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Exploratory analysis of living labs contribution to climate adaptation needs and innovative multifunctional dikes in the Netherlands

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Abstract

Climate adaptation strategies are commonly dubbed complex and context-specific. Institutional and social innovations, participatory and learning processes are among the needs for effective climate adaptation measures. In counterpart, living labs have emerged as open collaborative platforms for innovative solutions, actively involving users and responding to their specific contexts and needs. Although living labs experiences yielded success and proved utility, research on living labs for climate adaptation are noticeably limited.

The present exploratory research aims at identifying the distinguishing characteristics of living labs, then assesses their contribution to climate adaptation needs via the analysis of three selected case studies. The research also sheds light on the new integral approach for flood defense in the Netherlands. The potential contribution of living labs to innovative multifunctional dikes governance is explored, backed up with the insights of Dutch stakeholders interviewed and three case studies analysis.

The study finds that climate adaptation living labs differ in goals, activities and results but the methodologies applied are catalyzing climate adaptation innovation, participation, knowledge co-production and learning. In addition, the exploration revealed that connectivity between actors, creation of shared vision, and science-policy bridging are among the living labs contributions to multifunctional dikes governance.

Key words: Living Labs, open innovation, user-driven innovation, climate adaptation needs, flood risk management, multifunctional dikes.

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I.1 Background

Research published on climate change effects, predict for future generations to witness warmer and longer periods of drought, frequent heat waves, heavy rainstorms and severe coastal flooding's. If anthropic emissions concentration in the air continue their ascent, the 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC), predicts for a worst scenario of 2.6C temperature increase, a sea level rise of 32cm by 2050, and 5cm for a 0.8C scenario[1] (IPCC, 2014). On a global level, climate disasters will send thousands of refugees across borders, destabilize nations and cause wide spread extinction of species, most of cities below sea level will be forced to be abandoned.

Countries have responded to climate change through mitigation efforts and adaptation efforts. The mitigation efforts have focused on reducing or preventing emission of greenhouse gases (GHG) emissions, while climate adaptation has aimed to adjust natural and social systems to the consequences of climate change, to moderate the harm, and to exploit beneficial opportunities (IPCC, 2001). Both climate mitigation and climate adaptation efforts have made progress since Kyoto Protocol and later on, when Paris Agreement was adopted by over 170 nations (UNFCC, 2018).

Despite a growing number of climate mitigation policies, the environmental disruptions resulting from global warming, are happening faster than the population and the ecosystems can cope with. Changes in climate have impacted natural and human systems on all continents and across the oceans. Annual GHG emissions grew on average by 1.0 $GtCO_2$-eq (2.2%) per year, from 2000 to 2010, compared to 0.4 $GtCO_2$-eq (1.3%) per year, from 1970 to 2000 (IPCC, 2014).

Although adaptation can substantially reduce the risks of climate change impacts, there are factors that complicate implementing adaptation measures. The potential for adaptation, as well as constraints and limits to adaptation, varies among sectors, regions, communities and ecosystems. The scope for adaptation changes over time and is closely linked to socio-economic development pathways and circumstances.

Climate adaptation therefore requires the mobilization of knowledge, capacities, political and financial support, and scientific expertise to increase resilience to climate change. It necessitates a wide-range of interventions: governance, innovations, society engagement, etc (IPCC, 2014; Denton et al., 2015; EU, 2013). Filho, (2016) reported that successful implementation of adaptation policies, may only be achieved by a combination of a wide range of innovative approaches, methods and processes, with both a technical/technological and a non-technical dimension.

In the light of the aforementioned, the present thesis studies how effective adaptation could be enhanced through what is known as "Living Labs", as they seem to pertain several

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[1] Annual temperature relative to 1990 averaged across simple climate model, IPPC, 2014

requirements for successful adaptation, and are often presented as a contemporary initiative in which citizens, institutions, businesses and governments can jointly seek innovative solutions to complex social issues of our time such as climate adaptation.

However, there is no single definition of living labs in the literature, but they are strongly linked to open innovation processes and to participatory approach for co-creation and decision making, they differ from ordinary laboratories, not only in terms of the space where the experiment is done, but also in terms of the methods usesd, the nature of activities and their learning functions. The research will bring further understating on the aspects distinguishing living labs from other innovation approach. The innovation aspect of living labs refers to the development of new products (i.e., an object, service, technology, application, process, or system) and to the discovery of new solutions to existing problems. Learning and experimenting refers to the production and exchange of knowledge among participants (Steen & van Bueren, 2017).

In the Netherlands, the knowledge available has shown that climate adaptation is a necessity, in particular in two areas: climate resilience of infrastructure, and spatial development. Insuring climate resilience of the country is largely associated to flood risk management, and a new generation of flood protection structures has emerged, defined as integral solutions, where spatial adaptation and society are considered along with flood safety. Among these innovative structures are multifunctional dikes[2], offering an improved flood protection compared to traditional flood defenses (mainly dikes), and allowing added functions to the dikes, e.g. nature preservation, spatial development, and socio-economic benefits.

In this regard, the thesis is also concerned with flood risk management in the Netherlands, as an urgent adaptation task for the country, with focusses on multifunctionality of flood defenses (dikes) as an innovative way to improve adaptive capacity to flood risk, increase resilience and seize additional benefits for society. Moreover, existing experiences of multifunctional dikes are still at the level of pilots. Thus, the research on the possible contribution of living labs to the development of this innovative flood protection concept, was deemed of interest to the future adaptation plans of the country, as the living labs' attributes for innovation could support multifunctional dikes as an innovation.

I.2 Problem statement:

Climate has always been changing but recent changes has happened in much shorter time frame leading often to significant impacts: destroying lives and habitats, damaging infrastructure and disrupting communication and trade. The development of decisions and policies for the coming years will determine the frequency of these impacts and the effectivity and efficiency of Holland's capacity to adapt.

Commonly, adaptation to climate change is perceived as a learning process, and strategies need to integrate it into all levels of development and planning. Therefore, critical elements

[2] A dike is an artificial elevation that protects the underlying land from high water and waves. There are 3 main types of dikes: seawater retaining dikes, river dikes and inland dikes (Rijkswaterstaat official website, 2018).

of adaptation efforts include involving decision makers and both creating their awareness and increasing their understanding of the need for society to adapt.

Concrete methods are needed to collaborate and facilitate action, and it is essential that all parties are engaged: local governments, independent governing boards, the private sector and NGOs. Under this paradigm shift, the roles in society are changing. Citizens and business have more responsibilities under what is coined a “participatory approach”, they can lead initiatives, innovate and accelerate adaptation measures.

Participatory processes to tackle a complex problem such as climate change, requires innovative tools for participation and networking. Living labs emerged in the last decade as open and user centered platforms to fill in these requirements, albeit the method of living labs remains divergent from one project to another, and their contribution to climate solutions beyond these projects or single experiences requires systematic examination.

I.3 Research objective and questions

The research aims at exploring the possibilities of living labs as an innovation approach, define their distinguishing characteristics, and assess how they can contribute to**: i.** climate adaptation needs (innovation, information, participation, etc.), and **ii.** multifunctionality of flood defenses (dikes) in the Netherlands, as an innovative solution for flood resilient management.

Main research question: what are the defining characteristics of living labs, their contribution to climate adaptation needs, and the resilience of flood risk management in the Netherlands, through multifunctional dikes?

Accordingly, the study will address the following sub-research questions to answer the main research question:

1) What are the definitions, methodologies and contexts of living labs?
2) What are the defining characteristics of living labs?
3) What are, if any, the advantages of living labs to contribute to climate adaptation needs?
4) What is the possible contribution of living labs approach to multifunctionality of dikes in the Netherlands?

I.4 Research scope

The scope of the investigation is limited to living labs that are potentially contributing to various climate adaptation needs (e,g. social innovation, new technologies for climate, information, etc.). The living labs examined are located in Europe, at a physical location or as a project.

In addition, the living labs examined and possibly contributing to multifunctionality of flood defenses are all located in the Netherlands, at the scale of a dike project, or a flood protection area. Due to the limited number of initiatives, all the labs studied are operating on/for coastal flood safety.

I.5 Thesis structure

The thesis is organized in 8 chapters:

Chapter 1: outlines the research background, introduces the problem and the research objective and questions. The thesis scope and structure are clarified.

Chapter 2: overview the main concepts and theories related to living labs, climate adaptation needs and multifunctionality of flood defenses, as well as the relevance of the living labs to both concepts.

Chapter 3: review the academic sources on the different concepts/theories, the generated review will be used to build the research findings and analysis. The chapter answers the 1st research question.

Chapter 4: explains the research strategy, data collection and analysis, and gives an overview on the living labs cases selection. The methodological limitations of the research are indicated.

Chapter 5: presents the main findings on the living labs characteristics answering the 2nd research question, and presents the living labs cases investigated for climate adaptation needs and multifunctional flood defenses.

Chapter 6: Answers the 3rd research question and presents the findings, the analysis and the discussion of the living labs key contributions to climate adaptation needs.

Chapter 7: Answers the 4th research question and presents the findings, the analysis and the discussion of insights on the living labs contributions to multifunctionality governance of flood defenses in the Netherlands.

Chapter 8: Provides the key conclusions of the research and proposes future research niches to complete this explorative study.

II Central concepts and theories

This chapter introduces the fundamental ideas behind the thesis subject. The chapter is composed of five sections: II.1 living labs overview, II.2 climate adaptation needs, II.3 flood defense and climate resilience, II.4 relevance of living labs to climate adaptation needs, and II.5 relevance of living labs to flood resilience and linkage to multifunctional dikes.

II.1 Overview on living labs

II.1.1 Multiple definitions for living labs

The living labs concept was generated when Prof. William Mitchell from MIT (Boston) defined: Living Labs as a research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts (Almirall et al., 2012).

A widely shared common definition of living labs is lacking in the academic literature. By mid 2017, approximately 6,500 papers were published about living labs since the early nineties of the last century (Rathenau Instituut, 2017), but no article revealed a clear benchmark of living labs in discussion (Schuurman, 2015).

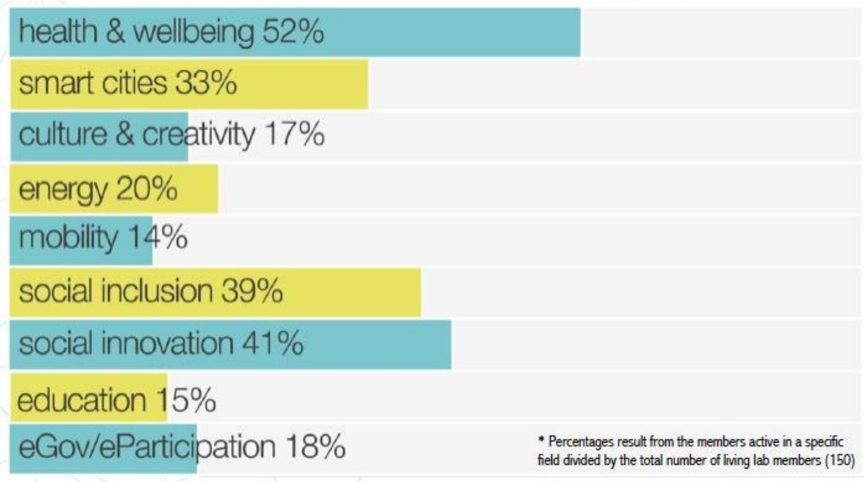
Living labs were defined in several ways, for example in terms of a method, an approach, an organization, an innovation ecosystem, an arena, and / or an environment for co-creation.

Almost all the articles consulted on living labs, referred to the variation and opacity in the definition of the concept. Some of the European grey literature consulted, cited the definition adopted by the European Network of Living Labs (ENoLL): “Living labs are defined as user-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings” (ENoLL, 2015).

II.1.2 ENoLL’s interpretations of living labs

The ENoLL represents the European-level network of living labs and further expanding to members from Africa, Asia, South and North America. It is considered somehow as embodying the global network of the living labs. At present, over 150 active living labs from the 5 continents are registered under the ENoLL, with various spans of action, characteristics, and methodologies utilized.

Figure 1 represents 9 thematic area of work of the living labs members of ENoLL. Over half of the inventoried living labs are active in the health and wellbeing sector, while mobility comes in the last position. Smart cities, or what is known as “urban living labs”, are also occupying an important share of the network members, followed by social innovation.



Source: ENoLL website, 2018

Figure 1: percentage of living labs by thematic area

The ENoLL (2016) qualifies living labs in Europe as a set of methods and milieus for innovation, where user’s reactions and interactions with technology are leveraged for and during the innovation process. Five basic components were adopted and reflecting a set of aims and characteristics as seen by ENoLL: 1. **active user involvement**: empowering end users to thoroughly impact the innovation process, 2. **real-life setting**: testing and experimenting with new artefacts “in the wild”,3. **multi-stakeholders participation**: the involvement of technology providers, service providers, relevant institutional actors, professional or residential end users, 4. **a multi-method approach**: the combination of methods and tools originating from a.o. ethnography, psychology, sociology, strategic management, engineering, 5. and **co-creation**: iterations of design cycles with different sets of stakeholders.

II.2 Climate adaptation needs

Adaptation requires adequate information on risks and vulnerabilities in order to identify needs and appropriate adaptation options, while engaging people with different knowledge, experience, and backgrounds in tackling and reaching a shared approach to addressing the challenges of adaptation (Tompkins et al., 2010).

The categorizations of climate adaptation needs proposed by Burton et al., (2006) and the IPCC., (2015), recognizes information, capacity, financial, institutional, and technological needs, and institutions are called upon to develop new adaptive options through social, institutional, and technological innovation. In the next chapter, we will develop with more details on these innovation needs, especially social, institutional, capacity and information.

II.3 Flood risk management and climate resilience

Flooding is a natural hazard that threatens lives and causes huge economic losses worldwide, flood risk, that is defined as a function of both flood probability and potential damage, is increasing not only due to climate change (likely to cause an increase in the probability of extreme waves discharges), but also due to continued investment in areas at risk of flooding (resulting in an increase in potential damage) (Klijn et al., 2010) .

Flood risk management is defined as all activities that aim at maintaining or improving the capability of a region to cope with the flood waves. An effective and sustainable reduction of flood risks could be achieved with flood resilience strategies, aiming at limiting flood impacts, and enhancing the recovery from those impacts through adaptive spatial planning. A resilience strategy is supposed to be able to better cope with climate uncertainties (de Bruijin, 2005) .

In the Netherlands, decision makers have been investigating innovative concepts for improving the dikes resilience, while integrating adaptive spatial planning, quality of living, work, natural ecosystems quality, etc. Among these integrated flood solutions are multifunctional dikes (Wetterskip Fryslân official website, 2018).

Multifunctional dikes are structure with the main function of flood prevention, integrating another function or more. They offer more robustness (higher protection from flood risk), and socio-economic benefits for the people. The concept can provide integral flood risk management solutions, hence, give an uplift to climate resilience in the domain of flood protection.

II.4 Relevance of living labs to climate adaptation needs

As mentioned above, climate adaptation needs institutional, social and technological innovations to be transformative. Engaging all parties from decision level to implementation, learning from each other, and sharing the knowledge produced are also key in the adaptation calculus.
In contrast, the overall rational of living labs is to provide in a defined scale, e.g., a neighborhood, city, or region, a research or innovation environment for public and private parties, experts and users to collaborate on solutions, from idea to design, from plan to implementation, all according to the principle of co-creation, participation, and learning.

Living labs can also combine social and technological innovation into a single project or process: new products are developed while simultaneously influencing the behavior of end users, because they are directly involved and are provided with new opportunities.

With a view to the integrated and complex nature of climate adaptation, the living lab instrument is now employed, to address the complex network of actors, issues, and taskings in climate adaptation (Delta Plan Netherlands official website, 2018). However, no academic research was found that explores how living labs contributes to climate adaptation needs, this thesis proceeds from this point by investigating how living labs criteria's match those transformational needs.

II.5 Relevance of living labs to multifunctional flood defenses

In the Netherlands, the Spatial Adaptation Plan is subsidizing the living labs instrument as, a way to engage stakeholders' contributions to climate-proof development (Delta Plan official website, 2018). Since multifunctional flood solutions necessitate a multi-stakeholder's perspective, and the broadening of collaborations with citizens, companies and knowledge institutes. The present thesis chooses to bring more understanding and explore how living labs can contribute to the uptake of multifunctional use of spaces on the dikes (more functions on a dike), as an integral solution towards better climate adaptation in the Dutch Delta.

The living labs contribution is examined from the governance perspective, as governance plays a pivotal role in supporting societal resilience to flooding (OECD, 2011). We will adopt the definition of Vinke-de Kruijf et al., (2015) of governance, as the structural context[3], in which various institutions with a role in the development and implementation of flood risk management policies act and interact.

In the next chapters, the analysis of multifunctionality will be further deepened, governance of dikes (mono-functional and multifunctional) will be examined, and the living lab contribution will be reflected on.

[3] refers to the institutions, culture, and social practices that frame any action within certain normative roles (source: California State University, Academic discourse, official website, 2004).

III Literature review

The literature review of the living labs is presented to answer the first research question "What are the definitions, methodologies and contexts of living labs?". In addition, the review of climate adaptation needs and multifunctional dikes is provided, based on academic papers and policy documents analysis:

III.1 Living labs: definitions, methodologies and contexts

III.1.1 Transiting from closed to open innovation

According to Kanter (2008), in the closed innovation paradigm, a limited numbers of different stakeholders participate in the innovation process. Historically, closed innovation was characterized by a linear process that is driven and managed by industrial parties (Mulvenna et al., 2010), where the corporations are at the core of the innovation process, when they discovered new breakthroughs, they develop them into products, manufacture the products in their factories, distribute, finance, and market those products-all within the four walls of the company (Chesbrough et al., 2006).

Gassmann (2006) added that closed innovation supposes that a firm or an organization limits the use of resources and knowledge from outside the firm, but relies mainly on its own resources and knowledge when developing or commercializing its products and services.

Early on Von Hippel (1976), identified the users as potential source of innovation, they were no longer seen as 'passive' respondents. Chesbrough (2003) reported that innovation can thrive from collaborations and partnerships between users and companies, beyond the traditional internal resources of the later.

The concept of open innovation emerged in the private sector in the nineties of last century, and was defined by Chesbrough (2003), as a new paradigm of innovation where research and development in firms, is treated as an open system and useful knowledge is widely disseminated, and where technology producers must identify, connect and leverage internal and external ideas and knowledge as a core process in innovation. It is about inviting problem solvers help reinvent products, services, or even business models that might contribute to the survival of the organization.

The concept of living labs has emerged as supporting the open innovation paradigm, they are considered both a milieu for innovation and an approach to innovation, where ideas generation and experimentation processes were taken outside the firms, to an inclusive real-life environment, where co-creation with users and other stakeholders is practiced.

III.1.2 Open innovation in living labs

Living labs are often referred to as an example of open innovation or open innovation environment, where the users are important informants and co-creators in technology development and testing, either in a physical or virtual real-life context (Westerlund & Leminen, 2011).

In accordance to Bergvall-Kåreborn et al., (2009), they are "an open innovation environment in real-life settings in which user-driven innovation is the co-creation process for new services, products and societal infrastructures. They encompass societal and technological dimensions simultaneously in a business-citizens-government-academia partnership. Kviselius & Ozan, (2008), called living labs" a tool for open innovation and a focal point for multiorganizational and multilevel collaboration".

Schaffers et al., (2007) argued that unlike the other forms of open and collaborative innovation, living labs provides a concrete setting, with four main activities: 1. Co-creation: co-design by users and producers; utilizers and enablers are also involved. 2. Exploration: discovering emerging usages, behaviors, and market opportunities. 3. Experimentation: implementing live scenarios within communities of users. 4. Evaluation: assessment of concepts, products, and services according to socio-ergonomic, socio-cognitive, and socio-economic criteria.

III.1.3 User innovation in living labs

Both qualitative observations and quantitative research in a number of fields clearly document the important role users play as first developers of products and services later sold by manufacturing firms (von Hippel, 2005).

Kareborn & Stahlbrost, (2009) categorized user innovation into "user-driven innovation" and "user centered/oriented innovation", and proposed the later as an umbrella concept of user involvement (see figure 2):

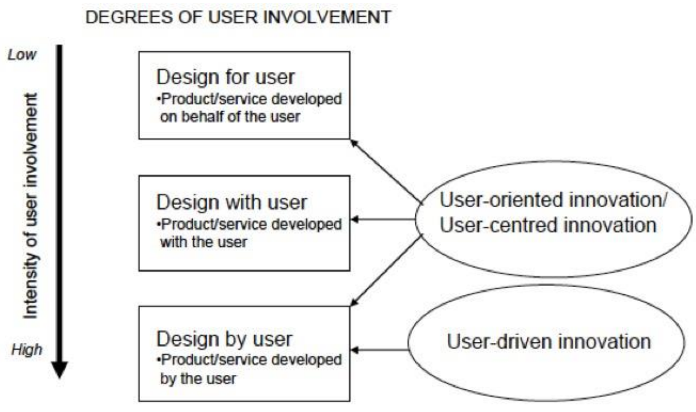


Figure 2: the difference between the umbrella concepts "user-driven" and "user centric/oriented innovation "

They deemed users- driven innovation characterizing a higher intensity of user's involvement, in which the user are the true initiators of an innovation process. The authors linked user-driven innovation in living labs to the co-creation process for new services, products and societal infrastructures.

To summarize, researchers associate living labs with different user(s) innovation degrees from user-centric or user-oriented innovation, where the design of products and services is done with and for the users, to a higher degree of user involvement through user-driven innovation, where the innovation process is piloted by the users themselves. In the next section, we will look into the different types of users and their involvement in living labs.

III.1.4 User involvement in living labs

Westerlund & Leminen (2011) agreed that living labs offer different approaches to user involvement. Leminen, (2015) determined that depending on the innovation development activity in a living lab, the user involvement can be associated with the validation and testing of activities which is associated with user-centric innovation, or the living lab is aiming at co-development and co-creation activities, hence, the user-driven innovation model is applied.

As far we have presented the different facets of user innovation and user involvement in living labs, the concept of co-creation was strongly present particularly under the user-driven innovation paradigm, where users become co-creators, and go beyond user-centered approaches (Kareborn & Stahlbrost (2009). To understand better how living labs, derive their efficiency from the creative power of the users, co-creation is discussed in the next section.

III.1.5 Co-creation in living labs

Kambil et al., (1999) defined initially co-creation as "a new dynamic to the producer/customer relationship by engaging customers directly in the production or distribution of value". Co-creative projects can be implemented on the basis of many existing theoretical frameworks: lead users, users toolkits for innovation, open source, open innovation and open source innovation, participatory design, etc (Viseur, 2016) .

Compared to these co-creation methods, the living labs are characterized by the strong engagement and the empowerment of users (Bergvall-Kåreborn et al., 2009). They can implement the co-creation practices on a large scale, and often unite more than 1000 users (Mulvenna & Martin, 2013).

In the CoreLabs project report (2010), empowerment and engagement of users is identified as key principle of living labs. It is fundamental to orient the innovation processes in a desired direction, based on people' needs and aspirations, thus, it helps construct a shared vision, contribute to the development of prototypes, participate to evaluations and test innovative products or services even from other collaborating living labs.

III.1.6 Testing and revising technologies in living labs

As we have found previously, the innovation development activity in living labs is also associated with user-centric innovation, that can engage users with the validation and testing of products, systems, or services, etc.
Ballon et al (2005) conducted an exploratory research on test and experimentation platforms (TEPs), and identified six types of TEPs: prototyping platforms (comprising usability labs, software development environments), field trials, testbeds, living labs, societal pilots, and market pilots (see figure 3):

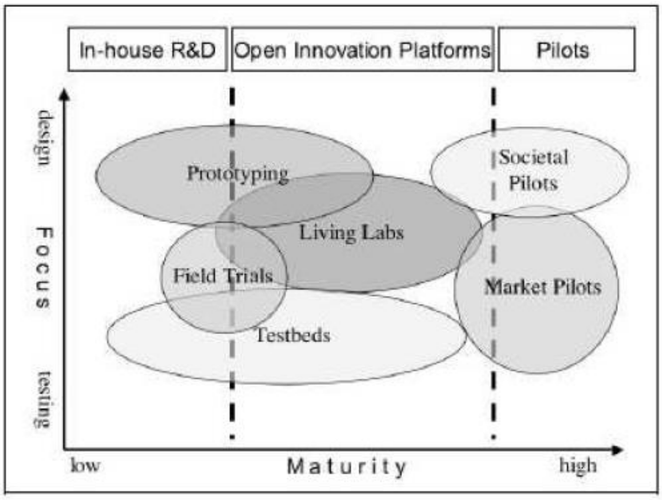


Figure 3: Conceptual framework of test and experimentation platforms (Ballon et al., 2005)

They interestingly characterized living labs as a specific type of test and experimentation platform (TEP), offering facilities and environments for (joint) innovation including testing, prototyping and confronting technology with usage situations. They also described living labs as “an experimentation environment in which technology is given shape in real life contexts and in which (end) users are considered “co-producers”.

III.1.7 Open collaboration in living labs

The International Symposium on “Open Collaboration”, defines open collaboration as a collaboration that is egalitarian (everyone can join, no principled or artificial barriers to participation exist), meritocratic (decisions and status are merit-based rather than imposed) and self-organizing (processes adapt to people rather than people adapt to pre-defined processes).

From the previous review, we can detect the practice of open collaboration in living labs, as Walt et al. (2009) suggested, that a new powerful innovation approach’s to effectively design sustainable communities, is to build collaborative systems called living labs, enabling communities to engage and being empowered to experiment and learn in real-life environments, and generate innovative solutions for their problems.

III.2 Climate adaptation needs

As reported by Rodima-Taylor et al., (2012), the efforts to generate appropriate adaptation response require a different form of institutional and social innovation, as an important elements in enhancing local adaptive capacity, comprising co-production of knowledge, engagement with stakeholders from local to global level, and leveraging of expert knowledge in the local context.
More essentially, it demands employing the richness of contextual knowledge to innovate technologies on demand, hence, give rise to communities' participation in the innovation processes as an alternative to the top-down approach of development and decision making. Andrew & Klein, (2010) affirmed that citizens mobilization and participation in decision making is crucial to social innovation, and promotes self-organization of people to meet their demands.

Because they are set-in real-life contexts e.g. a city, a neighborhood, or a village, etc. living labs might detain the potential to be intermediary spaces for institutions and citizens in local contexts, to co-develop and manage local adaptive processes, that can be technological or non-technological, through participation and horizonal coordination. To this regards, participatory and iterative learning processes for climate adaptation will be included in this review.

III.2.1 Participatory processes for adaptation

The capacity to adapt to climate change depends on many factors, one of the key factors is the capacity of collaboration between actors across-regions and sectors. Denton et al., (2015), argued that the participatory processes, are a governance culture suited for effective adaptation, and calls for a deliberative form of decision making among stakeholders. The IPPC 5th assessment report supports this finding. Stakeholder participation in the development of adaptation policies may induce various benefits. Participation may prop stakeholders' resources by increasing awareness, trust, skills and cooperation, as they can facilitate a deeper understanding of challenges, potential solutions and alternative options (Gardner et al., 2009)

Especially with complex issues such as climate change, participation processes can animate participants to reflect on their own behavior and can contribute to changes in attitudes and behavior (Rotter et al., 2013)

While participative frameworks to tackle climate adaptation challenges are strongly promoted, especially by the academia, many decision makers and public agencies may have reservations regarding public participation in policy making because of limited experience and unclear goals and results (Beierle & Konisky, 1999; Hophmayer-Tokich & Yoram Krozer, 2008). In counterpart, living labs can facilitate a blue print for public participation, as we have earlier determined that living labs provide typically high degrees of participation for multiple stakeholders in multiple contexts, for creation and observation (Eriksson et al., 2005).

III.2.2 Iterative learning for adaptation

Iterative learning was defined by Oppermann & Thomas, (1995), as an incremental learning process, where learner proceeds with their own competence by several trials to acquire knowledge, through exploration, or supported by technical or human consultants, error prone, with indirect solutions, and/or with dead ends.

Iterative learning as transformative adaptation pathway, is mainly associated with climate-resilient pathways, and numerous researchers argued for collaborative, iterative, self-organizing processes of learning-by-doing to enhance adaptive capacity (IPCC., 2015).

For example, Tompkins et al., (2008) found that in many cases effective response to extreme events benefit from iterative problem-solving and bottom-up engagement in risk management, and from human development to enhance capacities for risk management and adaptive behavior.

Tschakert & Dietrich, (2010) argued that given the urgency and the scale for resilience management under climate change uncertainty, knowledge should be accessible for those who need it most, through carefully designed yet flexible, iterative learning-reflection that is tailored to real day-to-day risks, that allows experimentation in practice, and that offers tangible and short-term results.

They proposed to create learning spaces to build adaptive and anticipatory capacity with and for vulnerable populations, to assess what adaptation options are most feasible, sustainable, and fair under future climate and development realities (Tschakert & Dietrich, 2010).

It was described previously that living labs are also defined as contexts supporting both teaching and learning experiences among participants, and that multi-stakeholders' involvement is needed for iterative steps (e.g. feedback loops). This suggest living labs as arenas for iterative learning, trial and error as part of the co-creation processes for adaptive measures.

III.3 Floods risk management in the Netherlands

In the Netherlands, about 60% of country is flood prone. Flood hazards are caused by floods on the two major Rivers Rhine and Meuse, storm on the North Sea, storm on the large lakes, or the combination of storm and floods in the deltas of the Rhine and Meuse. Almost 26% of the Netherlands lies below sea level. In theory, the damages in case of a flood are hefty, EUR 400 billion just for the region of South of Holland (Rijkswaterstaat, 2012). Climate change scenario effect on the country by 2050, predict a sea level rise of 15 to 40 centimeters (compared to 1981-2010 period), and a maximum sea level rise of 85 cm by 2100 (KNMI, 2014).

Aerts, (2009) calculated the increase in flood probabilities due to (combined) effects of sea level rise and increased river discharges, and found that the flood probability may increase with a factor 10 with each 50 to 80 cm sea level rise. He found that even if future flood risk defined as probability times damage are maintained at a constant level through heightening flood defenses (dikes), the potential damage of a flood is expected to increase. Therefore, an effective climate change adaptation policy should not only concern the reduction of flood probabilities with barriers but should also consider a wide range of adaptation options.

The European Environment Agency (2016), pointed out that high climate change scenarios could increase the socio-economic impact of floods in Europe more than three-fold by the end of the 21st century, and recommended a shift from a purely technically oriented flood defense, toward a more integrated flood risk management system with more adaptive value to the communities, including measures that reduce damage and exposure, spatial planning, flood defenses and response and rescue services.

The EU flood directive (2007/60/EC), obliged its member states to prepare flood risk maps for their water courses and coastlines, and define their flood risk management plans. For a long time, flood management in the Netherlands was dominated by technical flood prevention measures such as levees and dikes. The National Water Plan was published in 2009 in response to the EU Directive and climate change scenarios, the country shifted to an integrated risk approach, meaning reducing the probability and the consequences of flood (Hoss et al., 2013). The Plan included a multilayered safety strategy for an integrated flood management using three layers: layer 1: prevention of river and sea water floods, layer 2: Spatial solutions through spatial planning and adaptation of buildings to decrease the loss in the event of a flood, layer 3: crisis management to reduce causalities and damage of flood disasters through early-warning systems, evacuation, risk mapping, etc. in the next paragraphs, how multifunctional dikes contribute to this integrated approach is explained.

III.4 Traditional dikes vs multifunctional dikes

Dikes reinforcements aim to increase the stability and resistance of dikes against breaching, by heightening, broadening or adding spatial components to the dike. Heightening is the usual way to reinforce traditional coastal and riverside defense, however, it does not allow an integrated development or the combination of functions. Broadening may offer additional benefits, but might be difficult due to space limitations in urban areas or socio-economic reasons.

Although, dikes reinforcement is planned to pro-actively adapt to climate change, heightening for instance is recently meeting an increasing resistance from the population, as it can affect the landscape quality negatively (Climate Adapt EU website, 2015). In coastal zones in the Netherlands for example, higher dikes are cutting the communities from the sea that constitute often part of their history, and denying houses that are adjacent to the dikes, from the view on the landscape.

Innovations in flood defenses have been addressed in the report of the "State Committee for Sustainable Coastal Development" 2008[4], which advised the Dutch government on the future flood protection strategy. The Committee recommended, among other an integrated and multifunctional solutions to deal with the lack of space and, thus, deliver added value to society.

The "Delta Programme", was initiated in September 2008, and features the country plans to protect the Netherlands against flooding, ensure sufficient freshwater supplies, and climate-proof and water-robust spatial planning (deltaprogramma, 2018). The Delta Commission expressed interest in multifunctional use of flood defenses since 2008.

Multiple studies were carried out to explore the potential for robust multifunctional flood defenses in rural and urban areas, and develop an adaptable multifunctional design. The meaning and relationships between traditional dikes, Delta dikes and multifunctional unbreachable dikes concepts are illustrated in figure 4:

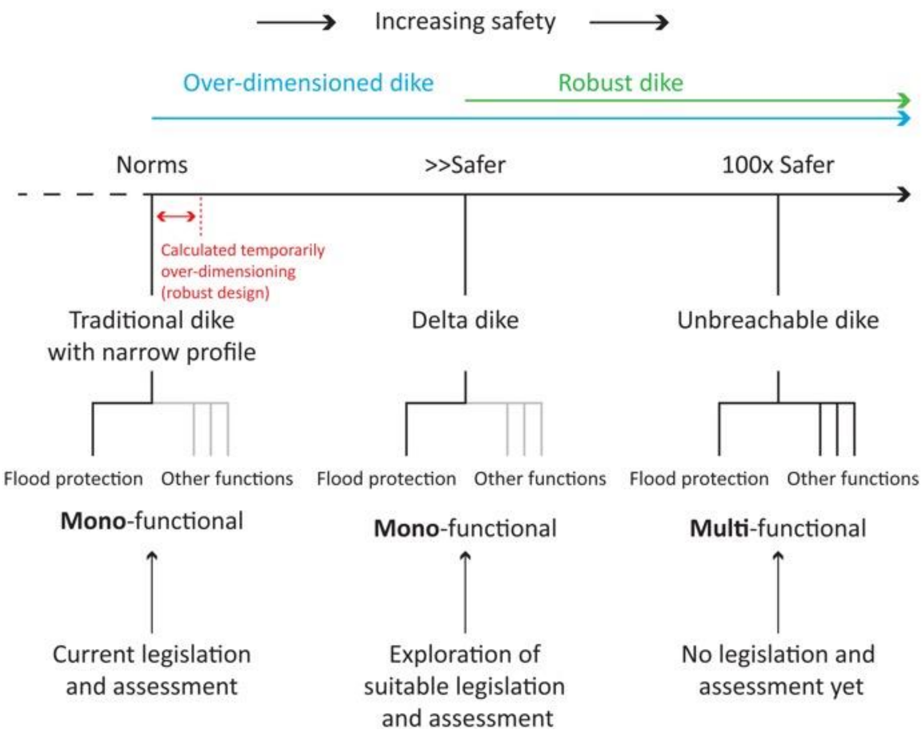


Figure 4: Visualization of the relation between different dike concepts in the Netherlands (Van Loon-Steensma & Vellinga, 2014)

Traditional dikes are mono-functional, thus, accomplishing the only function of flood protection. Due to their narrow profile, they are deemed less safe compared to other wider dikes concepts, as the overflow of a traditional dike during a flood wave, can cause catastrophic damage by the collapsing of the dike (breaching).

[4] In 2007, the Dutch government set up a committee to give advice on the feared consequences of 'rapidly' changing climate change on the Dutch coast and its hinterland. The committee was called the 'State Committee for Sustainable Coastal Development' (Staatscommissie voor Duurzame Kustontwikkeling).

Multifunctional unbreachable dikes are robust[5] and over-dimensioned, they are higher, wide or strong enough that the risk of total failure and subsequent total inundation is virtually zero, even at moments where the flood level is temporarily higher than the dike itself (Vellinga & et al., 2014).

The figures below provide insight into the flood hazards in the event of a traditional dike breach (figure on the left), and wave overtopping of an unbreachable dike (figure on the right) for the dike ring[6] area Walcheren. Traditional dikes will collapse under extreme conditions, and large part of the underlying dike ring area in inundated, while the inundated area and water depth are much lower for the unbreachable dikes (Rijkswaterstaat, 2008).

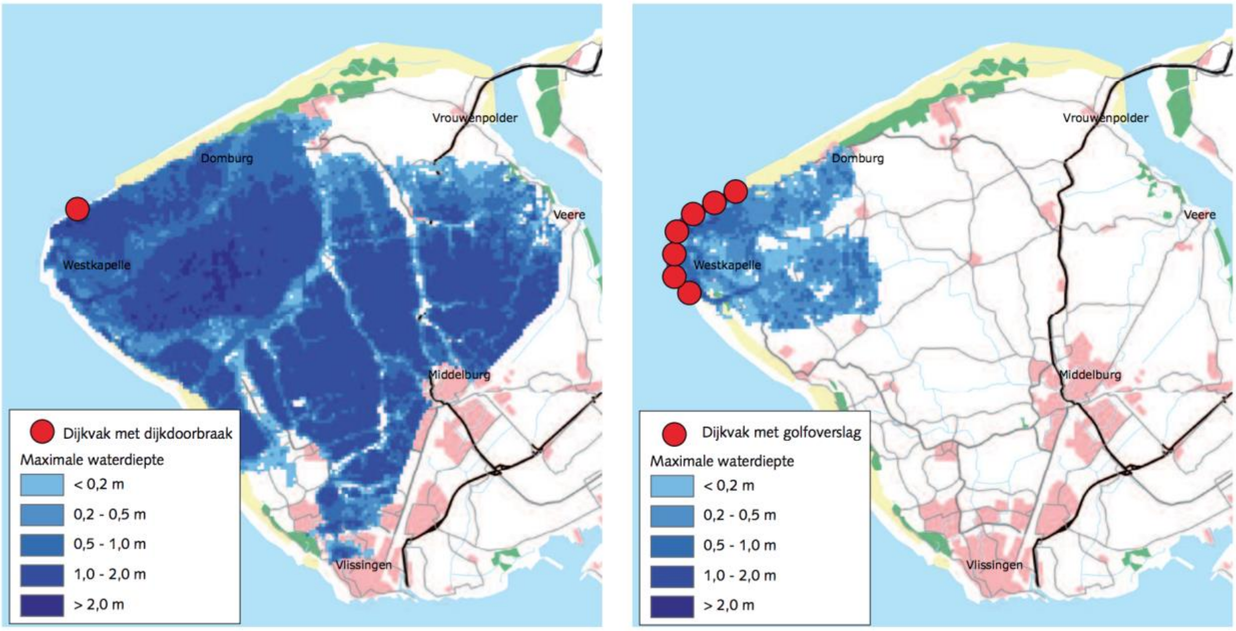


Figure 5: inundation hazards of traditional dikes (left figure) and unbreachable dikes (right figure) for the dike ring area Walcheren

Multifunctional unbreachable dikes could significantly improve the robustness of a flood defense system (climate adapt EU website, 2015), because they are unbreachable, they will not be overtopped, can withstand more extreme events than it is prescribed by the standards, and the catastrophic damages associated with devastating flooding of the hinterland are prevented. The incurred number of victims and the nature of damage are therefore, much lower than when a traditional dike breach (climate adapt EU website, 2015). These characteristics can also be interpreted from the adaptive capacity perspective, as both flood probability and damage especially in areas with high concentrations of population.

[5] Remains functioning without failure under a wide range of conditions, does not collapse during overtopping and reduces a flood disaster to a shallow flooding event. The concept of a robust dike includes the unbreachable dike and delta dike as subsets (van Loon-Steensma et al., (2014).

[6] a continuous line of flood defenses consisting of dunes, structures and dikes protecting the Netherlands from flooding. Each dike ring (enclosed area) is specified with a number from 1 to 53, and comprises several dike sections (Rijkswaterstaat, 2002)

The multifunctional dikes, are also known as multifunctional delta dikes. The main difference between delta dikes and multifunctional delta dikes, is that delta dikes are robust but serves the only purpose of flood protection, as a primary function, but multifunctional dikes enable secondary functions, serving other environmental, social and economic purposes (Tettero, 2013).

In figure 6 below, another comparison between a traditional dike (with reinforcement), a delta dike[7] and a robust multifunctional dike is illustrated:

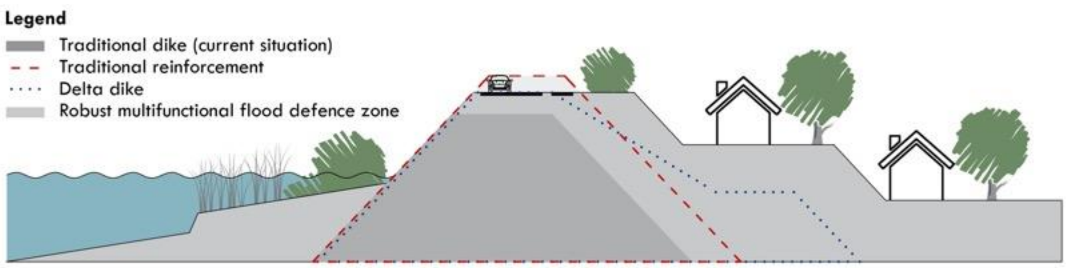


Figure 6: Cross-section profiles of a traditional dike, a traditional reinforcement, a delta dike and multifunctional flood defense (STOWA, 2013)

The cross-section shows the difference in height and width of different dikes concepts. The profile show that the reinforcement of traditional dikes is more about heightening of the dike, as mentioned in the previous section, while robust multifunctional dikes as stated by de Moel et al., (2010), requires more material and space, but would offer new opportunities for using the space. The secondary functions, can comprise urban development, transport infrastructure, recreation, agricultural use, and nature conservation or development, etc. These opportunities can contribute to the financing of dike, and can be partly or fully located in the flood protection zone[8].

Another safety perspective on robust multifunctional flood defenses, was reported by Gastelaars (2007), as they could also function as a place of safe refuge during a flooding disaster, or be part of an evacuation route. These refuge and evacuation functions are additional value to the multilayered safety strategy (3 layers) introduced earlier, that is based on both protection, spatial adaptation and effective disaster management.

III.5 Different interpretations of multifunctional dikes

According to Jonker et al., (2013), some forms of multifunctionality in flood defenses date back to decades ago, but are resurging in recent years, due to their cost efficiency and added

[7] a dike with a negligible probability of failure due to sudden or uncontrollable failure. Enhanced safety can be achieved by extra heightening or broadening of the dike by enlarging the landward berm (Deltacommissie, 2008).

[8] Flood protection zone refers to a reserved area around every flood defense, which can be used for future reinforcement.

value. The oldest example of such multifunctionality is that of sheep grazing on dikes. These sheep serve two functions, they help maintain the dike and are also a form of livestock farming. In recent days, sheep grazing does some of maintenance work on behalf of the dike manager. With sheep, not only livestock farming is generating income, but also maintenance costs are lower.

In addition to physical proprieties such as robustness presented earlier, the multiple use of space is an important concept in the interpretation of multifunctionality. Reeken et al., (2015) argued that any flood defense system is basically multifunctional, but a multifunctional flood defense system denotes a combination of functions in a way that the functions involved, do not just share space but also support one another. This can be understood when examining examples such as, road on a dike, the road improves the layout and accessibility of an area, and generate added value for the inhabitants.

Another example of mutual reinforcement, is illustrated by wind turbines on a dike. The turbines generate rental income for the dike manager, while the energy producer has a cheaper land than in urban areas, this multiple use of space results in cost savings for both parties. Dikes contribute also to the quantity and quality of the energy generated, because they offer a favorable wind climate due to their location on open ground, and enough space for several turbines (Jonker et al., 2013), but if the turbines help improve the strength of the dikes, e.g. because the deep foundations anchor the dike better, remains under investigation.

From these two examples presented (road and wind turbines on a dike), it appears that the multiple efficient use of space, sharing the costs of the land, and the extra revenues generated distinguish multifunctionality.

Hartmann et al., (2017), also emphasised that multifunctionality is based on multiple spatial demands that can, be achieved within a limited space: a smart combination of functions and technological solutions that often require multi-stakeholder decision making.

In a study commissioned by Rijkwaterstaat (2015), several opportunities for the dikes multifunctionality were inventoried, these opportunities can be in or near the water defense (see figure 7):

1. construction developments
2. infrastructure
3. nature development
4. recreational facilities
5. the creation of energy supply and transport
6. the structural reinforcement of the landscape

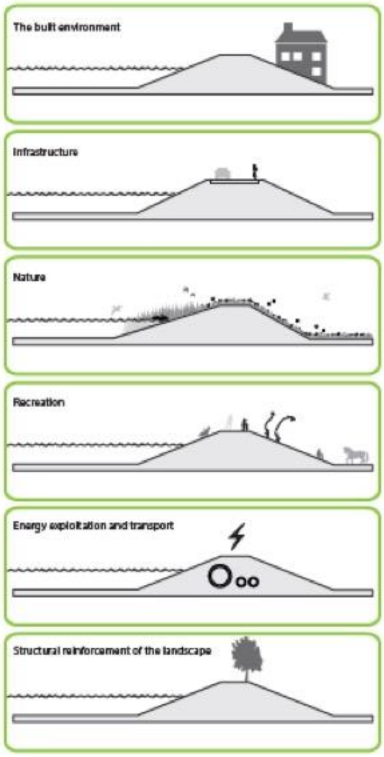


Figure 7: multifunction opportunities in or near the dike (Rijkwaterstaat, 2015)

Other opportunities with regard to the multifunctional dike surrounding area were identified (see figure 8):

- catching the water surplus/supplementing subsoil water levels
- operating a close-circuit ground balance of the soil through smart integration of activities
- applying the principle of multi-layered safety i.e. integral solutions for water defense and landward dike construction

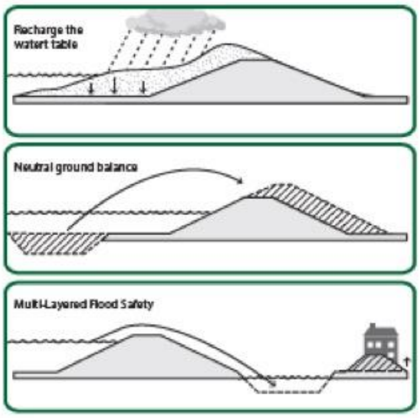


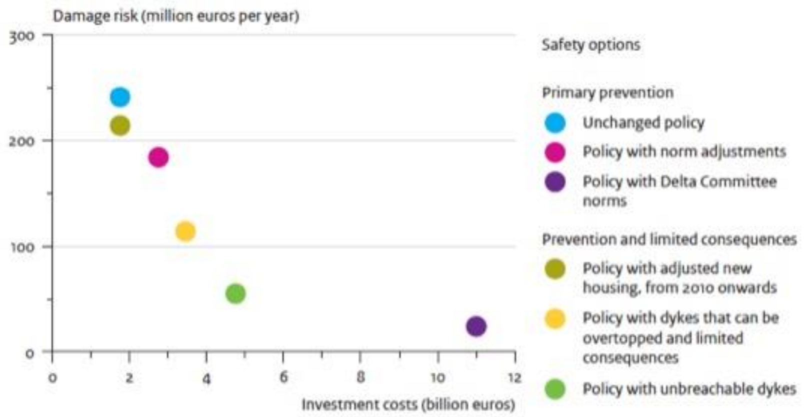
Figure 8: multifunction opportunities in the surrounding area of the dike (Rijkwaterstaat, 2015)

These opportunities were the results of a non-restrictive survey, of multifunctional flood defenses projects (19 projects), that have been implemented, or were at the reconnaissance or planning stages in the last 10 to 15 years, grouped in three major categories: sea dikes, river dikes, and lake and estuary Dikes. The survey also determined two main preconditions for a successful design and planning of multifunctional use of flood defenses: **i.** a cyclical design process, which equal inputs are demanded from technology (civil engineering, agronomics, hydraulics, geo-technology, etc.), and spatial planning (landscape architecture, urban development, etc.), and **ii.** carefully executed planning process in which all the relevant actors were able to play their parts.

III.5.1 Main advantages of multifunctional dikes

In many dikes' rings, there is a necessity to adapt the flood management infrastructure to account for climatic and socio-economic drivers (e.g., due to economic or population growth). Multifunctional flood defenses that combine the function of flood defense with a housing, commercial or amenity function, provide opportunities to balance economic and flood risk management goals (Jonkman & Dawson, 2012). Furthermore, the opportunity of integrating building, transport or other infrastructures is advantageous in terms of efficient use of available space, often limited in dense urban zones.

The research of Klijn et al., (2010), also showed that unbreachable dikes option can improve the cost-effectiveness of flood safety in the Netherlands compared to other options; they can reduce considerably the damage and causalities of floods (as seen in previous paragraph), with an acceptable additional investments (see figure 9):



Source: Klijn et al. 2010

Figure 9: indication of investment costs and damage risk related to flooding, 2020-2050

For multifunctional unbreachable dikes, the additional costs can be recovered from the revenues generated through economical secondaries functions (e.g. agriculture, energy, industry, etc.), hence, can contribute to the optimization of the investments made in the long-term on flood prevention in the country.

Additional values brought by multifunctionality of flood defenses, are the creation of recreational spaces (e.g. quality landscape, wildlife and natural amenities) and activities (parks, boulevards, shopping space, etc), thus a better life quality and higher value of the real estate, as stated by Jonker et al, (2013), who found that multifunctional projects increase the value of real estate in the area and usually determine the new market price of land at the location and the change.

Case description:

For example, the double dike project in the Province of Groningen, initiated in 2016 between Eemshaven and Delfzijl, as an alternative to the standard dike reinforcement, combines safety with nature, recreation and innovative agriculture. The reinforcement of the existing dike was taken as an opportunity to integrate other functions to the project scope, and create cost-effective operational management of saline agriculture (salt potatoes) and aquaculture (cockles). Farmers growing potatoes in the area are transiting to salt potatoes, and young farmers communities are reacting and adapting to future change in the area. People embraced the transition and were open to new ideas and benefits. In this project, the Province and the water board played a leading role (G. Lenslink, personal communication, June 26, 2018).

III.5.2 Main challenges to multifunctional dikes

The Rijkswaterstaat (2015) survey (introduced previously), concluded that without an institutional guarantee, most multifunctional flood defenses projects are realized as pilots within specific programs, where the initiators often fail to be informed about other projects or programs results, weakening mutual acknowledgement of experiences and systemic exchange of expertise.

Furthermore, the current flood protection standards are not conceived to assess multifunctional designs, and the combination between layers 1 and 2 is not mandatory or bond to a performance standard. The acceptance of other functions on a dike depend largely on the wiliness and proactivity of the water authorities.

Additionally, despite the economic benefits to yield from multifunctionality, it is still difficult to take these benefits into account during the decision making process of a project and include them in a cost benefit analysis, due to insufficient methods to calculate them (Athanasiou, 2015).

III.5.3 Monofunctional dikes governance and linkage with living labs

In the Netherlands, there are four levels of governance of flood protection, the European and national level, and two lower levels, consisting of 12 Provinces, around 400 municipalities, and 22 water boards (Rijkswaterstaat, 2012). The Ministry of Infrastructure and Water Management is responsible for spatial planning and flood protection. The Rijkswaterstaat is the national water authority, responsible of flood protection and flood control of water ways:

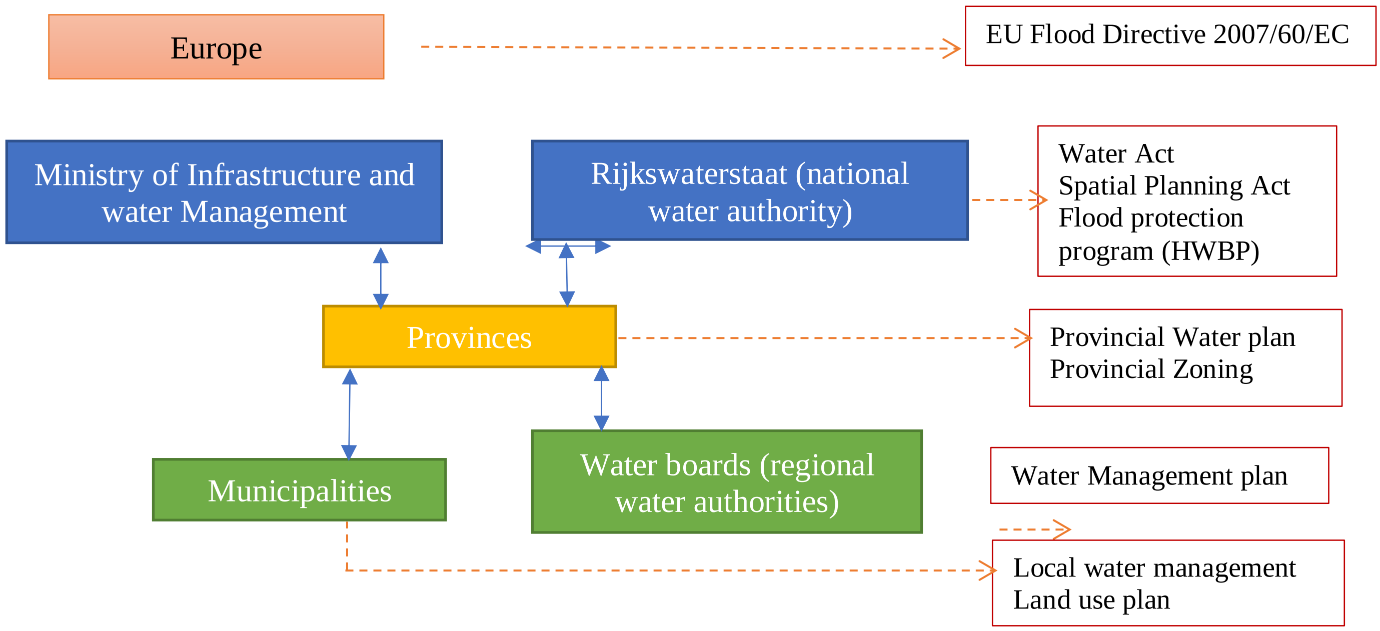


Figure 10: Organization of water management and spatial adaptation in the Netherlands and regulatory framework (own illustration)

Flood defenses are legally divided into primary and secondary defenses: **i. primary flood defenses** protect against flooding from surface waters such as seas, lakes and rivers, which are directly influenced in case of high storm surge or high river discharge, and **ii. secondary or regional flood defenses** protect against high water levels of canals and small rivers, (Voorendt, 2017).

Legal tasks in flood protection and spatial planning are laid down in the Water Act and the Spatial planning Act. Rijkswaterstaat and the water boards are the most important role holders for primary and secondary flood defenses. The role of municipalities and province is very limited. In contrast, municipalities and provinces are leading in the spatial domain and all functions that occur within this space.

The municipalities are in charge of the zoning plan for spatial development, and the permission of a second function e.g housing or nature in the flood safety area is only possible, if the second function is described in the water management plan of the water board. According to Van Mechelen, (2013), municipalities are obliged to consult with the water boards and the provinces, during the preparation of the zoning plan, so that an agreement can be reached with different governmental bodies to allow multifunctional use later.

The Hoogwaterbeschermingsprogramma (HWBP):
Improvement of flood defenses systems are funded by the Flood Protection Programme (in dutch: Hoogwaterbeschermingsprogramma HWBP), to which the central government, represented by Rijkswaterstaat, and the water boards contribute equally. Improvement measures to dikes managed by the central government are funded under the Delta Fund.
At present, 50km of flood defenses reinforcement have to be conducted every year, this is the largest volume by far of dike reinforcement projects in the history of the Netherlands, and implies, according to Jorissen et al., (2016), that the processes of the HWBP has to be optimized, by refraining from bureaucracy and stimulating Rijkswaterstaat and the regional water authorities to improve their performance.

When a dike reinforcement is due, water board collect information about hydraulic and physical boundary conditions, plan tasks, and identify constraints, while collaborating with other stakeholders along the process. However, they have no mandate other than flood safety, and taking other considerations such as landscape, nature, and historical context is outside their scope, and even if the project scope integrates other functions at beginning and meet the preconditions of the Water Act; resistance can arise making the implementation stop by court as over-dimensioning goes further than meeting the standards, or because expropriation of additional space is not possible (Van Loon-Steensma & Vellinga, 2014).

In the last years, living labs have emerged as innovation intermediaries, playing the role of mediator between the citizens, public and private organizations, and capturing insights in real-life environments. In a recent study by Gascó, (2017), the role of living lab in supporting innovations in the public sector was explored, and found that the living labs as public open innovation intermediaries can fulfill three main functions: **i.** connecting public agencies with people both individuals and organizations, **ii**. supporting and facilitating the exchange of ideas and knowledge, and **iii.** providing technological services, particularly trainings.

In the light of the previous findings, a regional, provincial or a monofunctional dike ring based living lab, can possibly play the following roles: **i.** balancing the influences during dikes reinforcement projects, in a way that flood safety, spatial planning and other development domains are equally considered. This will empower municipalities, and increase their influence along with the private actors and NGO’s in the decision-making process, **ii** increase the exchange of knowledge between the main players (water boards, provinces and municipalities), trough top-down or bottom-up approach; and **iii.** providing access to external resources (technology, funding, expertise), held by the businesses, the academia, and the local NGOs or individuals.

IV Methodology

IV.1 Research strategy

Considering the relative newness of the research problem, the research is designed as an "exploratory study" that consist, as defined by Edgar & Manz, (2017), as collecting, analyzing, and interpreting observations about known designs, systems, or models, or about unknown theories or subjects, with emphasis on the evaluation or the analysis of data, rather than providing conclusive final solutions to the existing problems. The exploratory research is therefore more flexible, and provides the opportunity for considering many aspects of the problem, gaining additional insights, and laying the groundwork for future studies.

Hence, the present research was conceived to explore the association of living labs' inherent characteristics with the acceleration of climate adaptation solutions, and the governance for multifunctional dikes through the collection, analysis and interpretations of data (both primary and secondary), in order to yield insight and comprehension of the living labs phenomenon and their potential role in climate adaptation. To deepen the understanding of this role, six living labs were chosen to be included in a multiple case study.

Case study research is a suitable approach to use when studying new phenomena that have not been studied to a great extent as well as for answering how- and why- questions (Yin 2014). Although the number of cases is limited, the method of multiple case study was considered appropriate since the concept studied is relatively new.

In this study, opting for an exploratory research method is also due to the limitations of time and resources needed to analyzethe research objectiveThus, a qualitative research is conducted by means of an extensive literature review, case studies and semi-structured interviews.

IV.1.1 Data collection and methodology

The following methods are used for conducting the research:

IV.1.1.1 Desk research

An extensive literature review is conducted in threefold way: **i.** examination of theories related to living labs , and previous research to identify and analyze criteria for living labs, **ii.** examination of the literature on climate adaptation needs, flood risk management strategy and existing research on multifunctional dikes in the Netherlands, and **iii.** examination of grey literature on living labs for climate adaptation, and multifunctional flood defenses initiatives, in order to gain knowledge on existing experiences and practices.

IV.1.1.2 Stakeholders interviews

Straits and Singleton (2011) suggest that in studies with an exploratory nature, 'open' interviews, more resembling a conversation, are often best suited to gather relevant and elaborate information on a particular subject. Therefore, it was chosen to conduct semi-structured interviews, and to that end an interview guide was developed, providing the basic structure to the interviews. However, no concrete questions or order of topics is determined before the interviews, as their formulation is dependent on the course of the conversation (Straits & Singleton, 2011). Appendix ii shows the interview questionnaire, outlining the general course of the interview, and an overview of the research objective, key concepts that are introduced briefly, and the main topics to be discussed.

Because of the complexity of the living labs concept, and the novelty of multifunctional dikes development, it was chosen to leave as much room as possible for the interviewees to express their ideas, opinions and evaluations, based on their own subjective experience and expertise. The final aim is to combine the primary data (interviews results) with the desk research results, in order to answer the research question.

The interviewees were either identified as having either a role within a living labs project or in flood risk management in the Netherlands. using the snowball technique (Bryman 2012), they were mostly identified through referrals from previously contacted stakeholders,. Some of the interviews were held in person while others were conducted over the phone. The interview notes and consent form were sent to the interviewee for respectively comments and approval for usage. The interview notes are highlighted in the thesis by referring to the participant "name, personal communication, date of the interview".

A total of 12 interviews were conducted with 5 representatives from the public sector (central and local governments, and executive authorities such as Rijkswaterstaat and Water Boards), 4 experts from the academia and other research institutes, and 2 representatives from the private sector. The detailed list of the participants is included in appendix iii.

The interview results helped mainly to determine the essence of multifunctionality, stakeholders' perceptions, the main challenges to overcome, and the living labs possibilities with additional functions on the dikes from the perspective of flood defenses governance.

IV.1.1.3 Living labs case studies

To identify relevant cases of living labs for climate adaptation and multifunctional flood defenses, a screening of exiting living was performed by consulting the ENoLL's database of living labs, combined with internet searches using the words: climate adaptation living labs, climate services living labs, flood management living labs, flood defenses labs, etc. However, referrals from interviewees in the Netherlands was a key source to identify all the 3 cases studied for multifunctional dikes, for which the lab actors were interviewed to gain knowledge of each lab's characteristics.

Climate adaptation living labs were selected based on the main criteria of contributing to one of the climate adaptation needs identified in the literature review. Due to the limited number of relatively mature living labs experiences, explicitly operating under the scope of climate adaptation needs, no distinction was made with regard to the scale or time frame of the living lab to select the cases. The analysis of the selected living labs was based on the lab's official webpage, or one of the lab partners (public organizations, universities, or NGOs) or funders, to gather the relevant information or publications for the research.

For all the six living labs identified (3 for climate adaptation and 3 for flood defenses with added functions to the dikes), their goals, users involved, facilities, location, geographic scale, activities conducted, tools used and results, in addition to the lab timeframe (existing or planned for) were listed.

IV.1.2 Data analysis

The data analysis is conducted in two separate parts. The 1st part answers the 3rd research question "What are, if any, the advantages of living labs to contribute to climate adaptation needs?

Climate adaptation needs found in the literature review constitutes the analytical framework and will form the basis for the case study analysis and. This framework provides an understanding of the components to achieve transformative and effective climate adaptation, including institutional and social innovations, learning and participatory processes. The selected cases are studied from the perspective of these needs, to understand their potential contribution to transformational adaptation.

The 2nd part will answer the 4th and last research question "What is the possible contribution of living labs approach to multifunctionality of dikes in the Netherlands?"

As introduced earlier (see section II.5), the living labs contribution is examined from the governance perspective. Flood governance for multifunctional dikes in the Netherlands (section VII.1.1 on findings), is therefore established as the analytical framework for the case study analysis. This framework contains the influencing factors to support multifunctionality governance of dikes. These factors are: connectivity between actors at different levels and scales, decentralization of tasks through a good combination of top-down and bottom-up governance, involvement of private parties (Deltares and Wagningen University, 2016), alongside the creation of a common vision among the stakeholders involved (Leeuwen et al., (2014). The interviews helped verify these factors listed by the literature, and added more clarity to the conditions surrounding the actual dike governance and the challenges toward multifunctionality. The living labs cases are examined from the perspective of the above-mentioned influencing factors to understand their contribution to the multifunctional governance of dikes.

For both groups of living labs cases (climate adaptation and multifunctional dikes), the goals, methodologies, users and results of the living labs are central for both understating their contribution, and for identifying which need/factor is addressed within the lab. The defining characteristics of living labs that resulted from the second research question were used to facilitate the examination of the living labs purpose, methodologies and contexts in each case study.

A summary of the method used to analyze the selected cases can be found in table 1.

Table 1: criteria's for analyzing living labs contribution

Analytical framework	Climate adaptation needs	Multifunctional dikes governance
Criteria's for evaluating the living labs contribution	institutional and social innovations, learning and participatory processes	connectivity between actors at different levels and scales, decentralization of tasks through a combination of top-down and bottom-up governance, involvement of private parties, and creation of a common vision among the stakeholders involved

IV.1.3 Methodological limitations

The data collection was constrained by the research time frame and the availability of relevant stakeholders of both living labs and flood safety domain in the Netherlands. Moreover, the academic literature on the topic of living labs linked to climate adaptation and flood risk management is scarce. There are also a limited number of case studies on climate adaptation and multifunctional dikes projects organized the living labs way that were assessed by academic researchers. Most of the documentation available is provided by the living labs initiators or partners, and it was not always possible to interview a direct representative of the living labs experiences examined.

V Living labs defining characteristics (criteria's)

Literature on living labs offers a broad variety of definitions and attempts to cover innovation activities or arenas. Leminen (2015) found around 70 different definitions on living labs in a systematic literature review, and identified 3 stream of livings labs studies. These studies continent and terminology review enabled the identification of living labs characteristics under four dimensions:

i. a living lab as a context: is described by studies as a variety of real-life environment where activities are conducted for the benefits of stakeholders and where users are engaged in activities with those stakeholders. Contexts can be single isolated places to broader environments, for learning such as schools, homes, neighborhoods, industrial facilities, etc. Thus, real-life environments incorporate daily life and everyday setting and contexts. stakeholders are university or a company or scientist utilizing the living labs for their needs to achieve goals that are otherwise unreachable.

(ii) a living lab as a methodology, focuses on development approaches, methods and methodologies and their processes, where products, services, systems, and their prototypes are developed, validated, and tested with users and multiple stakeholders.

(iii) a living lab as a conceptualization, which refers to studies for conceptualizing innovation activities in real-life contexts, tools such as networks, roles and innovation outcomes in Living Labs.

(iv) the living lab purpose is not part of study streams, but defines the overarching goal a living lab can achieve by applying its methodologies.

The outline on the living lab study streams completed the understanding of the defining elements of living labs provided by the literature review, and led to the identification of characteristics (or criteria's) distinguishing them under four defining dimensions. The criteria are synthesized in table 2, and might help single out real living labs from other innovation or initiatives involving users. However, the threshold of criteria required for a living lab to be called a "living lab", would call for further research.
In summary, living-labs can be described as innovation ecosystems anchored in the open innovation and user-oriented innovation approaches, with the objective of active involvement of users and stakeholders, for several validations and testing in natural and controlled situation experiments.

Table 2: defining criteria's of living labs for context, purpose, methodologies and conceptualization dimensions

Dimension	Living lab criteria
Context	Real-life environment
	E-environment
Purpose	Innovation: open innovation, community innovation
	Teaching and learning
	Knowledge production and sharing
Methodologies	Development with user
	Iterations
	Co-creation
	user-driven innovation
	Multi-stakeholder's participation (public sector, companies, academia, citizens)
	Users involvement
	Open collaboration (shared decision making)
	Multi-level collaboration
Conceptualization	Network, system, or platform Intermediary, focal point or innovation arena
	Actors role: utilizer, enabler, provider, user

VI Climate adaptation needs and living labs

This chapter is answering the 3rd research question by presenting the findings on climate adaptation living labs cases, their analysis in light of climate adaptation needs and the discussion of living labs contribution to these needs, hence, this part is divided in 3 main sub-sections.

VI.1 Findings on living labs cases for climate adaptation

They remain few but living labs initiatives for climate adaptation do exist. The following are three cases of European and Scandinavian living labs, with different aims, methodologies and concepts, but with the common scope of contributing to climate adaptation:

VI.1.1 European Market for Climate Services (EU-MACS) project:

Overview: This living lab is sheltered under the EU-MACs project, it aims at rendering actionable climate information accessible, and introduce mechanisms to induce climate service providers offer information, that are relevant and applicable by users. The project analyzes the weaknesses in the climate services field, identifies opportunities and potentials, tests market development approaches, etc.

The ENoLL utilized the Living Labs approach to help develop climate services through the project, by closely involving end-users and other stakeholders the “Living Lab way”. Workshops were organized in Finland and Italy, where the stakeholders have been engaged in: **i.** collaborative service development and interactive market exploration, and, **ii.** real-life experimentation, where a prototype has been created and tested for a collaborative planning process for climate change adaptation (EU-MACS, 2018).

Purpose: open innovation, knowledge production and sharing on climate adaptation collaborative planning processes
Methodologies: end-users and other stakeholders’ involvement, development with users, prototyping and testing.

Users: institutional actors from organizations’ working on climate change adaptation
Facilities: no fixed location for collaborative planning process
Context: Real-life experiment

VI.1.2 The iD-Lab, the Netherlands:

Overview: experts can access, combine and visualize data, models and tools from global to local levels to generate actionable information for decision-makers. Some of the models hosted by the lab and methodologies applied are: **i.** Global flood and storm surge forecasting model to directly provide accurate flood and storm surge predictions. Data is collected from open data sets and monitoring stations globally, **ii.** Global flood risk assessment analyzer providing global flood risk information on affected socio-economic aspects, and help conduct interactive stakeholder workshops to support risk-informed decision making, **iii.** Flood monitoring using social media tools such as Twitter feeds and news articles to monitor floods. People can tweet how they are affected by floods, if help is needed and how deep the flood water is, providing an important source of information for intervention, **iv.** International disaster preparedness and response to quickly generate useful information on water-related disasters e.g. floods, cyclones, tsunamis and storm-surges, and finally, **v**. Interactive decision-support sessions to support decision making on issues such as urban climate adaptation, collaborative design of water related projects, and interactive modelling using rapid assessment and visualization tools (iD-Lab, 2018).

Purpose: learning, knowledge production, innovation for flood risk management

Methodologies: participatory process for design and testing, multi-stakeholder's participation, shared decision making (open collaboration), visualization of data
Users: policy makers, researchers, disaster management specialists, consultants and designers in the fields of water and subsoil.

Facilities: interactive space at Delft University, acts as an experimental arena for innovation incubation sessions or interactive stakeholder workshops.

Context: real-life environment (interactive space).

VI.1.3 ENERGI & VAND greater Copenhagen living lab, Denmark:

Overview: started in 2016, Energi & Vand living lab is active in climate adaptation, education for Sustainable development (ESD) and communicational and educational partnerships. Collaboration of users for gathering knowledge and developing climate adaptation measures in the near city, the lab should conduct pilot projects involving citizens groups in the implementation of local climate adaptation projects. The final aim is knowledge sharing about how citizens can be involved in the climate adaptation of their local areas, learn more about how citizens' active participation in data collection, processing, planning and reporting can contribute to a better climate adaptation of the Capital Region of Copenhagen. As part of the Energi & Vand lab, a mobile science center enables school students to learn about securing houses from flood house, through active participation and interactive learning rooms (Energi & Vand, 2018).

Purpose: knowledge production and sharing, teaching and learning for local climate adaptation
Methodologies: user-driven innovation, users' involvement, multi-stakeholder's participation
Users: Citizens, students, utilities and public actors

Facilities: a fixed knowledge and learning center and a mobile science center
Context: real-life environments

VI.2 Analysis

The three living labs cases showed that the purposes, methodologies applied and users involved differ from a living lab to another, and allow a wide range of activities and users to be involved.

The EU-MACS project used the living labs way, for collaborative service development and interaction between end-users, which offer a flexible approach to real-life experimentation, at a temporary host location (one of the project partners) for a short timeframe. The lab builds on the interactive process between public institutions and climate service market developers, to co-produce a collaborative climate adaptation planning services, hence, leveraged the expert's knowledge while involving the institutional actor's as co-producers. The prototyping method utilized, is also a mean for joint innovation to empower and engage users (CoreLab project, 2017).

The iD-Lab case in the Netherlands, is organized as an experimental arena for innovation incubation, interactive stakeholders meeting place for decision making, that permit access to data, visualization and modelling techniques in the field of flood risk management. Access to data enables an informed decision making, visualization tools for decision-making can simplify the essence of the information and raise the awareness of the policy makers (Norwegian Computing Center, official website, 2016). The iD-lab uses participatory processes for design and testing of urban climate adaptation, that can be an alternative to the top-down approach for decision making (Andrew & Klein, 2010), and can contribute to changes in attitudes and behavior of participants towards climate issues (Rotter et al., 2013).

The last case of ENERGI & VAND living lab, has a social innovation dimension, the labs seeks to involve citizens in local climate adaptation, and to learn about citizens contribution to climate adaptation. It emphasizes on formalizing knowledge production on citizens mobilization for local adaptation to formulate lessons. At the same time, the ENERGI & VAND lab might be seen as learning space for the citizens involved as well, through collaboration with other stakeholders and co-creation. The lab in this case acts as a learning environment to build adaptive capacity with the populations. Although, it was not clear if the lab aims to learn from the experiences from the particular lab environment, or also replicate the lessons elsewhere.

In the three case studies, knowledge production, learning and innovation are the common purposes followed. Different categories of user's involvement is common to the three labs, depending on the innovation development, the user involvement aimed at testing and prototyping activities, or co-development and co-creation activities. Multiple stakeholders' participation is observed in the three cases, reuniting public actors with experts from the academia or the private sector. The ENERGI & VAND is the only lab involving citizens directly in its activities. Moreover, none of the labs is explicitly referring to iterative learning processes, although, the EU-MACS project lab is applying testing and prototyping methodology but more related to co-creation.

VI.3 Discussion: reflections on the living labs contribution to climate adaptation needs

The purposes, contexts, and activities of the living labs studied vary largely but the methodologies are interestingly comparable, with a predominance of user's involvement for user-oriented innovation (testing, prototyping), or user-driven innovation (co-creation and co-production). All the living labs have the purpose of producing knowledge on climate adaptation solutions, plans or decisions.

The participation process is present in all three labs, materialized by collaboration between different actors across sectors and levels, for the co-production (EU-MACS project lab) of a climate adaptation service, interactive decision making for flood risk management supported by experts' inputs e.g. data, modelling and information tools (iD-Lab), and for social innovation initiatives for local climate adaptation (ENERGI & VAND). Participatory approach was previously (see section III.2.1) connected to bringing stakeholders resources together, increasing awareness, trust, skills and cooperation (Gardner et al., 2009).

The connection between the methodologies used and solutions developed within the labs and their potential of contributing to climate adaptation needs is discernable, the contribution is shaped especially by a strong role of users, a good combination of top-down and bottom-up approach through participation, as a form of institutional innovation. The labs are allowed the users exchange of knowledge and learning from each other's, or through the innovation processes (co-production, co-creation, testing, etc.).

In contrast with climate adaptation needs, participation and iterative learning, we can summarize the following contributions of living labs: **i. institutional and social innovation:** living lab provide intermediary spaces for institutions and citizens in local contexts, to co-develop and manage local adaptive processes, that can be technological or non-technological, through participation and horizonal coordination. **ii. participatory processes:** living labs showed to offer spaces of open collaboration between governments, private companies, and communities, facilitating a higher degree of participation, improving trust and awareness, and beneficiating from knowledge and expertise of previous experiences and from different actors engaged, **iii. iterative learning:** living labs can be arenas with an iterative feature of research cycles, if applying co-creation with users and other participants, to generate, test/prototype and assess adaptive interventions, especially for climate resilience.

VII Multifunctional dikes and living labs

This chapter is answering the 4th and last research question "What is the possible contribution of living labs approach to multifunctionality of dikes in the Netherlands?". The findings on multifunctional dikes governance, and living labs cases are presented and analyzed, in the light of governance factors influencing the success of innovative dikes projects, identified via the literature review and the interviews. The living labs contribution to multifunctionality governance are discussed in the last sub-chapter.

VII.1 Findings

VII.1.1 Multifunctional dikes governance and living labs:

According to Oderker (2013), the governance of multifunctional flood defenses needs to be set in the context of multiple users, multiple sets of administrative rules and multiple legal frameworks. In some cases, the government (central government, municipalities or water boards) is leading and in other cases private companies are the initiators. Van Loon-Steensma & Vellinga, (2014) also reported that all different stakes (and their spatial and temporal aspects) make the implementation of a multifunctional flood defense a complex and often lengthy process from the initial planning, as well as for the management, maintenance and assessments of the projects afterwards.

The interviews confirmed that multifunctionality governance requires not only the public sector involvement (Rijkswaterstaat and the water boards), but also private actors, the provinces and municipalities, because of the complexity of the design, the specific character of each site or area, and the longer time needed for the design and the planning of projects (P. Vellinga, personal communication, June 27, 2018). The citizens are also requesting safer conditions but not higher dikes, as they create a barrier separating them from water and nature, hence the cultural context and history.

Strengthening flood risk governance of innovative dikes was examined by Deltares and Wagningen University, (2016), it was found that the following governance issues appear to greatly influence the success rate of innovative dikes projects: **i.** establishing connectivity between actors, levels and sectors, by bridging the gap between actors operating within spatial planning and flood risk management policy domains, **ii.** decentralization of tasks through a good combination of top-down and bottom-up governance, although it requires a shifting of formal powers and resources, and **iii.** involvement of private parties, including businesses, citizens and NGOs. The involvement of private parties is necessary both for substantive and normative reasons. They can provide extra resources for implementing a diverse set of solutions.

In compliment to these influencing factors to facilitate the governance question of multifunctionality, is the integration of multifunctional options to the scope of dikes reinforcements projects at an early stage (reconnaissance phase) (G. Lenslink, personal communication, June 26, 2018). For innovative projects, more time and money are needed, and the additional costs for the longer reconnaissance phase should be put forward by the provinces, municipalities or other stakeholders' organizations, e.g. agriculture, farmers, industry, etc. (R. Jorissen, personal communication, 19 July 2018).

Furthermore, the research showed that in many multifunctional cases, an enthusiastic and strong initiator is needed. For primary flood defenses, this role can be played by the Rijkswaterstaat, that can provide a stimulating contribution by:

- establishing technical and managerial guidelines for the design, management and maintenance of multifunctional dikes, these guidelines should define best practices for responsibilities attributions, decision- making and planning processes, learned from previous experiences,
- including binding indicators to integrate multifunctionality to dikes reinforcement projects, these indicators should guarantee the performance of the flood defense under spatial adaptation (layer 2), in addition to other socio-economic indicators (e.g. climate resilience, life quality, revenues generated, jobs creation, etc.).
- supporting the development and adoption of cost-benefits sharing methodologies through research,
- developing contracting strategies, such as framework agreements with the regional water boards to develop multiple use of flood defenses on the dikes rings, particularly, where innovative concepts are profitable, that were estimated at approximately 1400km by Klijn et al., (2010).

For the secondary flood defenses, it is also a realistic option for the central government to provide guidance for the design and testing of multiple functions, and make local authorities (provinces and municipalities) feel legitimized with regards to additional functions integration, and for water boards to share the vision of development of the local authorities, while conserving flood prevention as the primary function.

Some experts questioned during the interviews, agreed that dikes building is moving away from engineering and technical considerations to spatial planning, but the water boards remains monofunctional entities focused on lines in the landscape, and spatial planning is still the domain of the provinces and the municipalities (P. Vellinga, personal communication, 27 June 2018).

It is not yet clear if the national water authority will fully play the role of a strong initiator, but with the adoption of the new safety assessment of 2017, this can be facilitated, giving Jorissen et al., (2016) findings; The new standards offer to Rijkswaterstaat and regional water boards the opportunities to improve the strategic planning of dikes reinforcements. The discussions with local partners, can be initiated at an earlier stage over possible social and/or economic scopes. In the past, this was difficult as the period between the exploration phase and the construction phase of the projects was often too short to arrange decision making, funding and integral solutions.

Moreover, the proactivity required from the water boards is hindered by other non-regulatory or technical factors, identified for the Project-transcending explorations (POV) innovations (including multifunctional projects): **i.** the institutional and cultural core values of the organizations conflict with the knowledge developed from the innovation pilots, **ii**. the water boards do not have sufficient capacity to use the knowledge generated, or **iii.** the financial consequences of the innovations are too important (Deltares, 2016).

Project-transcending explorations (in ducth: projectoverstijgende verkenning POV)

The POV is an instrument of the HWBP, and has the mission of developing new knowledge and innovative solutions for dikes reinforcements that can be applied to projects. The POV projects are 100% eligible for subsidy with no necessary contribution of 10% of the water board. Innovative dikes concepts (including multifunctional) are a scope among others of the POV. For example, the Central Holland POV showed that the Lekdijk between Amerongen and Schoonhoven has to be reinforced over 53 km length. The Hoogheemraadschap De Stichtse Rijnlande aims to collaborate with residents, municipalities, the provinces of Utrecht and Zuid-Holland, Rijkswaterstaat and social partners to achieve optimum improvement of spatial, landscape, natural and cultural-historical quality in addition to safety. The execution of the first section starts in 2020 (deltaprogramma website, 2018).

VII.1.2 living labs experiences for multifunctional dikes: 3 cases from the Netherlands

In this section, three living labs cases from the Netherland, where multifunctionality of dikes is sought are studied. A representative of each experience was interviewed for the research, to understand how the living lab approach was employed in each case, who were the users, their roles and interactions are defined for each experience. Overall, the number of living labs initiatives for multiple dikes usage in the Netherlands is very limited, the cases identification and selection was mainly guided by the interviewee's referrals.

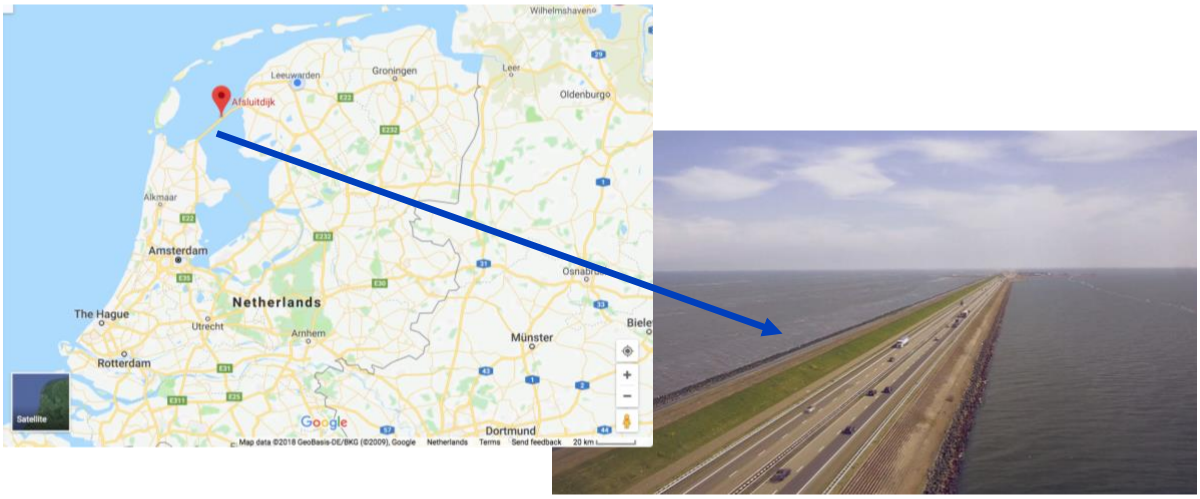
VII.1.2.1 The "nieuw Afsluitdijk" living lab

The Afsluitdijk is a 32 km long dike, it is a primary flood defense and a separation between two Seas: the salty Wadden Sea and the sweet stagnant IJsselmeer. The Afsluitdijk is a straight line from Wieringen to the Frisian coast.

Between 2018 and 2020, the dike will be renovated "De Nieuwe Afsluitdijk", in order to strengthen the protection against sea level rise, and discharge the excess of the Ijsselmeer water, but also to initiate showcases of sustainable energy production and test new delta technologies (Projectbureau De Nieuwe Afsluitdijk, 2013). Th Afsluitdijk living lab is a joint venture between the provinces of Fryslân and Noord-Holland and the municipalities of Harlingen, Súdwest-Fryslân and Hollands Kroon. It is part of the renovation plan of the dike, the plan comprises sustainable energy projects, for example, solar panels on and around the dike, hydro-turbines, a Blue Energy pilot, and a fish migration river from IJsselmeer to the North Sea (CDA Fryslan, 2017).

The implementation of the living lab is projected for 2018 by the province of Friesland as a lead partner, with a focus on sustainable energy knowledge and innovative pilots known as "energy dike", to be broadened later on to other sustainability areas: ecology, water, tourism, etc.
The vision announced is to make the Afsluitdijk energy-neutral and positioning it as a 'living lab', that is a testing ground for energy and water innovations. The energy dike partners would like to give the companies a real-life space to develop and test new energy innovations and delta technologies (T. Dijkstra, personal communication, 16 May 2018). The energy dike

living lab should assemble knowledge institutions, companies and governments in order to work together and learn from each other, in order to accelerate innovative energies developments (de nieuw Afsluitdijk, 2013).



Source: "de Nieuw Afsluitdijk" website, 2018 and Google Earth

Figure 11: Location of the Afsluitdijk

Users: Rijkswaterstaat, Provinces, municipalities, water boards, energy technology companies, consultancy companies, environmental NGOs, university..

VII.1.2.2 "Holwerd aan Zee" project living lab

In the case of the Holwerd aan Zee village development project, initiated by the Municipality of Dongeradeel (Friesland Province) in 2016, a multifunctional dike zone is developed where, a canal through the dike to the Wadden Sea will be constructed, touristic and recreational activities are envisaged, along with salt tolerant agriculture and history revival of the area.

Source: “Holwerd aan Zee” project website, 2018 and Google Earth

Figure 12: Location of the Holwerd aan zee project area

The project implementation is led by the Municipality but a working group was formed of farmers, local entrepreneurs, and citizens, who are conducting talks and sometimes providing data to the water authorities (Delta Commission, water Board, Rijkwaterstaat and nature organizations), in order to obtain technical support and funding.

The workgroup formulated a list of 70 research questions for study assignments and graduation projects for educational institutions. The research questions relate to topics such as: dikes improvement, nature, recreation, sustainable energy production, etc.

Holwerd aan Zee Living Lab aim at providing input for these research questions, thus, enriched the entire Holwerd aan Zee development program in the coming years. It has the task of linking education, and research institutions, with the business community and the water authorities present at and around the village, by making the area a testing ground and a showcase project. The project is also providing funding for the initial coordination efforts and explorations.

The living lab is the whole project area around the dike to the Wadden Sea, students and other academic researchers (universities and Hoogeschools), are in-situ and generated a large part of the informative and innovative input, used to develop the project plans, e.g: technical studies, maps, modelling, etc. the students were more inclined to think out of the box, which lead to creative ideas as a result (J. Zijlstra, personal communication, June 14, 2018). The living lab provided an open space for innovative ideas generation, data collection, and once the project construction is launched, will provide pilot results for the innovations tested.

On a local level, the project partners see the living lab contribution as a way for the realization of a sustainable future for the coastal region of Friesland and Groningen by showcasing and sharing knowledge between regional partners. At the national level, the living lab is supposed to contribute to various top sectors (i.e. water) and, answer to various research questions in the Dutch National Research Agenda (Holwerd aan Zee website, 2018).

Users: water board, province, municipality, Rijkswaterstaat, universities and schools, farmers associations, entrepreneurs, citizens.

VII.1.2.3 'Living Lab Marneslenk 2.0'

The Marneslenk living lab aim at making a former sea arm that formed the link between the city of Bolsward and the open sea more resilient to climate change through landscape planning. For the Marneslenk and surrounding area, the level of the Wadden Sea will gradually rise (by 35 cm by 2052). The living lab method was applied to develop ideas in a short time in a form of 'pressure cooker', led by 3 initiators: landscape architecture private company, university of Groningen, and the New Atlantis Pingjum Foundation.

Source: google earth, 2018

Figure 13: Location of the Marneslenk area

The living lab was initiated in 2017, during several days on the project site, a group of stakeholders from Water Board Friesland, the Wadden Academy, Groningen and Wagningen Universities, and other landscape and climate experts, were gathered and divided in workgroups to search questions and propose solutions for three areas of development and resilience: **i,** resilient of the seawall of the dike and the freshwater system, ii. agricultural use, and **iii.** Touristic and recreational development possibilities.
These solutions will be utilized to feed in the development vision of the Province and the municipality of Súdwest Frysland.
The living lab was organized in the project area (city of Pingjum), where the participants discovered the area environmental and historical assets, and discussed the area history and relation of development with history with the local citizens.

One of the living lab participants interviewed for the research, pointed out that the process matters more than obtaining specific innovative outcomes, the living lab outcomes was more about adopting a new way of thinking when developing the solutions, that enabled the participants to focus on the broad long-term suitable development and available technologies instead of the financial aspects (E. Ruiter, personal communication, 6 June 2018).
Users: citizens, water board, province and municipality, university, private consultancy firm.

VII.2 Analysis

The case studies analysis reveals variety in goals, organization and results of the living labs. Two of the cases are explicitly labeled as living labs (Afsluisfsluidijk and Marneslenk, while Holwerd aan Zee is are using the living approach for part of the whole programme.

Combining flood safety with other development considerations e.g. spatial planning, energy production, economic activities, recreation, nature, etc., is common to the three cases. Another shared feature is the involvement of multiple parties in each project, comprising in all three cases Rijkswaterstaat, water boards municipalities and provinces, in addition to local private parties i.e citizens, nature organizations, and private companies. Research institutes or/and local universities are as well among the partners engaged, and play important role in providing knowledge or data, expertise, or conducting studies.

The Asfsluidijk living lab "energy dike lab" is focusing on new energy technologies, and uses the dike to test and demonstrate the feasibility of the technologies or innovations, and to generate knowledge among the different partners. The learning, exchange and sharing of knowledge from the innovative pilots is announced as the main goals of the energy dike lab. Although, it is not clear how the parties will be interacting with each other, or how the living labs goals will be attained.
The dike itself is seen as a living lab, used as a demo site to test and monitor performances of the new solutions developed by technology companies. Interestingly, the Asfsluidijk lab acts as an innovation arena, connecting the public partners with the technology developers or start-ups, and also creating a network among the participating companies to learn from each other, in a sense that their capacities can be developed through the knowledge used from other companies' experiences.

For the Holwerd aan Zee project, the knowledge required to develop integral solutions for flood defense areas, that is usually carried out by the public sector (the water board at a local level), was in this case developed in collaboration with the hogeschools and universities in the area. The living lab served as intermediate to the top-down approach for development planning. The municipality as the leading partner played an important coordination role, and defined living labs assignment for researchers and students willing to use the project site as real-life laboratory. Multiple research assignments were carried with the resources provided by the hogeschools/universities (students, laboratories, knowledge, etc), in collaboration with local private parties e.g entrepreneurs, farmers, and nature organizations. The data and knowledge generated, served as feeding for Rijkswaterstaat and the water board decisions on technical and financial support needed for the project. The combination of the top-down and bottom-up approach is detected, and connected spatial planning and flood safety stakeholders, as one of the factors for successful innovative dikes projects (see section VII.1.1). Moreover, the living lab method facilitated the generation of innovative solutions, and particularly, shortened the initiation phase that took two years from its start to the development of the complete Holwerd aan Zee plan.

The "Marneslenk living lab 2.0" case has a prevalent focus on resilient spatial adaptation, the living lab method is used in the form of a "pressure cocker" round. The municipality and the university supported by a private expertise, engaged with other parties: water board, researchers and local citizens, in the co-development of solutions on the site of the project. The variety of the participants responsibilities, backgrounds and expertise responded to the various development areas explored: resilient flood risk, agriculture and recreation. The Marneslenk lab aim is to co-develop solutions tracks in a short time, however, this methodology could contribute to a change in the stakeholder's mindset about integral approach for spatial adaptation and flood protection planning, and raise the interest and awareness around additional benefits for citizens, as attested by the water board participant in the lab (see section VII.1.2.3). If this methodology is tested elsewhere to evaluate the impact on the stakeholders thinking, it can outline a new form of governance towards multifunctionality.

VII.3 Discussion: reflections on the living labs contribution to multifunctional dikes governance

Multifunctionality of dikes implies a change from the business as usual of executing flood management plans to the integration of additional tasks. For decision makers, it can mean managing, planning and assessing the interactions between flood protection task and other possible functions at an early stage of design. As opposite to traditional dikes, water managers have to manage and account for the interdependencies with other actors representing different backgrounds (spatial planning, nature associations, farmers, municipalities, industry, etc), and socio-economic interests and developments.

Findings on multifunctional governance revealed that innovative dikes governance requires connectivity between actors, levels and sectors, decentralization of tasks through a good combination of top-down and bottom-up governance, and the involvement of private parties, including businesses, citizens and NGOs.

The interviewees perceptions on the governance question, supported the above-cited influencing factors, and added the need for an enthusiastic and strong initiator mainly from the water managers side, otherwise, "it is difficult to develop the necessary support, smooth cooperation, and to deal with restrictive legislation" (Leeuwen et al., 2014). Furthermore, the integration of multifunctionality scope to the dike's reinforcement project is necessary at an early stage. Another key point is the need for a change in the institutions culture, as described by Leeuwen et al., (2014), a change of mentality within the various organizations involved is required for the success of innovative dikes projects, and experience showed that people may be tempted to think outside the box, when a common vision among the stakeholders is created.

The analysis of the case studies through the lens of the above findings and the living labs characteristics, unraveled the potential contributions of living labs for multifunctionality governance:

Accelerate solutions development at an early stage of dikes project:
The living labs can offer open spaces of interaction between partners to discuss smart solutions or combination of issues and challenges at the initiation "reconnaissance" phase of the dikes projects. In both cases of "Holwerd aan Zee" and "Marneslenk", applying the living lab instrument accelerated the solutions development, and formalization of the projects plan. More informative and innovative results for multifunctional space uses were developed, facilitated by the labs collaboration especially with academia and companies.

Connect actors and mobilize resources:
Allowing the living lab to play intermediary or focal point roles, to provide data, and assessment or knowledge tools, can improve the partners organization and pull the courage and resources of private partners who wish to join the projects early. In the same scope, the governmental involvement in a living lab, can facilitate innovative technologies and solutions testing, by making exceptions on some regulations or permits, in order to allow companies partnering to test innovations (R. Cremers, personal communication, 5 June 2018) .

Empowering water managers and private parties:
Living labs as multi-users platforms allow the input of non-governmental parties, bring resources and know-how to public partners when designing multifunctional structures. Likewise, gathering additional partners and resources around a dike reinforcement project, might prop the water boards proactivity, as the lack of knowledge and experience in other domains e.g. spatial planning, nature conservation, construction, etc. became less of a concern to them, resulting more acceptance by the water authorities of additional functions on the dike, and help with their decision-making process.

Shared vision and trust between stakeholders:
The involvement of residents in dikes reinforcement projects is also gaining importance, as citizens can show resistance if the reinforcement are not adding value especially to the spatial quality (see section III.4). Living labs are spaces where inhabitants can voice their demands and opinions about the functions design, and be part of the process as co-creators or adopter of the designs proposed. More importantly, living labs can create trust, legitimacy and acceptance of the solutions developed among stakeholders including citizens (T. Maas, personal communication, 28 June 2018).

Lastly, learning and testing in living labs can lead to the scaling up of multifunctionality governance practices, especially if the lab initiative aims to replicate the experience elsewhere. Water managers can play here an important ambassadors role, in transmitting the knowledge and lessons learned to local partners in other projects.

VIII Conclusions and future research

VIII.1 Key conclusions

This research examined the living labs numerous definitions and interpretations by the literature, and proposed defining characteristics to distinguish them from other innovation approaches. Living labs operate as collaborative ecosystems for user-innovation, they demonstrate adaptability to different context, purposes, flexible organization, and variety in methodologies applied.

To allow the understanding of their contribution to climate adaptation needs, three climate adaptation living labs were explored. Although, they differ in missions, activities and methodologies, the findings suggest their positive enablement of institutional and social innovation, broad participation of actors from different levels, sectors and scale, in addition, to the facilitation of collaborative learning among the participants.

This study also covered the question of multifunctionality of flood defenses governance in the Netherlands. The literature revealed multifunctional dikes advantages for climate resilience in flood risk alongside socio-economic opportunities. Interviews with local stakeholders and the analysis of three living labs initiatives in the Netherlands, allowed insights on promising living labs contributions to accelerate solutions development at an early stage, connect actors and mobilize resources, empower water managers and private parties, and lastly, building a shared vision and trust between stakeholders from different sectors.

The present study was aimed as an exploratory research of living labs, and attempted to associate this emerging innovation concept with adaptive climate action and resilient flood protection in the Netherlands. This association seems to hold many potential values to enhance adaptive capacities. The research showed limited experiences of climate adaptation living labs, so far, it is uncertain at what pace living labs will be mainstreamed for climate adaptation innovation. The answer might depend on the evolution of familiarity of policy makers and other organizations with living labs methodologies, and their enthusiasm for open collaborations and shared decision making in climate policy.

VIII.2 Future research

In order to build deeper understanding of living labs contribution to climate adaptation, systemic investigations are needed to analyze the living labs cases. The analysis can help build a body of knowledge on living labs practices and key characteristics, that may contribute to the demanding efforts for innovation, collaboration, learning and active involvement of citizens for climate adaptation.

Researching the practices, organizations and contexts in which exiting living labs for adaptation to climate operate is of importance. Additionally, how living labs environment (real-life or virtual) affect their functions and outcomes, requires further attention.

Furthermore, it would be interesting to examine if user-centric innovation in living labs can strengthen practices of inclusive climate adaptation governance, by stimulating a mindset change among the participants.

Lastly, how climate knowledge is developed and shared through living labs? how innovations are presented, and via which networks or channels they are communicated? at what degree the knowledge is understood and exploited in other locations, and / or scales by different users? are relevant questions to understand the living labs impacts as information providers for climate adaptation.

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X Appendix

Appendix i: Research proposal

Research questions

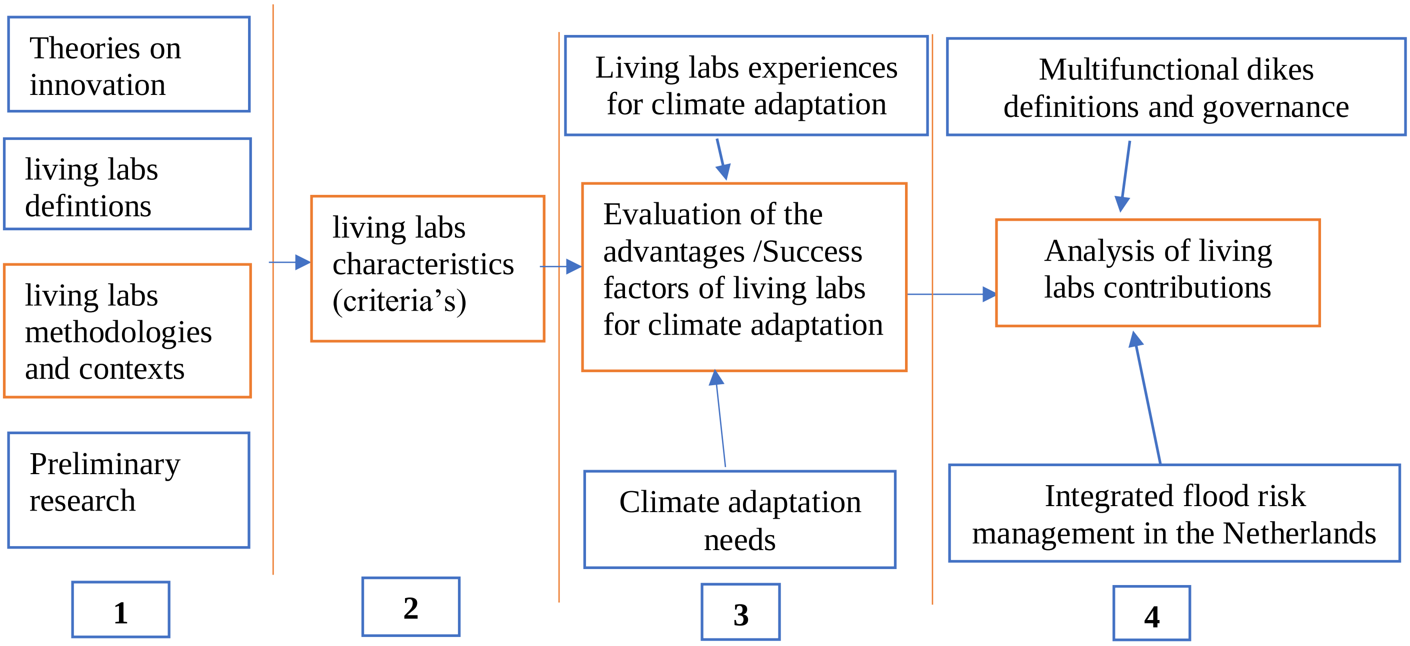
Main research question: what is the definition of living labs to in the context of climate change adaptation challenges, what applications and advantages they can bring to innovative climate solutions, especially flood risk management innovation through multifunctional dikes?

Accordingly, the study will address the following research questions:
Research sub-questions:

5) What are the definitions, methodologies and contexts of living labs?
6) What are the defining characteristics of living labs?
7) What are, if any, the advantages and success factors of living labs to respond to climate adaptation needs?
8) What is the possible contribution of living labs approach to flood risk management in the Netherlands? with focus on multifunctional dikes.

Research process:

The research process is giving in the following schematic representation of the research objective, including the appropriate steps to answer it:



The steps to be taken during the research project are the following by research question:

1) A preliminary research on innovation theories, living labs definitions, methodologies and contexts is conducted through a literature review,
2) on the basis of which the characteristics of living labs are determined and analyzed,
3) the advantages and success factors of living labs for climate adaptation are assessed, with regard to living labs already defined characteristics, climate adaptation needs and existing experiences,
4) for the last question, integrated flood management possibilities and multifunctional dikes needs and challenges in the Netherlands are identified, the results of question 3 are also considered to build this assessment of living contributions.

Data and materials analysis:

The data and information required and its accessing method and sources are for each of the sub-research questions in the following table:

Sub-questions:

1) What are the definitions, methodologies and contexts of living labs?
2) What are the defining characteristics of living labs?
3) What are, if any, the advantages and success factors of living labs to respond to climate adaptation needs?
4) What is the possible contribution of living labs approach to flood risk management in the Netherlands? with focus on multifunctional dikes.

Sub-Question	Research strategy	research material	access method
1 - 2	Desk Study	Secondary data: published research papers and books on the theoretical framework related to the study Primary data: Interviews using open questionnaire	• Open access scientific journals (Scopus, web of science, google scholar, other online data bases) interviews with national and local stakeholders
3	Desk Study and interviews	Analysis of primary and secondary data collected for questions 1 and 2 Primary data: Interviews using open questionnaire	• Open access scientific journals (Scopus, web of science, google scholar, other online data bases) • Published reports and studies: IPCC, UNFCCC, EU, ENoLL • Documents or webpages of living labs experiences interviews with national and local stakeholders
4	Desk Study and interviews	Secondary data: published research papers, reports, policy documents on flood risk management in the Netherlands and multifunctional dikes Primary data: Interviews using open questionnaire	• Open access scientific journals (Scopus, web of science, google scholar, other online data bases) • Dutch official reports and studies: governmental, Ministries, water boards, research institutes interviews with national and local stakeholders

Appendix ii: interviews questionnaire

UNIVERSITY OF TWENTE
MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT (MEEM)

MASTER THESIS RESEARCH:
Living labs contribution to climate adaptation needs and multifunctional in the Netherlands

Research objective:
Living labs are defined as open collaborative platforms for innovative solutions, actively involving users and responding to their specific local contexts and needs.

The thesis research aims first at exploring the various definitions of living labs with regard to innovation approach and applications to climate adaptation innovations and collaborations. Previous living labs experiences will be examined to identify the advantages and key variables of those living labs, leading to successful implementation.

The thesis will look at innovative flood risk management in the Netherlands, with focus on multifunctional dikes. The research will determine the challenges, perceptions and criteria inherent to multifunctionality in dikes. The analysis will be confronted with living lab approach and conclusions will be drawn on their contribution to multifunctionality development in dikes construction.

Research duration: Mai 2018 -August 2018

Some key concepts:
LLs characteristics: active user involvement (i.e. empowering end users to thoroughly impact the innovation process); real-life setting (i.e. testing and experimenting with new artefacts "in the wild"); multi-stakeholders participation (i.e. the involvement of technology providers, service providers, relevant institutional actors, professional or local end users); multi-method approach (i.e. the combination of methods and tools originating from a.o. ethnography, psychology, sociology, strategic management, engineering); co-creation (i.e. iterations of design and testing cycles with different sets of stakeholders).
Multi-function dikes: defined under robust dikes concepts 10 times safer than a traditional dike with a time horizon of 100 years for the hydraulic boundary conditions. They combine other functions with the primary function of flood protection like nature or buildings, energy, agriculture and other added values for business and spatial quality.

Semi-structed interview guiding questions:

Name:
Organization:
Date:

Introduction:
What is your function in your organisation?
What is the role or link of your organisation or Department with Flood risk management?

Delta programme/dikes improvement projects:
How are you involved in the implementation of the flood prevention component of the delta programme in the Province?
What is your role, if any in dikes improvement projects?

Multi-functions dikes opportunities and constraints:
Are you familiar with the concept? If yes, what does it mean to you?
What might be lacking to develop this concept further: technology, finance or a new approach to governance?
Research on multi-functions dikes showed that a motivated initiator is necessary to promote these innovative dikes, who could it be in your opinion (one or multiple)?

A living lab for multifunction dikes:
Are you familiar with the concept of living labs? If yes, what does it mean to you?
What would be for you the main input of a living lab to help develop multifunctionality of dikes projects? expl. generation of ideas or concepts, prototyping and co-design, real life setting for demonstrations, financial support

End of the interview:
Do you have any other comments?
Notes of the interview will be sent for check with a "consent form" to approve usage of information provided for the research.

Appendix iii: interviews list

	Name	Function	Interview date
Public sector (government, local authorities)			
1	Tjalling Dijkstra	Program Manager of the Nieuw Afsluitdijk Friesland	16.05
2	Eva Ruiter	Quality of water and plan advisor on water management Wetterskip Fryslân	06.06
3	Jan Zijlstra	Holwerd aan zee living lab coordinator, Municipality officer Friesland	14.06
4	Wout de Vries	Specialist advisor on flood protection at Rijkswaterstaat WVL Lelystad, Flevoland Province	29.06
5	Richard Jorissen	Previous Program Director of the Flood Protection program (HWBP)	19.07
Private sector			
6	Remko Cremers	Senior Adviser Energy living lab Ewkadraat, Friesland	05.06
7	Joop Mulder	Sense of the Place initiator, artistic Director	03.07
Academia and researchers			
8	Frank Gort	Program Manager Smart Sustainable Industry, NHL-Stenden, Leeuwarden	08.06
9	Gerda Lenselink	Member of the Knowledge network of the Delta program Integrated Water management expert at Deltares	25.06
10	Pier Vellinga	Climate change impact expert Vrije University of Amsterdam and Wageningen University Member of the Wadden Academy	27.06
11	Timo Maas	Researcher Rathenau Instituut, Den Haag	28.06

2Appendix iv: interviews notes

Interview number 1: May 16th, 2018

Tjalling Dijkstra, Friesland Province

Climate adaptation is umbrella of many water management related concepts

International institute for Climate adaptation to be launched soon:

- Centres located in Groningen and Rotterdam.
- Funded by the UN, aim at information and sharing and networking.
- Province to communicate success stories through the Groningen Centre, exp. Afsluidijk and Holwerd aan Zee. UN expertise Centre to host lessons and knowledge from the region innovative water management solutions.

Waterschappen (Water Boards):

- involved with secondary and third category of water management infrastructures
- Cut off from politics and involved in managing water and some dikes and including many farmers, own funding and legislation
- Building on high ground was way to manage water originating the concept of Polder as founding of water management regulation and democratic systems in the Netherlands

Wadden Sea area program:

- Noord Holland, Friesland and Groningen
- Investment program EUR 150M to be multiplied 300M
- Projects of ecological, economic or energy interests in the area to be funded
- Exp: Make Wadden Sea islands energy neutral, fish migration, tourism and fishing
- Projects to be shared through the UN climate adaptation expertise Centre, international sharing of the Dutch experience, integration of cross boundary topics under adaptation

Acceptance of integrative approach to adaptation:

- Getting people involved through Centres such as the Afsluidijk Centre, sharing how water is managed, awareness on innovation and energy, water management can also be recreational topic through hidden story telling
- It is a strategy of the Government to bring message to people in a didactic way and make it recreational

Province for economic spin-off concentrating on innovations on the Afsluidijk, expl:

- blue energy project tidal systems
- Off Grid Centre combining tidal, wind and solar energy with storage and smart computing to deliver sustainable energy continually
- Hogeschool Alkmaar: Special program on “off grid energy” Centre similar to living lab to be built in 2018, Funding by Province and businesses, Living lab focused on tidal energy to serve for students learning
- Dike living lab help companies to get demo sites for their technology through the dike to learn faster and get quicker introduction to the market, hence promote job creation

- Investing in innovation is investing in economics while creating touristic attraction

Ecology:

- Nature was overlooked when the Afsluidijk dike was built
- New approach integrating nature for new dikes exp. Zeeland
- Fish migration river infrastructure to be built to restore the ecological system around the dike and will be accessible to tourists

Stakeholders in charge of water management:

- In the Netherlands, Water management is established by laws hence cannot be affected by politics
- Central government charged of sea protection through delta fund but exclusively for safety
- Water boards in charge of dikes
- The Province with other partners (Provinces and Municipalities) developing projects beyond safety exp: innovation projects on the Afsluidijk, however, the Delta Fund doesn’t cover these projects.
- In water management, central government have the Delta fund dedicated to safety, tasks division makes it sharper and everyone focuses on issues from its own perspective, better way to organize tasks

Living labs on the Afsluidijk:

- started around sustainable energy innovation to help blue energy projects
- however, companies aren’t learning from each other on technology innovation
- new technology permits obtention can be facilitated through new data and analysis and knowledge data base
- government, business and schools to collaborate. organization under discussion to introduce NHL, Van Hall, Inholland Hogeschool, companies are interested in the concept
- Politics interested in LL concept: formal request from Parliament to local government to invest in LL with broader topics
- Discussion with NHL on collaboration on concepts and questions to answer for a broader scope for the LL
- Identification of organization and funding and stakeholders talks on going. LL to be preferably embedded in schooling system exp. NHL

Vital regions programs: climate adaptation as chance to increase vitality of the region, whole network being created now with companies and schools
NHL problem-based schooling program: place students in the region and LL as a way of storing knowledge on climate adaptation in schooling programs.

Interview number 2: June 5th, 2018

Remko Cremers:

- Programme manager for energy transition at Ekwadraat, Leeuwarden
- Transition manager for the Municipality of Henglo, from linear to circular economy
- Amsterdam smart city: living lab energy project with citizens involvement, 8 years experience
- Perception of living lab: Field lab in real environment with real stakeholders and users

Living lab for energy at the Afsluitdijk:

- Afsluidijk as door to energy innovation in the Netherlands
- Energy innovations projects ongoing on the dike with multiple partners involved
- An extra layer added to these projects to create more opportunities by combining these projects in a living lab

Challenges of the living lab:

- feeling of responsibility by stakeholders of own projects but don't see opportunities offered by a LL
- Initial investment needed to set the living lab while opportunities aren't visible but easy for more partners to join afterward

Opportunities of the living lab:

1. Communication, public relation and marketing through LL as a layer above, physical location of several innovative energy projects in one dike important to combine marketing and public relations

2. Monitoring the amount of renewable energies produced and efficiency of these innovative technologies considering the specific environment, scale opportunities to combine them in a LL

3. Permits /legislation/ regulation: easier access to permits for innovative technology once they obtained it initially under a living lab project and learn from it. At present project permits but, in the future more of location permits independent of the innovation tested.

Future of the living lab:

- Having business partners but also knowledge and research institutions willing to conduct new research combined with the businesses practice and innovations
- Important to develop research roadmap
- More finance for the projects provided by European Union and Wadden Fund
- Province Friesland and Noord Holland Province as main partners

Stakeholders engagement:

- Afsluitdijk Wadden centre as way to involve citizens through meetings and opportunities for co-creation
- Businesses developing own energy innovations from technical perspective, necessary to test technology readiness and technical efficiency by involving users

Interview number 3: 06.06.2018

Eva Ruiter, Wetterskip Friesland

Functions: Quality of water and plan advisor on water management

Delta programme:

Not only safety goals but also how ecology can benefit
New concepts for flood concepts, let the water in

Living labs perception:

- Group of people with different backgrounds and coming from different organizations with different knowledge
- Limited time not detailed solutions but looking at broader picture and main problems
- Long term planning

Living lab project:

- September 2017, 4 days session
- Area next to Sea dike on the Wadden sea and nearby the Afsluitdijk
- Event defined as LL as different stakeholders participating, organized in the area and discussion with citizens on area history and relation of development with history
- Future challenges of the area: sea level rise, salt water intrusion, intense rain falls, lack of tourists
- Objective of the LL: define development plans for tourism and recreation, farming and climate/water
- Participants: Water Board, Municipality, Province, Wageningen and Groningen Universities researchers and students and other guest speakers
- Discussion on wider dikes with benefits for nature, and in the sea to experiment with agriculture in salty water
- LL outcomes on the way of thinking but not in term of action taken in the area later, focus on bigger perspective history pf the area and long term suitable development

Wetterskip policy making:

- Policy making for water quality (ecology), quantity and safety better to work more together and interact and define large challenges in the future by the Water board but also what farmers and citizen's needs, interaction with Province and Municipalities important.
- Wetterskip Innovation Department: contact with schools and researchers, budget to try new innovations
- Wetterskip can benefit from LL as challenges are clear, take more efficient measures, Province or Government to encourage LL
- Multifunctionality is about living and recreation hence Province or Municipalities have broader scope and responsibility is shared to work together

Not look first at feasibility of solutions but what are the long term challenges, what is appropriate for the specific area, who are all the stakeholders in this area and what are the available technologies then financial aspects

Interview number 4: 08.06.2018

Frank Gort, NHL

Program manager “Smart Sustainable Industries”: renewable resources, serious gaming, computer vision, water technology, maritime, economics, computer vision, serious gaming, etc

Role:

- connect NHL and stakeholders at strategic level
- Example: Innovation cluster Drachten and NHL: shared facility lab
- Promoting NHL work

Living lab Asluitdijk:

- Working with cross-overs, exp. Computer vision and serious gaming
- NHL contribution: funding/subsidies

NHL existing LL:

- Designed based education lab, virtual reality and others
- Pressure cooker workshops: hospitality, design,…

Stakeholders engagement:

- NHL to capitalize knowledge and expertise in the dike LL
- Understand each other’s, new vision and solutions
- LL help break traditional governance scheme

Living lab Asluitdijk initiators:

- 2 Provinces, local governments and Rijkswaterstaat
- Provinces as main actors to set a LL agenda: energy, hospitality, tourism, etc
- Funding by European Commission and Rijkswaterstaat
- Involve NHL students and the school knowledge
- At present, collecting topics for an “agenda of the LL” to make connections with other partners and detect links
- Important to start step by step, initial big funding not necessary
- Rijkswaterstaat creating a web map on “the Lab offer” in the Province to inform companies on technologies, create connections, know each other’s
- Innovation: Bring multi-disciplines together and LL approach give decision making powers to everyone

Interview number 5: 14.06.2018

Jan Zijlstra

- Public servant at Dongeradeel Municipality
- Member of Holwerd aan Zee development project working group

Holwerd aan Zee development project:

- Community project with citizens involvement
- Government need to learn about engaging citizens (new way of governance)
- Work under Foundation allow inclusion of new projects, more flexiblity compared to Municipalities 4 years programmes with determined budget

Holwerd aan Zee problems:

- Collapsing houses
- Decline of population
- Youth leaving village
- Many barriers and fences between the village and the Wadden Sea (declared by UNESCO as World heritage)

Integral development projects planned:

- Connect village to the Wadden Sea through a canal in the dike
- New economy through tourism and recreation activities
- Preserving the history
- Export salt tolerant potatoes
- Use high tide low tide
- Fish migration
- Birds nesting (Natura 2000)
- For the future: 1. Electric only plane flying to the wadden sea Islands, 2. pier of 2km in the Wadden Sea for more greener landscape 3. dredging to reinforce dikes
- Project budget: EUR 60M funding from Friesland Province EUR 10M, Wadden Sea Fund 25M and Rijkswaterstaat 25M
- crowdsourcing: requires time and effort
- Project starting spring 2019 and to end by 2023

Working group:

- in charge of the project implementation: farmer, entrepreneurs conducting talks with partners and citizens exp. Delta Commission, Wetterskip, Rijkswaterstaat, nature organisations, etc
- Connect entrepreneurs with each other from touristic places in North and South of the Province

Connection with the Water Board:

- Understand effect of salt water penetration on the soil
- farmers to measure salt water levels using equipments
- collecting data for the water board

Project initiation:

- right ambitions and the Government tasks at this time (right timing)

- village representatives connecting with the Municipality
- designation of the working group to contact partners and citizens, put ideas together
- extra funding to be secured with help of Wadden Foundation, Vogelbescherming, WWF (interest in the project)

Holwerd aan Zee living Lab:

- involve schools and universities
- get the picture through students research activities, ideas and innovations
- students research are generated with informative and innovative way. reports are generated and used to develop the projects
- different from traditional way: hiring consultancy firms is more time and money consuming

Stakeholders engagement:

- stems mainly from economic constraints, necessity to develop the area development: loss in real-estate value, population decline, lees farming activities
- discussion of innovative approach to development through the working group, no one is against the project, everyone sees the importance and interest
- engagement enhanced by the participatory approach adopted and innovative way of developing ideas

Success factors:

1. Working group motivation and engagement, freedom to move and meet people outside administrative hierarchy
2. Ideas from people through participatory approach are integrated and developed
3. no discussion about costs at the beginning, "there is always money for good plans"!
4. keeping people informed: project website and social media (twitter, Facebook)

Climate adaptation linkage:

- Climate adaptation was not the initial drive for the project initiation
- Connexion to climate adaptation because available finances allow the reinforcement of the dike

Interview number 6: June 26th, 2018

Gerda Lenselink, Deltares

Member of the Knowledge network of the Delta program
All component of program represented including flood risk prevention, presence of knowledge institute. Network members meetings discuss the program content development and decision-making process.
Big delta decision every 4-5 years, At present execution phase,

Delta program:

- Deltares working on new standards for flood prevention/monitoring and evaluation/cost benefits analysis / safety and investment
- New dikes standards discussed in 2010, was difficult at the beginning

Room for the river:

- Gerda worked for the preparation phase as part of spatial quality team
- Integrating Safety and spatial quality equally
- 39 projects, EUR 2.4Billion Larger rivers

Delta program initiation:

- Economic crisis at that time, right wing party elected questioning climate change
- Difficult for delta commissioner to focus at the beginning on flood safety and spatial adaptation
- Integrated approach for dikes reinforcement combining with other functions was not considered

Dikes multi-functionality:

- Projects scope should integrate other functions of dikes at the beginning
- Water board are very important and some very pro-active and could enrich the scope of programs

National Flood Protection Program (HWBP):
in charge of all dikes reinforcements, executive program of the Ministry of Infrastructure and Water Management, and provide fund to water boards 50 km a year in dikes reinforcement

- Realizing dikes is a line but within a context and area, HWBP have to consider what makes a dike attractive, people don't want higher dikes because they live nearby,
- Program and the Ministry determine dikes projects and water board to decide about joining to enrich the project scope
- If Province is agreeing and study to be made in a short time

Example of innovative dikes: Province of Groningen double dike project

- Benefits: cockle's aquaculture and agriculture of salt potatoes, very attractive to experiment, higher value to land
- People involved as benefits generated from aquaculture and saltwater agricultures
- Important to have someone willing take risk and explore new areas
- in area around, farmers growing potatoes area are transiting to salt potatoes, young farmers communities reacting and adapting to future change in area (brackish waters)
- people embrace transition and look for new ideas and benefits

- province and water board playing very important role

some conditions to develop innovative dikes projects:

- good ambassador, strong cooperation and knowledge
- discuss with inhabitants what is possible for new revenues and integrated into the history and context of area
- other disciplines to learn from each-others, accumulation of knowledge although it takes time, expl. Nature protection and spatial planning

Living labs experience:

- Gerda experience with Rijkswaterstaat
- management of nature areas, developing polders and lands in a way to gain more agriculture land and be connected to the sea (delta works)
- expl. Lauwersmeer nature area in the 90's: are example of LL where new concepts of water management are tested, by practicing and monitoring with small steps
- at present transition to real bigger living labs, more learning even results are unknown, example of. Marker wadden project as more recent experience

knowledge program Marker wadden:

- challenge is working with mud and clay for dikes reinforcement instead of sand
- learning how to make new robust nature with extra nature values and integrate the social dimension
- cooperation of different parties, companies, NGOs, government, dredging companies, and others.
- Learning and testing will lead to scaling up of projects

Knowledge dissemination and living labs:

- Living labs have many owners and can be intermediate platforms to stimulate knowledge dissemination
- Living labs are about action and practice and is different from knowledge dissemination
- Knowledge dissemination: not getting enough attention, difficult, lack of finance and infrastructure

Defining living labs:

- are different kind of experiences not only connected to dikes, other experiences: built with nature, siting of dikes, multifunctional approach such as energy production
- are tangible to people and a way to engage them, people need to be engaged and feel responsible, and can be connected to projects to ask questions, it offers more than awareness but also taking people seriously starting the dialogue to avoid fragmentation and connect to people needs.

Climate adaptation:

- Life in delta is rather complex, vulnerable and common challenge to live in a delta
- Develop a vision to speed up climate adaptation, If sea level rise it will affect all the country system, creativity needed: new governance approach, decision making process is based on polder model but it takes time, more adaptive and flexible approach needed

- Awareness to be made about cooperation and bottom up approach
- North-South cooperation important: take experiences outside borders, and solve other problematics expl: social equity, migration, …

Delta approach based on (exported vision):

- Multi-governance
- Integral approach
- Joint fact finding: stakeholders deciding together this is the truth

Interview number 7: June 27th, 2018

Prof. Pier Vellinga, Professor Emeritus at Wageningen University Research and VU University Amsterdam, Climate and Water Portfolio Wadden Academie

Defining a living lab with regard to dikes planning:

- LL are where experiments are relatively frequent
- However, in the Netherlands looking at dikes is happening every 6 years and plan made to reinforce them for 20 to 30 years ahead
- we should consider the whole of the Netherlands as living lab, permanently plans are made and experiments with dikes at a specific location every 5, 10 or 20 years are opportunity to try out new dikes concept

Expl. Groningen Province: prepared for 5 years for double dike concept and 5 years to carry it out, another project" green dikes" 8 years of preparation and 5 to 10 years to carry it out

- living lab depend on criteria to be successful: many experiments and opportunities and relatively high frequency (couple of times a year) to call something a living lab
- living labs sounds are kind of permanent open laboratory and laboratory has something permanent

A city has many neighborhoods, so many opportunities for testing and city itself is permanent, 30 to 40 experiments in 5 years, with dikes no need to speed up, dikes are long term planning

Delta program and POV:

- delta program as organization and all technicians are involved are living lab
- POV is innovative program of the Rijkswaterstaat, learn from each other maybe we have a LL already and it is called the "delta program
- Sub program of delta program "POV" is completely designed as a living labs, during groups "water boards" are allowed to carry experiments and to learn from each other, speed up innovation and try new ideas.

Multi-function dikes and POV:

- POV is meant as LL but within it multi-function dikes are one among other innovative dikes concept, there is no emphasis on multifunctionality
- Less attention to multifunctionality, found more difficult to conduct pilots
- If governance decide to implement more multifunction dikes, should focus on better incentives expl: premium on multifunctionality,
- at present multifunctionality is kind of a penalty because of the complexity and time needed
- Scaling by definition of multifunctionality is difficult because each location has its own multifunctionality
- Multifunctionality requires not only public sector (Rijkswaterstaat and Water Boards) involved but also private actors and Provinces more complex, specific and takes time

Rather ask how we can promote more multifunctionality and more unbreachable dikes in coastal protection, and why is not happening?

Obstacles:

- Not certain if living labs can be the answer to multifunctionality in dikes, complexity and unawareness are among other obstacles (existing studies)
- Further research needed: what are other obstacles (complexity, subsidy scheme lacking, unawareness) and what premium could counter balance the obstacles?

Recommendations to promote multifunctionality:

- Multifunctionality it is more complex but have more societal benefits, that is why government have to remove obstacles and put premium on multifunctional design and implementation
- Design program by Government to put premium on multifunctionality, additional subsidy for top-down encouragement
- Present subsidy schemes are mainly for monofunctionally, the need to create multifunctionality subsidies combined from Government, local municipalities, water boards and private stakeholder's funding
- Make the Provinces more responsible for dikes building can be an option
- Dikes building moving away from technical constructions much more to spatial planning, however, water board are focused on lines in the landscape and spatial planning is the domain of the Provinces,
- Modern dikes building: water boards are monofunctional to pick up innovation

Finance option: Crowdsourcing

- In cities is possible for dikes rather impossible, very costly, short term benefits are small and dikes are long term planning (20-50 years),
- Water boards can raise taxes and have authority but are mono-functional institutions

Future of multi-function dikes:

- Development step by step because of the shortage of space
- They are macro-economic societally more beneficial
- increasing application of multifunctionality but very slow
- People trust what they have done over the ages

Citizens and entrepreneurs can play a role:

- Benefits of multifunctionality for them, expl: parking, golf fields, etc.
- Create safer conditions for themselves behind the dikes through local NGOs that promotes one or the other (benefits and safety)
- Dikes is a fish too big for city living labs but citizens could be of influence

Innovation for climate adaptation:

- Private sector to play important role and find new opportunities, early movers Exp. Saline agriculture as innovative adaptation concepts, entrepreneurs showing interest
- Citizens can help with subsidy with innovative adaptation through city or national governments
- Subsidy schemes for innovative adaption are very helpful and are occurring

- Citizens have smaller role on coastal defense, they can organize themselves in local NGO to have some influence, but in practice usually private sector, agents with innovative schemes of building or nature management who lobby or push government for innovations to obtain subsidies if available
- citizens can have opposition in the construction of large scale infrastructures but not push innovation

Interview number 8: June 28th, 2018

Timo Maas, Researcher at Rathenau ***Institute (independent Think-tank)***
Researcher on Societal aspects of new technologies and innovation systems

Living labs study by Rathenau Institute:
Literature and quick scan of Living labs in the Netherlands to clarify the notion of living labs

4 types of LL identified with different

- characteristics and goals
- audience
- types of collaboration (between university and companies)
- co-creation through citizens involvement

Most common types of LL:

- innovating in industry: implementing and testing technologies in factories
- Real life living labs: Testing technology in the real world (exp. Behavior cycling)
- Societal challenges: help with solving contested issues

Many people recognize the term and aware of risks and pitfalls
No type is better than others, each depend on the goal

Risks and pitfalls:

- create expectations that cannot be met
- Ethical issues (privacy and data)
- Small in size and scope especially with regards to users group involved
- Data is small so scale up is difficult exp. Understand technology, social or organizational arrangements to implement elsewhere

Governments:

- In many cases, Governments are very helpful players, can be funders and sometimes involved to omit some regulations and help make exceptions to test new technologies
- Act as bridge between different LL initiatives exp. Room for the river
- Other initiators: companies, Universities, citizens, utilities

Example of success factors of living labs:

- Defined scope (What is measured)
- be aware of the different expectations of each group of stakeholders involved: citizens, entrepreneurs ….
- Shared vision on what is to be achieve by the living lab
- Structure the LL work to document what was learned otherwise experience will not reach any further

Benefits of living labs approach:
Exp. Amsterdam streets living lab by Uni of Applied Sciences

- field lab, researchers trying to find out solutions to low literacy rate and debt among young people in some neighborhoods

researchers using living lab approach:

- built different relationship between the researchers and the neighborhood people
- created trust

- legitimacy and acceptance of the process of solution providing
- built rapport with people
- opportunity to people to give their opinion and be part of the project, hence were more receptive and the solutions are better as they fits the circumstances of people

Co-creation in Living Labs:

- there are degrees of co-creation in living labs depending on parties from different backgrounds with different goals involved
- It starts becoming co-creation when government officials, citizens are involved
- Very important characteristics of living labs
- Co-creation is more inclusive and open to the input of non-governmental parties

Exp. of Climate adaptation innovation living lab: “Climate adaptation city deal” in the NL

Interview number 9: June 29th, 2018

Wout de Vries, Rijkswaterstaat, Flood risk management expert *(coast, dikes and dunes)*
Previous work with Water Board Friesland

Multiple uses of dikes:

- Main function of a dike is to provide safety against flood.
-
- Only country in the world with norms against floods laid down in the national law. This reflects the importance of a sound flood protection/flood risk management for the Netherlands.
- Norms are strict, so these dominate in the risk domain. Under daily circumstances, flood defences seem to offer enough possibilities for multiple use. However, flood defences need to withstand norm conditions: very high water levels and strong waves (and enormous winds). These conditions are very severe; during such conditions there is no possibility for human intervention (e.g. repair). Facilities related to multiple use are often hampering a sound functioning during these conditions. Problem is that such conditions seldomly occur. So the general public does not automatically understand what the fierce conditions are for that the flood defences have to withstand. And that flood defence managers can not just be flexible and can not reduce the strict norms to just allow for multifunctionality.
-

Delta dikes concepts:

- The dutchdikes usually consist of a sand core, which is protected with (relatively) thin layers of asphalt (15 – 20 cm), stones (30 - 50 cm) or clay with grass (70 – 80 cm). Ifsuch protection is breached, resulting in exposure of the underlying sand core, such adike will erode in short notice; Actually such a dike will then behave like a dune.
- Delta dikes are often much wider than traditional dikes. These look, because of their width, very strong. However, also here such a dike will behave like a dune when the protective layer is breached.
- Protection is priority (and duty) of dike managers

From dikes managers perspective, 2 principle options are open for multi-functionality in dikes:

1. Outer slope of dike left free to allow for inspection and maintenance
2. Make a very strong dike underneath, so that the covered dike can be used for other usages (multifunctionality), expl. Schevingen coast, stronger dike buried under the multifunction dike. However, in the zone of the dike, strict restrictions still remain. E.g. digging is strictly not allowed.

This implies extra investment for projects developers. These extra costs are mostly marginal in relation to the total cost of such initiatives.

Some obstacles to multifunctionality:

- Flood protection in the NL with very strict norms, guarantee a sound flood protection with very small chances of occurrence (1/10000 years).
- Other usages of dikes should be such that the primary function (safety) is not damaged/affected,

- Innovative alternatives of multifunctional dikes are to be tested under extreme conditions as to prove that such alternatives do not hamper the main function of dikes. Building experiences is necessary.
- Problem with the importance of sound flood protection in The Netherlands is the (luckily) absence of big floods. General public is not aware of the potential danger of flood conditions. This makes discussions of multifunctional flood protection difficult. Under daily circumstances, such strong dikes are not needed at all. That is mostly the reference of the public. That is why dike managers are not often understood, because their reference conditions are seldomly expierenced.most commonly Municipalities develop multifunctional areas. Problem is that in the plans usually no budgets are reserved needed for extra flood protection works (including extra costs for maintenance).
- Water board is responsible for flood protection and have to obey safety rules, financially not big constraints extra costs are relatively low when compared to the investment sums of multifunctional use (most commonly recreation, urban expansion).

Some examples of multifunctional dikes:
city of Almere, Lelystad (housing to look over water) and Harlingen dike integrating an underground parking space
Existing studies by Delft University on multifunction dikes guidelines

Conclusions:
- Creativity for multifunctionality to come from developers ánd dike managers
  Expl. Green dikes are dikes with a gentle outer slope. They offer the required protection, but need much more space. This space should be available.
- More research is needed to prove and test that safety standards are maintained under extreme conditions while multifunctionality is allowed, although it can be costly
- Innovative dikes experiences are possible but may cost extra money and space

Interview number 10: July 19th, 2018

*Richard Jorissen, Rijkswaterstaat, **in charge of the Rijkswaterstaat's strategic agenda for the river area***

Previous function: Flood Protection Program (Hoogwaterbeschermingsprogramma : HWBP) Director (until May 2018)

The HWBP role:

- Prepare national program based on national urgent flood protection projects
- Size of the program limited by the available budget (provided by the Ministry of Infrastructure and Water Management and collective of regional water authorities)
- Distribute funds to regional water authorities according to priority, based on urgency (risk): 90% subsidy of regular projects and 100% subsidy to the regional authority for the smart projects or solutions
- Stimulating innovation through: guidelines, sharing experience and knowledge, capacity building

Innovation within HBWP:

- Technical innovations aimed at reducing scope (smarter safety assessments) and smarter measures, examples are vertical geotextiles for piping measures (instead of berm or sheetpiles).
- Process oriented innovation, governance and maintenance, aimed at smarter processes, for example "regional authorities not taking into-account the benefits of a foreshore in a dike"
- Stimulate innovation through subsidy (100% for smart projects) contributing to the program goal in term of dikes reinforcement and enhanced quality, etc
- Stimulate authorities to share their innovation needs and come up with an overarching proposal for innovation
- Stimulate private industry (contractors and consultants) and research institutes to come up with proposals for innovation (innovation scan)
- Over 4 years, nearly EUR 100M spent on innovative projects (e.g. Double dike Groningen, but also POV Piping and Macro-instability)

Innovative projects stakeholders:

- Differ for each project
- In technical innovation: industry and research institutes, Provinces involved for spatial planning issues, nature conservation for nature and ecological development and preservation
- Number of tools generated to improve quality of work of the water authorities
- Tools developed are becoming the new standards
- HBWP helping the shift toward innovative options: e.g innovative solution for piping now costs less than the traditional solution, hence, the new innovative solution is established as a financial reference for the subsidy
- Upgrade the way of work (dikes reinforcement) through new standards and new tools used
- Hardly new dikes are built, almost all dikes reinforcements concern existing dikes

Main obstacles to multifunctional flood defences:

- Regional water authorities have history of addressing dikes as monofunctional systems and financial arrangement are made on that basis
- Public budget not allowed to be spent on other purpose that flood protection (excluding spatial concerns), although a dike may comprise a road/bicycle path, etc. and have cultural values in the area
- To transform from monofunctional system to multifunctional system require new approach of projects: management and maintenance
- At present water authorities assess the quality of the flood protection structure without the effect of the offshore, that have ecological and natural values, they operate the offshore as part of the flood protection defences, to be maintained as well as part of the flood protection. Foreshore is often managed by another authorities (Rijkswaterstaat, Province, Municipalities or nature conservation authorities), integral agreement needed on how to manage the foreshore from flood protection perspective also, multifunctionality complicate the arrangements.
- Authorities to come up with more integral approach, water boards are the party to initiate and team up with other authorities, supervised by the Provinces as spatial planning authorities, to develop inclusive solutions, but it requires discussions on the type of project and approach for the area.
- 3 stages per project: reconnaissance, planning and construction
- Flexibility for integral solutions is often limited by time, money and budgets.
- Discussion on type of project to be carried at the start for scoping instructions

Example of integral project (multifunctional): Grebbedijk project, region of Wageningen, short structure dike, 6km reinforced, collaboration of the water board with Province, Municipality and Rijkswaterstaat, and other partners), joined at early stage of project to explore possible integral solutions, alliance concluded on integral spatial development of the dike reinforcement.

Integration of multifunctionality in Delta program decisions:

- Approach of Grebbedijk project showed the way the process is organized is decisive whether monofunctional or integral solutions will come out of it.
- Grebbedijk project needed wider reconnaissance stage so more time and money to find out in-flow of solutions, HBWP subsidy additional budget compared to flood protection. Initial costs will have to be put forward by municipalities or farmers associations. Financial arrangements are also important for the reconnaissance stage.
- Delta fund should at least cover all initial development costs of projects
- One national integral fund is complicated, because of the multiplicity of funds available in scope and level: national, local, regional, private (exp. State lottery)
- Because of the large number of budget holders, it is more effective to plied for slight combination of available budgets, it is more about smart cooperation than full integration of funds.

E.g. of smart combinations: If water boards can accomplish ecological goals for the Province, then Province can pay the water board for it.

- Smart combinations 3 levels of approach: **1. project level:** water board have a project and integral solution are to be explored, or **2. Program level:** HBWP has a defined portfolio for the next 30 years (what projects, when and where will be executed), to combine with other programs e.g housing, sediment management in rivers, ecological development, etc. induce more flexibility in sectoral prioritization, hence give partners more options to collaborate on, or **3. Financial "dictatorship**": one budget for all

- Additional option (done after the interview): mix between 2 and 3, by conducting joint and integral reconnaissance stages for all projects in a specific region. Planning and construction can be done separately if an integral approach does have any added value.

Living labs approach and multifunctionality:

- Offer open space of interaction between partners to discuss smart solutions or combination of issues and challenges
- Living lab can be interesting for the "Initiation, scoping, framing" of integral projects, at this stage, research for partners and smart ideas, before decision making and formalization of solutions
- Living labs are a process type of approach but has to be framed in time, space and functions, otherwise it could transform into a research initiative (regular) instead of initial stage of the project
- Multifunctionality is not always necessarily long-life span and robust infrastructure, because a form of integral solutions can be adaptive solutions allowing flood protection infrastructure or build with nature solution, to interact or adapt to the environment, e.g. instead of rising the dike heights because of climate change scenarios, we can enhance the quality of the foreshore for flood protection, by allowing it becoming higher and wider. Living labs not only as working source but real project allowing construction to grow overtime: physical living labs
- Since 1990, protection of coast with foreshore or beach nourishments done on regular phases, small natural measures, a form of living lab, instead of regular nourishment, mega nourishment near the Hague: natural process to take place and provide sufficient safety, to be considered as a living lab on full scale instead of laboratory scale.