislate policy Financial independence of governing bodies Procedures for taking actions
	High flux	High flux represents a fast rate of movement of resources through the system that ensures a fast mobilization of these resources to respond to threats and changes quickly. This mechanism addresses rapidity by seeking ways and implementing conditions to maximize promptness in response.	Easy-to-modify land uses Fixed protocols (in calamity, continuation, recovery plans) about quick mobilization Pre-event arrangements of financial resources Governmental reimbursement for hazard-related expenditures The monetary resources and skills for citizens to shift livelihoods
Phase 4. Adaptation	Flexibility	Uncertainty requires flexible planning, spontaneous responses, and adopting flexible elements that are apt for several scenarios to come. Flexibility can be perceived as a design principle for	Room for change in structure and processes in institutions Anticipatory physical, structural elbowroom for future adjustments, extensions or

	adaptation measures according to reversibility and avoiding limitations on the range of possible future measures.	retrofitting in spatial means Regulations that allow strategy change and amendments A long-term planning horizon
Learning and reflectivity	Under uncertainty, learning is the driver for strategic adjustments and for new strategies to cope with change. Reflectivity refers to organizations and individuals' capacity and willingness to apply new knowledge, adopt a novel, alternative strategies in response to changing circumstances.	Experimental and innovative projects Support for pilot initiatives Active figureheads and advocates History of climate adaptation Lessons learned from previous experience Employing of "no regret" No one-fits-all solution

Table 2. Urban sea-level-rise resilience framework, created based on Wilk, 2016.

Methodology

A central assumption underlying this study is the crucial relevance of flood mitigation and water-related risk management strategies for the city's resilience building to potential sea-level-rise impacts. The study collects quantitative and qualitative data in relevant policy documents and in semi-structured, in-depth interviews (Annex 1). Two case cities, Rotterdam in The Netherlands and Yokohama in Japan, are chosen.

Two key theoretical frameworks, the Protect-Accommodate-Retreat-Avoid (PARA) framework and urban resilience diagnosis, are applied in this study. As presented in the second section, the PARA builds a complete structure that acknowledges the progressive strategies for a coastal city to mitigate the risks of rising sea levels. Every associated policy and program in a given place and time is described and conceptualized in the framework. According to the data collected, the urban resilience diagnosis then rates multiple parameters of eleven principles in four phases, assigning values with a five-point Likert scale: "– –" to indicate weak resilience and "++" to indicate strong resilience (Annex 2). It sheds light on a comprehensive evaluation of the effectiveness of a city's resilience-building to sea-level-rise. A visualization with radar charts of the overall resilience quality creates a glance into whether the resilience principles are fulfilled, neutral, or flawed. Moreover, it allows for a comparison between the two cases.

To ensure that all types of stakeholders with diverse perspectives are taken into account, a total of eleven individuals, representing eight different organizations, are selected as the subjects of the study and interviewed as key informants (Annex 1). Organizations involved in the study include municipal and city level government entities, enterprises, civil society organizations, research institutions and consultancies; only individuals with sufficient experience in their position within the respective organization are addressed.

By organizing the analysis along two dimensions with two cases, the study elaborates that delta cities have developed common strategies to defend against sea-level rise, which follows a general pattern, a PARA framework. The study also allows discovering that cities have different advantages and disadvantages while building their resilience, which are rooted in different governance, social, and cultural contexts. At last, the study furtherly discusses the relationships between a city's resilience-building and its long-term sustainable development.

Results

Case study Rotterdam

PARA strategy

"God created the world, but the Dutch created Holland". The Netherlands has hundreds of years' experience of fighting against water. At present, the sea level on the Dutch coast is rising by 20 cm every century, and the speed is accelerating (Suiker, 2018). Highly embedded with resilience thinking, the PARA strategies city of Rotterdam adopts balance out the specific solutions, making the city overall protected against the sea.

Protect	Hard engineering projects: Storm surge barrier-dam-dike system (The Maseslant storm surge barrier[4], 50-kilometer dikes[5] inland, reinforcement of existing dikes.) Pump water out (900 pumping stations (Brears, 2018), e.g., Kinderdijk Windmills) Attenuation and collection of stormwater runoff (permeable pavement in pedestrian pathways, water-squares, bioswales, private "rain gardens" and "façade gardens") Soft engineering structure: Water square[6] (e.g., Museumpark[7], the water square in Benthemplein[8]) Urban river ecological restoration (River Schie, River Rotte)

[4] The Maseslant storm surge barrier is the largest hydraulic engineering work in the Netherlands and works automatically. When a water level that equals +3m NAP or above is forecasted, the two huge curved gates close the New Waterway. In this way Zuid-Holland is protected against high tides.

[5] Netherlands' dike network extends for over 22,000 kilometers, while the Dutch coastline measures a mere 880 kilometers.

[6] A water square is composed of a collection basin where rainwater is collected and retained. The water square is dry for most of the time and is then used as any other public space in the city.

[7] A park which accommodates 1,150 cars, and also houses a reservoir with a capacity of 10,000 m³ when there is heavy rainfall. As soon as the sewer system threatens to overflow, the hatch of the underground water reservoir is opened, the reservoir fills up with 10 million liters of water. When the downpour ends, the water in the reservoir is pumped into the sewer.

[8] The square functions as a green space and provides opportunities for activities such as skate-boarding. When it rains heavily the square functions as a water storage reservoir.

Accommodate	Recreational dikes (e.g., multi-functional terraced dike[9], dikes integrated into cycling routes, dike warehouse, Dakpark[10]) Adaptative floating constructions (e.g., Floating Pavilion[11]; Floating farm[12]; BlueCity[13], Floating community in Rotte River) Create early warning and monitoring system (responsible departments: The Royal Netherlands Meteorological Institute[14], Rijkswaterstaat[15], Water board[16], Rijnmond rain radar[17]) Improvement of the drainage system
Retreat	Land-use restrictions in outer-dike areas[18] (Construction work is only allowed if the same elevation is raised to maintain the height of ground)
Avoid	Land-use restrictions in outer-dike areas Urban design to avoid pluvial flooding in inner-dike areas (e.g., Green Roof[19], permeable pavements, the transformation of Zoho district[20], Blue corridor[21])

Table 3. Detailed PARA strategies in Rotterdam

Being on the frontline of sea-level rise, the PARA strategies in Rotterdam follow comprehensive and systematic protection: a “storm surge barrier-dam-dike” system as hard engineering solutions and multi-use water squares as soft engineering solutions. The idea of “accommodate” and “avoid” is performed in urban design as Rotterdam “let water in”, employing storing rainwater, enhancing drainage capacity, and creating floating buildings according to the city’s geographical conditions, etc.; many innovations emerge with various ways of Rotterdam’s adaptation efforts. However, as

[9] With wide terraces on both sides that can be used for road construction, landscaping and even building construction, enabling it to generate revenue and add value to the districts (Brears, 2018).
[10] With 1000 m long and 80 m wide, as an elevated park on a former railway yard, the Dakpark plans to build a new shopping center, and the largest green roof in Rotterdam.
[11] The Floating pavilion consists of three interlinked spheres, the largest of which has a radius of 12 meters. The floor space of the pavilion island is over 46 to 24 meters.
[12] Launched by a Dutch property company, Beladon, Floating farm has built the offshore facility in the middle of Rotterdam's Merwehaven harbour and is farming 40 Meuse-Rhine-Issel cows milked by robots.
[13] Bluecity is situated in former subtropical 12,000-square-meters swimming oasis Tropicana, and functions as an incubator for circular entrepreneurs.
[14] Also called KNMI, the Dutch national weather service. It forecasted an increase of sea level rise of 35 to 85 cm in the period until 2100 in The Netherlands.
[15] An agency for public infrastructure works and water management. Annual average sea level for The Netherlands is determined on the basis of the measurements from Rijkswaterstaat’s six main stations.
[16] There are 21 regional water authorities – water boards in the Netherlands. Water boards work on water safety, water quality and water quantity, as well as improving dike conditions. Municipality Rotterdam is managed by 4 water boards: Delfland, Schieland & Krimpenerwaard, Rivierenland, Hollandse Delta.
[17] Installed in Rotterdam in 2015, the radar was installed on the roof of one of the tallest buildings in city center.
[18] The outer-dike areas are not protected by dikes and are directly affected by sea level rise. While the inner part is well-protected by dikes and therefore is less vulnerable. Most of inner-dike Rotterdam is below sea level.
[19] Between 2008 and 2014, Rotterdam provided a subsidy scheme (up to EUR 30 per m^2) to promote the creation of green roofs. It led to 150,000 m^2 of green roofs developed.
[20] The Zomerhofkwartier (Zoho) district was built after World War II, mainly to accommodate businesses and schools. A new concept of “slow urbanism” was promoted in 2014 in this district.
[21] As a 10-year plan from 2012, it aimed at a green-blue link between the Zuiderpark in Rotterdam, the future landscape park Buijtenland in Rhoon and the Zuidpolder in Barendrecht. It will act as a water storage facility.

densely populated and urbanized, there is a lack of “retreat” plans, especially for the unprotected outer-dike areas, which prepare for the worst case.

Urban resilience diagnosis

Rotterdam Resilience Strategy was formally published in 2016, ambitiously targeting technological innovation, democracy, and preparing for climate change in 2030. Regarding the current situation, below is the assessment of the city’s resilience building (Figure 2) for it. The evaluation is based on data collected through document review and information gained during interviews with key stakeholders in Rotterdam (Annex 1).

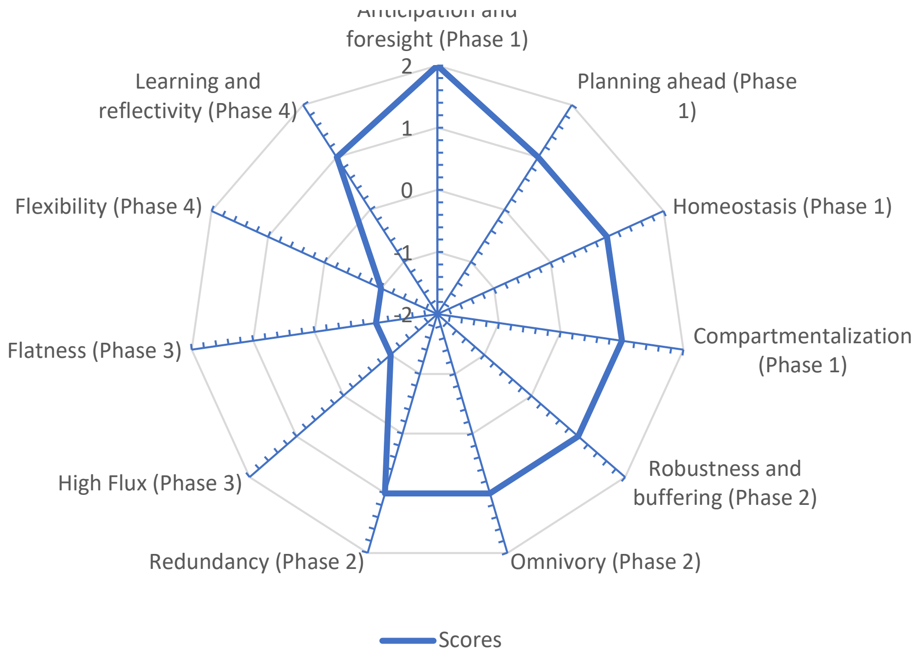


Figure 2. Diagnostic diagram of resilience-building to sea-level rise in Rotterdam. Resilience principles cover 4 focal directions with 11 principles (see also Table 2): Phase 1) planning and preparation, Phase 2) absorb, Phase 3) quick response, Phase 4) adaptation. The scale ranges (Annex 2) from -- (-2; very weak currently, very negative impact of plans) to ++ (+2; very strong currently, very positive impact). The diagnosis model is created based on (Wilk, 2016) and (Wardekker et al., 2017).

Concerning its strength, weaknesses, opportunities, and threats, firstly, Rotterdam has a long history of living on a seacoast; after the 1953 North Sea flood[22], overall precautions are updated with multi-layer dikes and a national monitoring system. Therefore, the city is strong in Phase 1) planning and preparation, especially in “anticipation and foresight”: various technologies are utilized, the city is intensively involved in knowledge exchange (e.g., 100Rc). With 41 m^2 of green space per resident[23]

[22] A flood caused by a heavy storm that occurred on the night of 31 January and morning 1 February 1953, large areas of the Netherlands were flooded and 1,835 people were killed.
[23] Source: land use statistics 1996, Rotterdam Urban Vision. The number in Rotterdam is higher than Amsterdam, Utrecht, Den Haag.

and continuous ecological restoration, Rotterdam receives a high score in "planning ahead". High diversity and solidness of flood defense systems lead to relatively high levels of "robustness", "homeostasis", and "compartmentalization". The Delta Fund[24] also provides financial resources for flood risk. These can positively mitigate the potential consequences of sea-level rise. However, there are either emergency response or buffer zones created for sea-level rise yet.

Secondly, Rotterdam is a mega port city, with 50% of residents are non-Dutch origin (estimated 2009), contributing to its cultural diversity. The city is also promoting cycling routes, diverse new energy use such as wind (e.g., the Haliade-X 12 MW[25]), solar and biomass, as well as the energy-neutral built environment. Gaining high credibility, water governance in Rotterdam involves multi-level actors (water board, Rijkswaterstaat, municipal government, Resilience Office) and redundant solutions (Water Act, Resilience Strategy, Climate Proof, Delta program, etc.). Therefore, the city receives a high score in "redundancy" and "omnivory", in Phase 2) absorb, efficiently preventing the "system failure". However, the inefficient bureaucracy limits the room for institutional reform, and to break such path dependency is very difficult, which reduces efficiency in cross-departmental collaborations. "Normally, no one would like to take the leading position in joint operations, and the project will always be dragged and even left unsolved in the end" (Interview, Annex 1). An example can be seen from the current function of the function of Rotterdam Resilience Office. Although releasing the Resilience Strategy, the Office still has no real authority to initiate new plans, which has drawn criticism like "founding this office is nothing but a city branding strategy" (Interview, Annex 1). Therefore, the scores for "high flux" and "flatness" in Phase 3) quick response are low, it reveals a lack of governance capacity of maximizing promptness in response.

Lastly, as being protected by dikes for hundreds of years, Rotterdam's local population has not treated sea-level rise as an urgent threat; the corresponding public participation is quite low. Spatially, to create anticipatory physical, structural elbowroom for future adjustments or extensions is also impossible in the densely developed outer-dike area. Therefore, the level of "flexibility" in phase 4) adaptation is low, which means the ability of self-sufficiency, self-regulation, and self-organization, is still doubtful. On the other hand, due to Rotterdam's business-friendly climate, private sectors actively invent new adaptative ideas; the pilot project floating farm has set an example. This, along with water squares and multi-functional dikes, show a higher score in "learning and reflectivity" in Phase 4) adaptation.

[24] Supplied from Central Government. In the period 2019-2032, a sum of approx. 17.5 billion euros will be available in the Delta Fund, which brings the average annual budget to nearly 1.3 billion euros. However, only a small percentage of it is non-allocated, which is relatively flexible.

[25] The most powerful offshore wind turbine in the world, Rotterdam Port is chosen as the test location in 2019.

Sustainability analysis

In Rotterdam, most of the PARA strategies are implemented with no regrets and in the long term. High technology is also actively applied. Concerning the relationships between resilience and sustainability, in Rotterdam, resilience-building creates added value for sustainability: the PARA strategies impact sustainable development from three “pillars” (economic, social, and environmental perspectives). Many examples can be seen: The recreational dikes, water squares, green banks, and green roofs increase green spaces in the city; Bluecity is an incubator for circular economy; The floating constructions offer pilot lessons towards the city’s transformation to a creative and knowledge-based economy; New Zoho district improves the life quality of vulnerable groups.

Moreover, the economic and environmental considerations are particular components integrated into Rotterdam’s resilience-building, as the high motivation from private sectors and the target of stimulating ecological values are planted in the first place in many adaptative initiatives. In contrast, public awareness of sea-level rise is still limited. Because of insufficient local participation and empowerment in this specific issue, the PARA strategies may not be socially sustainable.

However, while facilitating both resilience and sustainability, Rotterdam Resilience Office does not have a precise answer (Interview, Annex 1) about how to balance or integrate one into another. The resilience strategy is criticized as “nothing but a big umbrella covering everything already existing (Interview, Annex 1)”. This vagueness and the limited connectivity across governments result in overlapping in implementations of the city’s resilience building and sustainable development. Under the rise of sea levels, these difficulties in institutional change will possibly be an obstacle for the transition of resilience from “just a buzzword to an operational paradigm for system management” (Linkov et al., 2014).

Case study Yokohama

PARA strategy

Tokyo Bay is an area notoriously prone to massive natural disasters like storm surge, typhoon, tsunami, earthquake. Yokohama, a central commercial hub of the Greater Tokyo Area, is currently relying on 150 km coastal dikes and 157 km river dikes in Tokyo Bay (Ruiz Fuentes, 2014). Yokohama is now facing significant challenges like an accelerated aging population, a declining economy, and energy-transition necessity after the 2011 Great East Japan Earthquake[26]. Therefore, the PARA strategies are prepared for extensive potential natural disasters (Table 4).

[26] Happened on 11 March 2011, it was the most powerful earthquake recorded in Japan and resulted in the Fukushima Daiichi nuclear disaster. Since then, nuclear power plants started to be shut down in Japan.

Protect	Harding engineering projects: Flood gate-dam-super levee[27] system (see also Annex 3) Floodways River channelization Attenuation and collection of stormwater runoff (permeable pavement in pedestrian pathways and parks, 22 stormwater storage pipelines with 1,059,000 m^3 capacity, 9 stormwater reservoirs with 245,000 m^3 capacity, rainwater tanks, detention basins, installation of infiltration inlets[28]) Soft engineering structure: Multipurpose retarding basin (the Kirigaoka Regulating Reservoir[29], Yokohama International Sports Stadium[30])
Accommodate	Renewal of dikes to super levees Create an early warning and monitoring system (responsible departments: Japan Meteorological Agency[31], City of Yokohama[32]) Erect emergency shelters (113 evacuation sites[33]) Improvement of the drainage system
Retreat	Set set-back waterfront zones (Waterfront Axis[34], Kanazawa waterfront city[35]) Re-purpose land use in Minato Mirai[36] (creation of pedestrian spaces) Kanazawa land reclamation[37]
Avoid	The urban design of green spaces (10 major locations, 461.5ha, and 160 sites[38]; e.g., Green Axis[39]; Improve parks; Design pedestrian network in Minato Mirai)

Table 4. Detailed PARA strategies in Yokohama

The PARA strategies in Yokohama form robust protection against the sea. The idea of urban design is "to keep water out", with continuous updates of the expensive super levees. Inside the city, efforts are made to strengthen ecological functions such as building multipurpose retarding basins,

[27] A "super levee" is a thick embankment created by applying a layer of fill material over a conventional embankment. This dike has a very gentle inner slope on which urban rehabilitation is possible. Super levees are designed to prevent catastrophic flood damage and thus are very costly.

[28] Residents are recommended to install infiltration inlets on their own properties and the costs are partially subsidized by the City of Yokohama (Interview, Annex 1)

[29] The reservoir is used as a tennis court in normal time.

[30] It is designed to regulate the amount of water flowing into the river during a flood and can hold a maximum of 3.9 million liters of flood water. The elevation of the basin is lower than the surrounding area.

[31] Responsible for monitoring national sea levels since the 1980s. It is also in charge with emergency warnings, disseminated through administrative organs and wide variety of media.

[32] Responsible for issuing emergency warnings if heavy rain, storm, storm surge, high waves, snowstorm, heavy snow, earthquakes, tsunami and volcanic eruptions on a scale is observed. It also provides shelter lists.

[33] Source: https://translate-en.city.yokohama.lg.jp/kurashi/bousai-kyukyu-bohan/bousai-saigai/map/koiki/hinan/20150225175223.html

[34] In 2010, the Urban Waterfront Area Inner Harbor Project proposed to develop a ring-shaped urban structure around the Bay of Yokohama, a Waterfront Axis, which used to be dominated by heavy industries and factories in the 1960s. It aimed to preserve and form coastwise greeneries.

[35] Kanazawa Ward is located in the southeast corner of the city of Yokohama, bordered to the east by Tokyo Bay.

[36] A seaside urban area in central Yokohama, the Master Plan-based Development for the Minato Mirai 21 District targeted to forming a pedestrian network.

[37] Starting in 1971, Kanazawa Land Reclamation Project primarily aimed at creating a site for relocating factories. The site selected for the relocation is situated approximately 15km from the center of Yokohama.

[38] As of September 2018, source: https://www.city.yokohama.lg.jp/business/bunyabetsu/kenchiku/toshikeikaku/yoko/sankou/history.files/0005_20190411.pdf

[39] An organic connection that travels from inland to the sea.

improving rainwater infiltration, creating green connections. Located in the world's most densely populated metropolis, Yokohama is making maximum use of every piece of the land proceeding with flood control and urban improvement simultaneously (Takeuchi, 2002): along with reclamation of land, the super levees make the land traditionally used for embankments alone be available for use as parks, green spaces, roads, as well as for emergency evacuation sites. Another added value in Yokohama's PARA strategies is "retreat": thanks to enormous lessons learned from multi-scale natural disasters, notably the earthquake, Yokohama has thorough planning for evacuation. However, Given the city's dense urbanization, the waterfront areas have been precisely identified and not ready to be abandoned.

Urban resilience diagnosis

Urban resilience building in Yokohama focuses on disaster-resilience like earthquakes, tsunami, typhoons, fire, and floods, of which the consequences involve considerable uncertainty; thus, these measures also have a high potential to withstand perturbations caused by sea-level rise. Below is the assessment of the city's resilience building (Figure 3) for it. The evaluation is based on data collected through document review and information gained during interviews with key stakeholders in Yokohama (Annex 1).

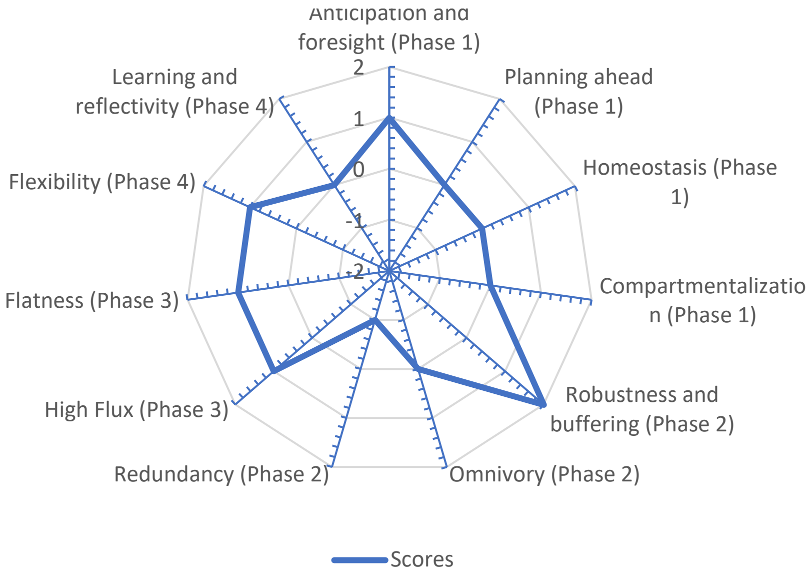


Figure 3. Diagnostic diagram of resilience-building to sea-level rise in Yokohama. Resilience principles cover 4 focal directions with 11 principles (see also Table 2): Phase 1) planning and preparation, Phase 2) absorb, Phase 3) quick response, Phase 4) adaptation. The scale ranges (Annex 2) from -- (-2; very weak currently, very negative impact of plans) to ++ (+2; very strong currently, very positive impact). The diagnosis model is created based on (Wilk, 2016) and (Wardekker et al., 2017).

Concerning its strengths, weaknesses, opportunities, and threats, firstly, Yokohama is influential in engineering “robustness and buffering” in phase 1) planning and preparation, with super levees as an excellent example. “What this fragile island spends on fighting against natural disasters is enormous; “to defend” or “to protect” is in the blood of Japanese culture (Interview, Annex 1)”. Whereas relying too much on the single protection of super levees, as well as a lack of diversity in corresponding governance functions and roles, low scores are captured in “redundancy” and “omnivory” in phase 2) absorb. A similar trend happens to “learning and flexibility” in phase 4) adaptation; counting on past experiences limits innovations of new adaptative ideas from private sectors.

The nation-wide sea-level-rise rate projection and the Climate Change Adaptation Platform[40] offer research results on climate change impacts. Japanese has a complete monitoring system regarding all types of natural disasters, well connected to citizens, and well-rooted in the education system. These elements result in a better performance in “anticipation and foresight”. However, the City of Yokohama has not taken a sea-level rise in prioritized urban planning and is not extensively involved in global knowledge networks, the stage for “planning ahead”, “homeostasis”, and “compartmentalization” stays “business as usual” (Interview, Annex 1).

With rich experience in disaster recovery, Japanese institution gains high scores in “high flux”, “flatness” in phase 3) quick response and “flexibility” in phase 4) adaptation. The General Director for Disaster Management[41] is mandated to plan necessary disaster management policies and overall coordination and collaboration (Suzuki and Kaneko, 2013). All Japanese government ministries are more or less in charge of disaster management, and they have the power to issue specific disaster-related legislation and laws. By providing evacuation advisories for different types of disasters, Yokohama is supposed also to quickly respond to sea-level rise.

Sustainability analysis

In Yokohama, PARA strategies are implemented in three pillars: economic, social, and environmental aspects, in the long term and with high cost, thus, with no regret. The public awareness of sea-level rise is still limited. “There was a certain period when the issue of sea level attracted the public attention, but that was in the context of Tsunami and earthquake after 2011 Great East Japan Earthquake, not of climate change (Interview, Annex 1).”

[40] A-PLAT: http://a-plat.nies.go.jp/webgis/index.html
[41] The position of Minister of State for Disaster Management was established in 2011 in Japan.

About the relationship between resilience and sustainability, the *Middle plan for the period of 2018-2021* tends to combine sustainability and resilience, with the same goals and achieving methods. However, the implementations of these two seem to be separated. Like all Japanese cities, Yokohama has a deep sense of crisis. Current resilience-building continues the traditional idea of coping with disasters, such as 10-meter super levees. Moreover, sustainable development seeks new solutions for urban challenges, such as renewable energy (e.g., Zero Carbon Yokohama) and creative industries. There is a lack of paradigm shift towards the perspective of adaptation, making it difficult to comprehend how to integrate resilience into sustainable development, as well as how to invent new solutions. Just as Climate Change Policy Headquarters stated: “The Adaptation Strategy is still on paper” (Interview, Annex 1).
An added value in Yokohama is citizen power: Initially, Yokohama launched *Area Development Project,* which supported residents’ own community development efforts in 1992. Stepping in the 21st century, the establishment of the *Ordinance for the Promotion of Civic Activities* in 2000 and *Ordinance for the Promotion of Community Planning* in 2005 forward the community development. “There is a high level of civil power that has solved various issues so far (Interview, Annex 1)”. Therefore, more opportunities should be discovered from bottom-up pathways.

Comparison and conclusion

Comparison between Rotterdam and Yokohama

Rotterdam and Yokohama are two delta cities, representing humans encroaching the sea for hundred years and nowadays being in the frontline of sea-level-rise threats. Both cities have explored their PARA strategies to defend coastlines and adopt adaptation ideas. Regarding “protect”, Rotterdam and Yokohama have applied similar approaches of flood control throughout the centuries, which is remarkable due to the differences in geographical location and meteorological conditions (Stalenberg et al., 2008): There are massive flood-defense constructions in hard-engineering aspects and a combination of urban functions and flood protection for soft engineering strategies. One difference is that the Japanese appear to continue advancing on the sea, but the Dutch start to adopt the idea of “let water in”. However, the unprotected outer-dike areas in the two cities are both the most vulnerable; development continues by raising the entire coastal land. As for “accommodate” solutions, trying to utilize the land efficiently, Rotterdam and Yokohama recreate their dikes (multi-functional dikes and super levees). However, the land-use requirements remain unchanged in floodplains, and there are no types of insurance for properties yet, either in Rotterdam or in Yokohama. Both assume their defense is unbreakable. Nevertheless, each city has its advantages: Rotterdam breeds many innovative adaptive designs such as floating infrastructure, and Yokohama has a better-prepared emergency evacuation system. Concerning “retreat” and “avoid” solutions, though Rotterdam and Yokohama try to increase greenery and blue corridors, there is no thorough evacuation plan for large-scale areas.

Rotterdam and Yokohama commence resilience-building intensively. In Rotterdam there is Rotterdam Resilience Strategy, and in Yokohama resilience building is addressed out in several official plans. Below (Figure 4) compares their resilience diagnosis: Firstly, Rotterdam is actively taking measures in phase 1) planning and preparation. In phase 2) absorb, with expensive super levees that are likely unfeasible for other cities, Yokohama has better performance in “robustness and buffering”. In comparison, Rotterdam has more diverse and “redundant” solutions. As for the phase 3) quick response and phase 4) adaptation, because massive damage caused by natural phenomena of extraordinary magnitude frequently occurred in Japan, Yokohama has a higher level of “high flux”, “flatness”, and “flexibility”, referring to a fast mobilization of resources and a flexible structure be operational under fast-changing conditions. On the other hand, Rotterdam shows strong “learning and reflectivity” abilities by offering a favorable innovation environment.

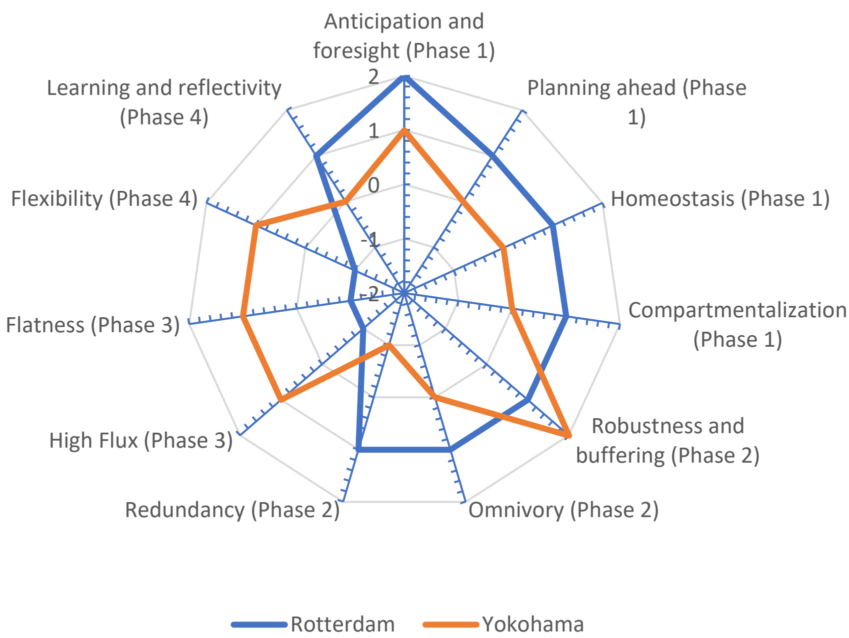


Figure 4. Diagnostic diagram of comparison of resilience-building in Rotterdam and in Yokohama. Resilience principles cover 4 focal directions with 11 principles (see also Table 2): Phase 1) planning and preparation, Phase 2) absorb, Phase 3) quick response, Phase 4) adaptation. The scale ranges (Annex 2) from -- (-2; very weak currently, very negative impact of plans) to ++ (+2; very strong currently, very positive impact). The diagnosis model is created based on (Wilk, 2016) and (Wardekker et al., 2017).

For the relationship between resilience and sustainability, Rotterdam and Yokohama's PARA strategies are both precautions for climate adaptation and have economic, social, and environmental considerations. Thus, the idea of sustainability is embedded in resilience-building. However, one

similarity between the two cities is that the public awareness about sea-level-rise consequences is relatively low since people trust their flood-defense system very much. In the long term, with a reliable citizen power, Yokohama may create more social impacts. On the other hand, in composing an excellent economic environment, Rotterdam may encourage new ideas from private actors.
The research also found a high potential for international cooperation with the arrival of Sdgs. Rotterdam and Yokohama have ever collaborated in the field of resilience building, however, the Resilience Office in Rotterdam and Climate Change Policy Headquarters in Yokohama, two responsible institutions, both indicate similar challenges: 1) Urban resilience-building remains as an "umbrella-kind" idea; 2) The vagueness of the concept "resilience" makes it hard to integrate into renewal policy cycles; 3) The affiliated "resilience" institutions have limited power for issuing and implementing new policies or plans; 4) The connectivity and cross-departmental collaborations for linking resilience and sustainability are very limited. Based on these findings, for local institutions in Rotterdam and Yokohama, the stately institutional change is necessary to break decisively with the past and to respond rapidly to the quickly changing circumstances of sea-level-rise impacts. From an international perspective, the similarities discovered from the two case studies can be generalized and global knowledge-sharing may provide creative solutions to these common challenges, hereby a novel and systemic international cooperation scheme for developing resilience on a large scale is recommended to establish, complying with the globally-shared blueprint – sustainable development.

Conclusion and discussion

The speed of sea-level rise is accelerating, a variety of adaptative strategies emerge worldwide; the PARA framework sheds light on the consummation of the primary practical efforts and affords lessons for delta cities to adapt to sea-level rise systematically. The similar pathways Rotterdam and Yokohama have followed demonstrates the framework's universality and effectiveness. With results in Rotterdam and Yokohama, the study shows that resilience thinking has already fitted in current development strategies and climate policies in both Europe and Asia, and there is an evident willingness to trigger urban transformation by climate adaptation. However, as the concept of resilience is vague, it is difficult to integrate it into the existing development plans, as well as to issue "tangible" or "real" strategies for policymakers. Moreover, different cities have different understandings and implementation manners of resilience-building in which the historical, political, and sociocultural settings play an essential role. Both results from Rotterdam and Yokohama proves that the relationship between sustainability and resilience is very complicated, with inconsistency between two concepts and additional overlaps and fuzziness in implementations. Local governments have struggled with inefficiency in either defining the boundaries of two approaches or implementing repetitive solutions, which is criticized as a waste of investment.

Thus, the accurate interpretation of resilience and the concretization of sustainability in urban development should be the new emphasis on deploying climate adaptation strategies. On a local scale, various social innovations, climate change education, and broader public participation should be encouraged. On an international scale, integrating resilience-enhancement into achieving The 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change should be a consensus. New international cooperation for inclusive development for all delta cities with rising sea levels should be established explicitly in terms of 1) capacity building; 2) organizational resources; 3) technology cooperation; 4) policy experience sharing. Such cooperation will offer good opportunities for unifying effort and acting jointly to tackle the global issue of sea-level rise. Under the scheme, the pioneers should maximize their impacts and visibility; Rotterdam and Yokohama are supposed to cooperate and coordinate closely with less-developed regions by providing good practice, technical assistance and knowledge sharing. Further research should fruitfully explore the context-specific resilience-building, the relationship between path dependency and institutional change, etc., concerning inter-and transdisciplinary disciplines and project-based collaborations.

Annex

Annex 1: Interviewees in Rotterdam and Yokohama

Rotterdam, The Netherlands:

Engineer, Floating Farm Rotterdam
Senior advisor in City of Rotterdam, in charge of Rotterdam Climate Initiative
Policy coordinator of Municipality of Rotterdam, in charge of urban development in the BAP Team Next Economy / Sustainable Department
Researcher in the city's Chief Resilience office, in charge of the Resilience program of Rotterdam
Researcher, a supervisor in IHS (Institute for Housing and Urban Studies, Erasmus University Rotterdam) and works for a political party for animals in Rotterdam

Yokohama, Japan:

Climate Change Policy Headquarters, City of Yokohama

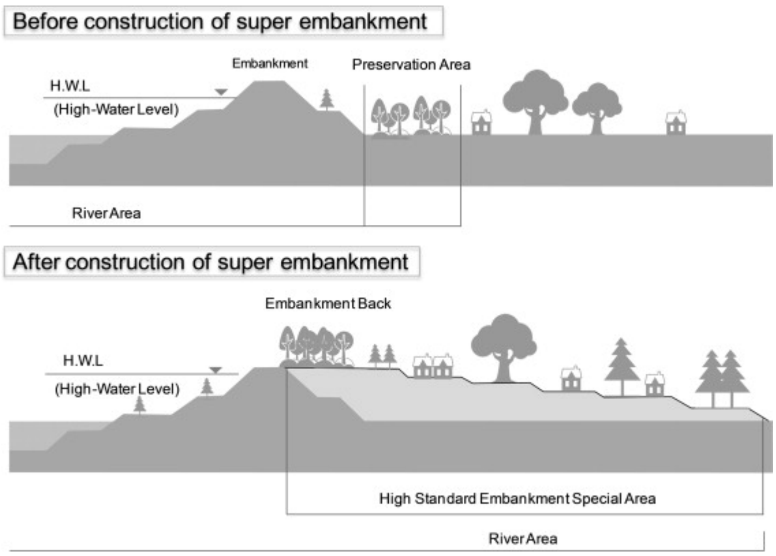
Sewerage Management Division, Kanagawa Prefectural Government
Sewage Management Division, Environmental Planning Bureau, City of Yokohama
Environmental Planning Division, Kanagawa Prefectural Government
Professor, Faculty of Contemporary Society, Kyoto Women's University
Professor, Research Institute of Sustainable Future Society, Faculty of Civil and Environmental

Engineering, Waseda University

Annex 2: Scoring scales for urban resilience assessment (Wardekker et al., 2017)

--	-	0	+	++
The current situation is very weak regarding the principle. There are key weaknesses in most aspects, no strengths. Opportunities may be missed.	The current situation is weak regarding the principle. Either overall weak or a mix of weaknesses and strengths that are still largely unfavorable.	The current situation is neutral regarding the principle. A mix of strengths or opportunities and weaknesses, with an overall neutral or unclear effect.	The current situation is strong regarding the principle. Either overall strong or a mix of weaknesses and strengths that is still largely favorable.	The current situation is very strong regarding the principle. There are key strengths in most aspects, no weaknesses, and possibly valuable opportunities.

Annex 3: Before and after the construction of super levee (Luo et al., 2015)



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Acronyms

Asean	Association of Southeast Asian Nations
Ascc	Asia Smart City Conference
Czms	Coastal Zone Management Sub-group
Ipcc	Intergovernmental Panel on Climate Change
Oecd	Organisation for Economic Co-operation and Development
Para	Protect-Accomodate-Retreat-Avoid
Sdg	Sustainable Development Goals
Sid	Small Island Developing Nations
Un-desa	United Nations Department of Economic and Social Affairs
100Rc	100 Resilient Cities