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Social construction of Stormwater Control Measures in Melbourne and Copenhagen: a discourse analysis of technological change, embedded meanings and potential mainstreaming

Running title: Social construction of stormwater management

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Keywords: Sociotechnical Systems; Social Construction of Technology; Water Management; Stormwater Management; Cities; Water Sensitive Urban Design

Highlights:

- Melbourne and Copenhagen are known for green and participatory planning approaches
- Challenges exist with urbanization and climate change, including drought and flooding
- Stormwater control measures (SCMs) are similar but applied differently
- Technological stabilization is currently higher in Melbourne than Copenhagen
- Multilevel supportive policies and closure by redefinition may further development

Abstract

Urban stormwater systems in cities around the world are challenged by urbanization and climate change, and a range of Stormwater Control Measures (SCMs) are being implemented as solutions to these challenges. We developed a conceptual framework of technological stabilization based on Social Construction of Technology (SCOT) and Transition Science, and conducted 16 in-depth actor interviews as a basis for mapping the historical development of in the two cities. The SCMs applied in Melbourne and Copenhagen are similar, but using a new framework for technological stabilization we identify differences in their application due to different physical, organizational and cultural contexts in the two cities, drought being the main driver during the past decade in Melbourne (1997-2010) and pluvial flooding in Copenhagen (2007-). In Melbourne there is currently a strong integrated understanding of SCMs: after decades of “new technology” development, “testing” and “opportunity” seeking a large degree of “agreement” about stormwater management as a mainstreamed professional practice has arisen. In Copenhagen there are

currently multiple conflicting understandings of SCMs and signs of an emerging integrated understanding that offers “opportunities” for further development and implementation. It is clear from Melbourne’s history that: successful full scale demonstration projects supported and developed by a wide range of actors helps building a common vision for SCM technologies, supportive policies across several governmental levels provide incentives for implementation, and inclusive actions in the closure process provides a sense of ownership for SCM technologies across disciplines.

1 Introduction

Urban stormwater systems in cities around the world are challenged by urbanization and climate change. This leads to problems in multiple places of the management of the urban water cycle; including issues such as drought, flooding and poor water quality (Chocat et al., 2001). Copenhagen and Melbourne are two cities on opposite sides of the earth, which experience these kind of challenges but yet in recent years have been voted as some of the most livable cities in the world (Leigh, 2014; The Economist Intelligence Unit, 2015), celebrated for their green, sustainable and participatory approaches to urban planning and urban life. Both cities have been given these awards despite the experienced problems with the urban water cycle, a changing population, parallel urban expansion and densification, and climatic changes. Specifically, Copenhagen has experienced flood damages of more than 800 million EUR in one very large cloudburst event and Melbourne had significant losses not only in farming and industry but also in the everyday lives of urban citizens due to e.g. fire and watering bans(Brown and Clarke, 2007; Institut for Beredskabsevaluering, 2012). Seemingly, both cities have seized the opportunity for positive change created by these challenges, but the detailed mechanisms are so far unexplored.

In Copenhagen, Melbourne and several other cities around the world it is attempted to use green and sustainable stormwater technologies to solve the experienced problems of the urban water cycle (Chocat et al., 2007, 2001; Mitchell, 2006). Fletcher et al., (2015) suggested the term Stormwater Control Measures (SCM) to encompass the wide variety of global terminology encompassing these solutions, which is still evolving and now includes “Nature-based solutions” in Europe (Kabisch et al., 2016) and the “Sponge city” concept in China (Gaines, 2016). In Australia these technologies are called “Water Sensitive Urban Design” (WSUD) solutions and in Denmark they are called “Lokal Afledning af Regnvand” or “Lokal Anvendelse af Regnvand” (Local Rainwater Drainage or Local Use of Rainwater – LAR). The basic technologies involved in WSUD and LAR solutions are very similar (Fletcher et al., 2015) even though they may bear different names and be used for different purposes (see Figure 5 for further details). In this paper, the term LAR is applied to the Danish setting, the term WSUD to the Australian setting, and the term SCM is used in contexts that encompass both the other two terms.

WSUD is defined as an integration of urban planning with the management of the urban water cycle, and therefore incorporates several values, considerations and goals that mostly relate back to the term sustainable development (Fletcher et al., 2015; Wong, 2007). Behind the broader principles are the specific technologies (Fletcher et al., 2015). WSUD systems consist of different elements, here also referred to as technologies or SCMs, and a combination of several WSUD elements in a treatment train will result in a stormwater management system. The SCMs are different but they are all to some extent based on the following hydrologic processes: detention, infiltration or harvesting, evaportranspiration, transport and treatment (Engineers Australia, 2007). LAR can be defined as any initiative that controls rainwater and stormwater locally and therefore reduces the amount of water led to the piped sewerage system (Aabling et al., 2011). LAR is connected to urban ecology and therefore also perceives stormwater as a local resource (Anthonisen et al., 1992; Lützen et al., 1994). Like for WSUD, LAR consists of different elements, and a combination of these elements results in a stormwater management system. The SCMs involved in LAR are based on the same range of hydrological processes as mentioned above for WSUD (see e.g. Københavns Kommune, 2010a).

Especially the story of Melbourne's urban stormwater system has been well investigated as part of a larger study of integrated approaches (Mitchell, 2006) and with specific focus on the transition towards a Water Sensitive City (Brown and Clarke, 2007; Brown et al., 2013; de Haan et al., 2014; Ferguson et al., 2014). The story of Copenhagen's urban stormwater system has recently been investigated in relation to climate change planning (Fratini et al., 2012a) and in relation to the narrative of harbor bathing (Jensen et al., 2015). The aim of this study is to compare the development in these two cities towards stabilization of stormwater management as a mainstreamed professional activity addressing often mentioned challenges such as drought, flooding and poor water quality, to establish a basis for further development of innovation and implementation of SCMs. Main focus is on the technological change and embedded meanings related to the applied SCMs and the actors connected to these. For this purpose we first develop a conceptual framework of stabilization based on Social Construction of Technology (SCOT) and Transition Science, identifying the four typical stages "new technology", "testing", "opportunity" and "agreement". We then draw parallels between the SCMs used in Melbourne and Copenhagen and apply the new framework for analyzing 16 in-depth actor interviews and supportive literary sources, in order to identify how far the stabilization process has come in the two case cities. Finally we compare and discuss the underlying drivers of development in the two cities and the role of actors, full-scale demonstration projects, and supportive policies and institutions for mainstreaming of WSUD and LAR – and thus SCMs in general - in urban stormwater management.

2 Theory and method

2.1 Research design

The overall research design of the study was based on two types of data: primary and secondary data. The primary data consisted of in-depth actor interviews that were supported by secondary data in the form of literature. Figure 1 shows the flow of the overall research design. An initial study of literature on Social Construction of Technology (SCOT) and Transition Science as well as grey literature for both case cities was used to conceive a conceptual stabilization framework and to structure the interviews. Primary interview data were then collected and analysed in distinct rounds for each case city. Finally a comparative historical analysis was made of the two data sets using the proposed conceptual framework.

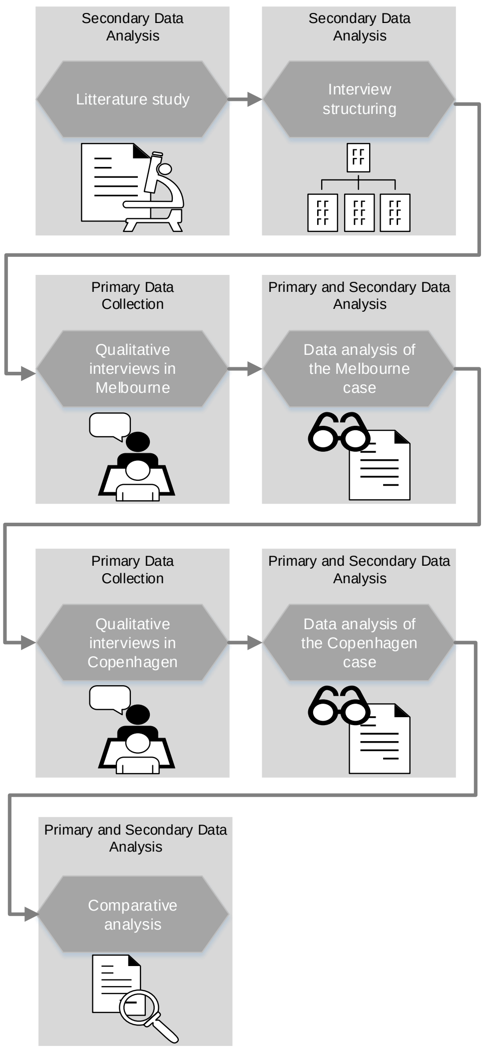


Figure 1. Research design structure of the study.

2.2 Social Construction of Technology in the context of innovation and technology studies

The socio-technical analysis framework SCOT (Social Construction of Technology) was used to examine the stabilization process of WSUD in Melbourne and Copenhagen. SCOT is aimed at analysing changes in a socio-technical system and originates in Science and Technology Studies (STS). SCOT was chosen because it is the negotiation between the human actors in the technological development process that is in focus in this study. However, SCOT can also be related to the newer scientific fields of Transition Science (TS) and Innovation Systems Science (ISS) in the way that SCOT takes a more "specific focus on technology" (Markard et al., 2012) in the analysis of a transition of a socio-technical system. SCOT, TS and ISS all take as a starting point that technology is developed through a competition of different designs in a complex interaction between technology and people. SCOT distinguish between humans and non-humans in a way other technology studies such as e.g. Actor Network Theory (Latour, 1987) do not, and this is especially powerfull when studying (infrastructural) technology and the impact it has on humans (Pinch, 2010).

SCOT proposes a series of terms that forms a framework in the socio-technical analysis: *meaning*, *relevant social group*, *stabilization*, *closure* and *interpretive flexibility*. The aim of the SCOT analysis is to describe the stabilization process, the development of the technology in focus towards a more stable situation. *Stabilization*, as used in SCOT, involves settling arguments between different actors involved with a technology, called *closure* (Pinch and Bijker, 1984). *Closure* does not necessarily require that the technological problems forming the basis for the argument have been solved, the actors just need to feel they have been solved, and *stabilization* therefore results in an agreement on a set of meanings and a stable expression and vision for the technology, which might not be the technically optimal solution but remains the immediate negotiated result. Different closure mechanisms are *rhetorical closure* and *closure by redefinition* of the problem. *Rhetorical closure* is related to convincing others that there is no problem by simply advocating for your meaning to be correct or others to be wrong, and *closure by redefinition* of the problem is connected to seeing problems and solutions in a different light and to include several problems in one solution (Pinch and Bijker, 1984), which makes it unnecessary to convince others.

SCOT analysis focuses on why and how a certain technology design has prevailed by looking at the *meanings* that have been in focus of the social groups concerned with the artefact (Pinch and Bijker, 1984) . A meaning is connected to a social group and not only to the technology. Meanings can relate to both psychical and other properties like aesthetical values and are therefore often connected to the use of the technology by a social group. Closely related to meanings are *relevant social groups* which are defined as: "all members of a certain social group (whom) share the same set of meanings, attached to a specific artefact" (Pinch and Bijker, 1984). The term *interpretive flexibility* relates to the variations in meanings and designs of artefacts. A high interpretive flexibility of a technology therefore represents a relative high number of meanings and designs being in play, while a low interpretive flexibility represents a relative low number of meanings and designs.

Transition Science and other theories of change are often described by the well-recognized S-curve, see Figure 2, which originates in the ideas of improvement in the technology factor from the IPAT equation. The S-curve was first mentioned by Rip and Kemp (1996) in relation to Transition Science and further developed to the more complex Multi-Level-Perspective by (Geels, 2002). When developing transition science into Transition Management a sequence of phases were introduced: *predevelopment*, *take-off*, *acceleration* and *transformation* (Rotmans et al., 2001), and it was shown that transitions may not always actually take place (van der Brugge and Rotmans, 2007). Sometimes the old regime is so strong that there is a path-dependency and a *lock-in* between two regimes. If there is not enough momentum for innovations to *take-off* then there is a *system breakdown* of the innovations. Finally it also happens that the new regime never settles in a new equilibrium, which results in a *back-lash* (de Haan and Rotmans, 2011).

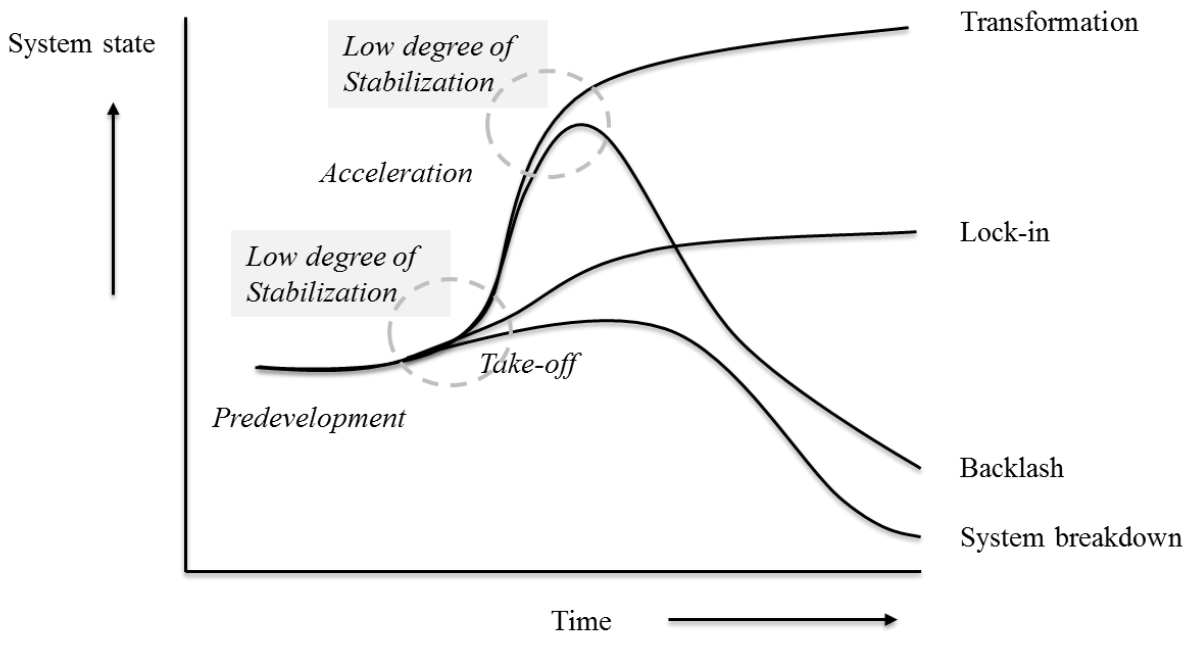


Figure 2. The different pathways of the system change, organised in phases. Modified from van der Brugge and Rotmans, (2007).

Stabilization is only a reflection of the meanings that are in play and the conflicts between them, it does not mean that a technology is mainstreamed or part of a new socio-technological regime. A transformation to a socio-technological regime may or may not follow after a stabilization, this is among other things connected to institutionalization. One can visualize the degree of stabilization as the radius of curvature of the S-curve of transition, see Figure 2. In the *take-off* and the top of the *acceleration* phase there is a low degree of stabilization and a small radius of curvature, while in the *predevelopment*, the *acceleration* and the end phases there is a higher degree of stabilization and a large radius of curvature. The stabilization is therefore a sub-set of a transition with partially un-known outcome: it may result in a transformation, or in a lock-in, a backlash or a system breakdown.

2.3 Conceptual framework for stabilization analysis

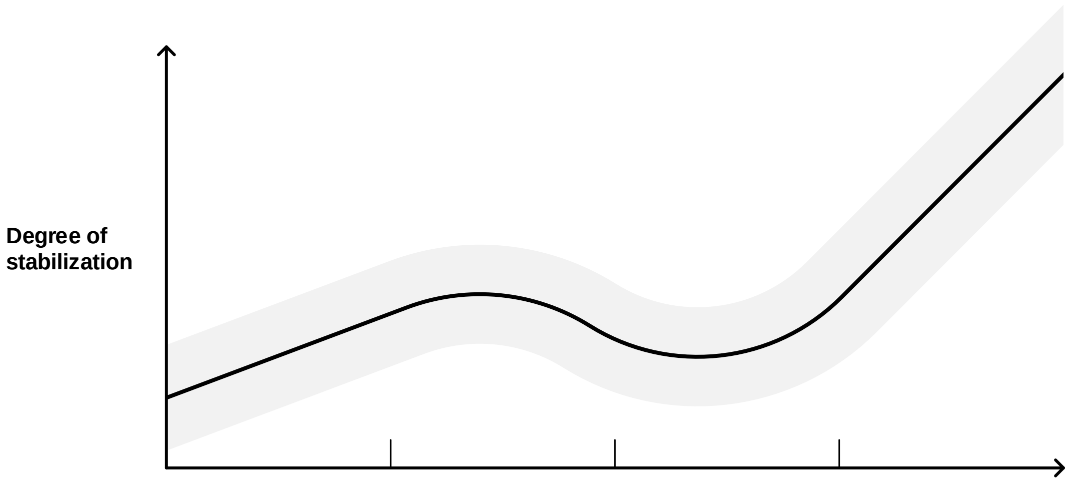
We propose a new conceptual framework for describing and analyzing stabilization processes. It is based on the purpose of our study (potential mainstreaming of WSUD/LAR, i.e. SCM technologies), the literature study, Transition Science and the SCOT framework. Our framework outlines four stages that SCM technologies go through (Figure 3):

- New Technology, where a technology emerges as a result of a conflict with the current system often caused by a change in the surrounding of the system.
- Testing, where test cases are used to improve the technology and only few actors are involved.
- Opportunity, where new actors are involved because of new dissatisfaction, which leads to new confrontations that need to be settled.
- Agreement, where the confrontations have been settled over time and agreement among the actors arises.

Throughout these periods, the level of complexity in the technologies increases, resulting in technologies that address several problems, are composed of more elements, and include more high-tech elements.

This conceptual framework forms the basis of our SCOT analysis and the general table (Figure 3) will therefore later be elaborated for both Melbourne and Copenhagen, by specifying for each period leading up to the present day what actors and meanings have been/are in play and what the relative degree of stabilization has been/is.

The network of dominant meanings and technologies in a period will be visualized in bubble diagrams (see Figure 6 and Figure 7). The size of the circles represents the degree of prominence of meanings in the period. The dual-line links represent a mutual positive relation, the full-line links represent a one directional relation and the dotted-line links a mutual negative relation. In positive relations the two meanings are not in conflict, which stands in opposite to the negative relations where the meanings are in conflict. The shaded areas represent the prominent technologies in a particular period; the size does here not reflect any degree of prominence.



	New technology	Testing	Opportunity	Agreement
Description	The technology emerges as a result of an issue with the current system.	Test cases are used. Only few actors involved.	New actors are involved because there is dissatisfaction. Leads to new confrontations that need to be settled.	Confrontations are settled over time, agreement arises.
Technologies in play	Few emerging technologies	Few more complex technologies	More complex technologies	Complex technologies
Main actors in play	Researchers Industry frontrunners Government Citizen	Researchers Industry frontrunners	Researchers Industry Government Citizens	Government Industry Citizens
Meanings in play	New technology is needed. Improvements of new technology are needed.	Improvements are needed. Benefits and risks are weighed.	Dissatisfaction with current system. LAR/WSUD are the solution.	LAR/ WSUD are a significant supplement to the original system and integrate several values.

Figure 3. Conceptual framework used to analyse the stabilization process of WSUD/LAR in Melbourne and Copenhagen.

2.4 Data collection, analysis and validation

The primary data was collected through semi-structured qualitative interviews preformed in Melbourne and Copenhagen during January-May 2013. Two types of interviewees were selected in each of the two cities: interviewees related to specific cases and a few industry interviewees whom we considered frontrunners in relation to SCMs. The case specific interviews gave an opportunity to construct in-depth narratives with specific examples and relations to the surrounding context. The frontrunner interviewees often knew of one or more of the specific cases but their narratives were not bound to specific examples.

16 interviews were conducted based on a maximum variation sampling strategy, i.e. the interviewees were selected to cover a wide range of actor types in each city (Weiss, 1994). 8 interviews were conducted in both Melbourne and Copenhagen, covering public managers, industry professionals, researchers, citizens and politicians, and 3 of these were considered frontrunners, Table 1. The interviews in Melbourne referenced the specific WSUD implementation case of The Darling Street Stormwater Harvesting Project (City of

Melbourne, 2012). The interviews in Copenhagen referenced the specific LAR implementation case of Vilhelm Thomsens Allé (Lützen, 2012).

Table 1. Number of qualitative interviews performed in Melbourne and in Copenhagen across a range of actor types. (n) Number of frontrunner interviews.

Actor type	Melbourne	Copenhagen
Public management	2(2)	1
Industry	2	3(2)
Research	2(1)	2(1)
Citizen	1	1
Politician	1	0
Other	0	1
Total	**8**	**8**

The secondary data included a wide range of grey and white literature sources. Most literature for Copenhagen included governmental reports: ranging from one of the first mentions of LAR in a report from The Environmental Ministry dedicated to explaining the potential of LAR technologies (Anthonisen et al., 1992); a report from The Ministry of Housing advocating local backyard LAR projects (Lützen et al., 1994); the recent climate adaptation plan and cloudburst plan of The City of Copenhagen (Københavns Kommune, 2012, 2010a), and a range of posts advocating for or against LAR in public media, notably Ingeniøren which is a weekly professional journal of Engineering and Natural Sciences (Daugaard, 2013; Holm, 2013; Marfelt, 2013; Marfelt and Andersen, 2012; Paludan and Arnbjerg-Nielsen, 2011). Most literature for Melbourne consisted of peer-reviewed journal publications (most noticeable (Brown et al., 2009, 2013, Ferguson et al., 2014, 2013; Gardiner and Hardy, 2005; Wong, 2007)) as well as technical reports and books (Engineers Australia, 2007; Melbourne Water, 2005; Victoria Stormwater Commitee, 2006; Wong et al., 2012).

The analysis method used for both the primary interview data and the secondary literature data was a fusion of meaning condensation and meaning categorization. The contents of the interviews were shortened to specific meanings expressed by the interviewee, then specific themes were flagged for use in the reporting, which allowed reducing the transcription in size but not content. The coding variables were based on the SCOT framework and the Water Aspects as they are described by (Fratini et al. 2012b). The Water Aspects express different values and perceptions in relation to water and were used by Fratini et al. (2012b) to map actors into the different domains of water professionals. The SCOT framework was hereafter used to describe the stabilization process of WSUD in Melbourne and LAR in Copenhagen based on the coded data. A range of verification methods were applied in this process: 1) constant reflection and revision of the interview guide to improve the interviews throughout the interview period; 2) verification through the interviewee, the real meaning was pursued with follow-up questions and by presenting a summary for confirmation and elaboration by the interviewee; and 3) verification through the research community, with the transcripts and coding being reviewed by more than one researcher. Furthermore when serious doubts arose in the transcription or coding a follow-up to the interview was conducted by telephone or electronically.

3 Results and discussion

3.1 Water infrastructure and context in Melbourne and Copenhagen

Melbourne is located on the south-east coast of Australia in a temperate climate with a population of 4.25 million in Greater Melbourne in 2012 (UN Data, 2014). Copenhagen is the capital of Denmark, a country located in northern Europe in a temperate climate with a population of 1.28 million in Greater Copenhagen in 2015 (Statistics Denmark, 2015). Figure 4 conceptually illustrates the urban water systems of the two cities. Please note that Copenhagen's water supply is based entirely on groundwater while Melbourne's is based on surface water reservoirs, and that Copenhagen has a combined sewage system, while Melbourne has a separated system.

The debate around urban water management in both Melbourne and Copenhagen is of course broader than what is covered by this investigation; alternative water supply sources in Melbourne including the controversial building of a desalination plant and swimmable water in the inner city of Copenhagen made possible by massive investments in conventional underground storage are for example not covered. The main points raised in this section should therefore be considered in the narrow context of SCM; however indicating a further opportunity for comparison and cross-city knowledge exchange concerning urban water management.

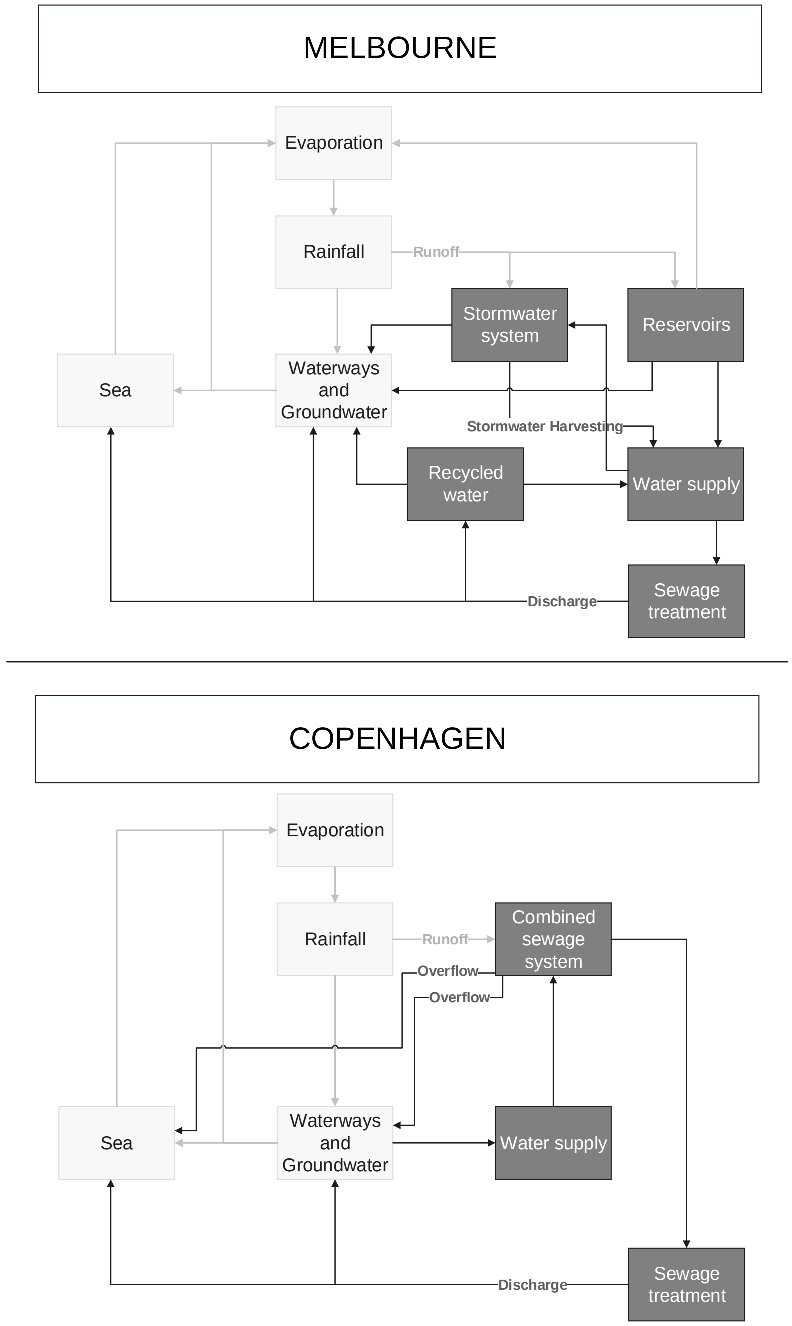


Figure 4. Conceptual illustration of the urban water systems in Melbourne and Copenhagen.

3.2 Stormwater Control Measures and meanings in Melbourne and Copenhagen

When reviewing Stormwater Control Measures used in Melbourne and in Copenhagen, see Figure 5, it becomes evident that the technologies are very similar and that they are based on the same hydrological processes: detention, infiltration or harvesting, evapotranspiration, transport and treatment. The similarities in the theoretical technical elements can be attributed to a global research community with fast knowledge sharing. Different terms are however used for some types of SCMs that function in the same manner in Melbourne and Copenhagen, which becomes clear after translating the Danish terms into English (see Figure

5). The technologies are furthermore applied in different combinations in response to the different contexts and drivers in the two cities. These differences include culture and politics, but also the physical environment including the water infrastructure and the natural environment. Similarities and differences in applications of the technologies are also present in the meanings expressed by actors in the two cities. Table 2 visualises the different dominant meanings present in the two cities with citations from primary and secondary data. Most meanings are present in both cities reflecting a shared technical base, but the meanings are present to different extents due to differences in context and drivers. Flooding was e.g. not a big issue to the interviewees in Melbourne, whereas it was very much so in Copenhagen where technical distinctions between *nuisance flooding* and *cloudburst flooding* were even made. Furthermore, groundwater was not mentioned by Melbourne interviewees but by those in Copenhagen, reflecting the difference in main water supply source in the two cities.

The water infrastructure in Copenhagen and Melbourne is fundamentally different. Melbourne has a separate sewage system; while most parts of Copenhagen have a combined sewage system. Both systems have led to problems with eutrophication and improvement of water quality has therefore been a major driver in both cities. In Copenhagen there is a very strong tradition for regulation and policy measures, which also applies to the case of SCM; the driver of water quality has firstly been handled though regulation with specific reference to detention storage and therefore led to little progress for the LAR solutions in Copenhagen. Moreover, differences in the natural environment have led to different drivers for and different applications of WSUD and LAR. Water is generally scarce in Melbourne's dry climate, and the Millennium drought during 1997-2010 (Ferguson et al., 2014) has therefore placed water scarcity as a main driver for the development and implementation of WSUD technologies. Extensive flooding due to cloudbursts has occurring increasingly in Copenhagen starting in 2005 and so far culminating in 2011(Arnbjerg-Nielsen et al., 2015), and flooding and climate change adaptation is therefore now the major driver for developing and implementing LAR technologies. Since the pressure from the natural environment is so different in Melbourne and Copenhagen, there have also been significant differences in what has been the focus of the implementation of SCMs. There has historically been a focus on volume reduction and detention in Denmark, while there has been a focus on treatment before harvesting in Melbourne.

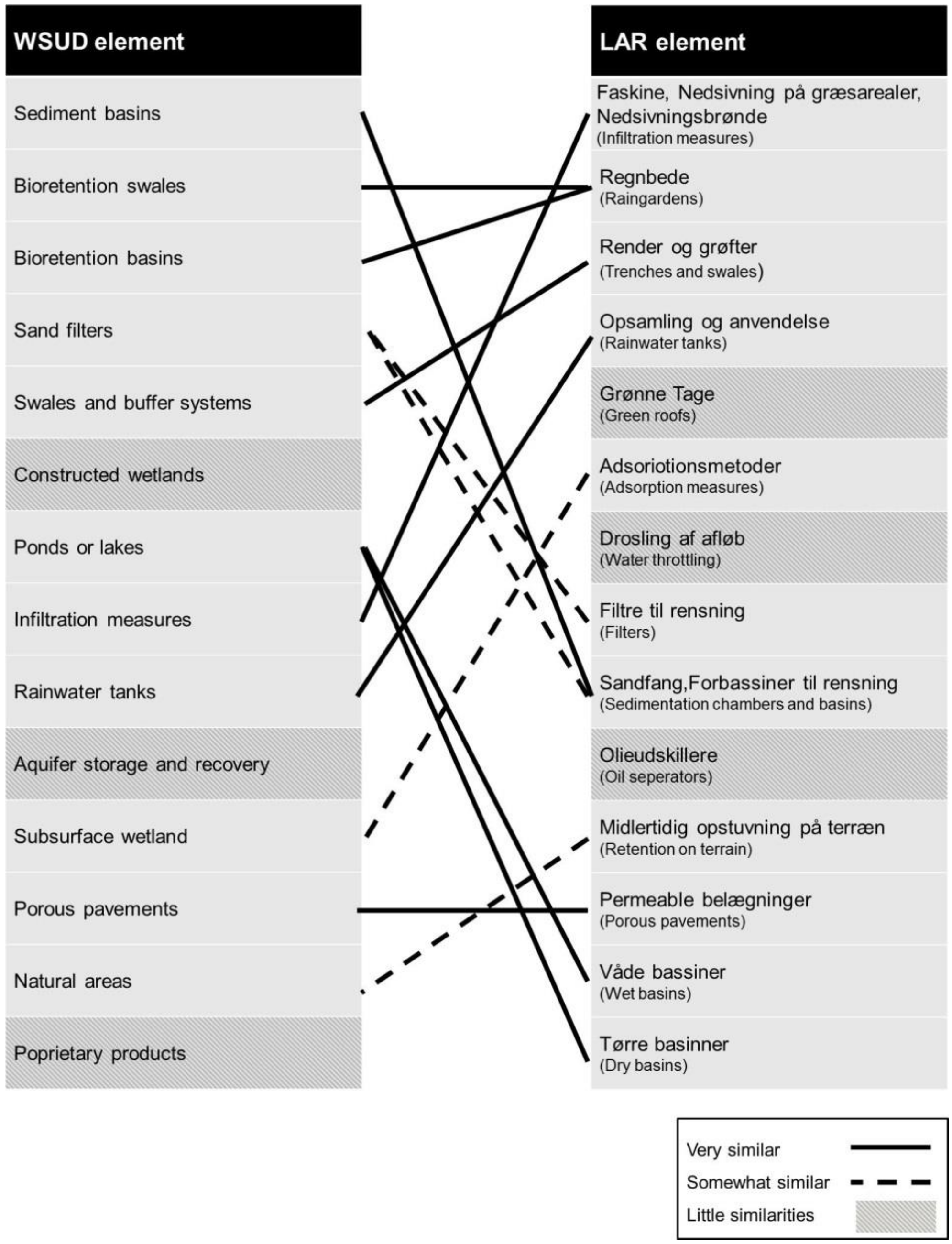


Figure 5. Comparison of WSUD and LAR elements, definitions from (Københavns Kommune, 2010b; Melbourne Water, 2005) respectively.

Table 2. Embedded meanings of WSUD in Melbourne and LAR in Copenhagen represented with quotes.

Meaning	Quotes Melbourne	Quotes Copenhagen
Water quality	*"There is other benefits to these things [WSUD] in terms of cleaning up and making the water cleaner in our rivers. Maybe we will actually swim in our river again without worrying [about] the toxins in them."*	*"There are multiple benefits…it [LAR] lowers the numbers of overflows to recipients…"*
Environmental protection	*"I think the environmental service contribution of the [urban] forest is something that is incredibly complex and incredibly important. ...The urban fabric is in essence an alien environment for good healthy trees and vegetation growth. So WSUD or permeability provides a below ground environment that provides a healthy growth…"*	*"We might get a more holistic city, which then also needs to be more sustainable. And I think this understanding of the natural foundation, which the city rests on in relation to pollution, CO2, water resources and other resources, is all important."*
Water harvesting	*"We have a lot of very old significant parks, that needs a good amount of water to supply them, so we had to – we were keen to find alternative sources"*	*"But I think that there will come a time where more water can be used, if you for example used the water for toilets..."*
Flooding	*"If you look at flood protection, someone else will look at the business case for flood protection in terms of reduction in damage and all that."*	-
Nuisance Flooding	-	*"If you consider LAR in the restricted Danish sense as very local infiltration possibilities; and then consider the larger and more intensive rain events – Then no, these two aren't comparable."*
Cloudburst Flooding	-	*"We can go and combine LAR elements, so that we have an element of detention, an element of infiltration and an element of cloudburst detention; this makes the local systems able of handling 100 year events without anything major, because we have a connection to the sewerage."*
Groundwater Recharge	-	*"In some cases it [LAR] also benefits the groundwater resource."*
Groundwater Threat	-	*"Both because it [LAR] functions worse and it doesn't provide any treatment, the water bypasses directly to the secondary groundwater table."*
Economic Efficiency	*"…there is a cost-benefit analysis. You can see that it [WSUD] actually will be paid back over 10 or 15 years…"*	*"…but it is also about saving some investment in the sewerage system."*
Economic Inefficiency	*"…there is going to be an ongoing cost and then most rain gardens properly has a 10 year life span, and then you have to replace the media and stuff. So that is properly a fairly large cost to keep them running … If they are not kept on a reasonably maintenance regime, they just block up and don't work"*	*"It is related to the economy in general, pipes are just an effective and cheap solution."*
Health	*"The climate modeling suggest that we are going to get dryer and hotter. We like these green spaces. They do make people healthy."*	*"The vegetation is important for the air quality, for the urban climate"*
Community	*"..and that Darling Square Garden is a very important garden for that area"*	*"Does the area have industry development, does it have biodiversity issues, does it have security issues, social segregation? What kind of issues exists that the [LAR] design can work to improve?"*
Aesthetic	*"And they look out, and instead of looking out over asphalt they look out over a vegetated area and the backdrop of that is the park in itself."*	*"Let's do it with some methods so that it doesn't just result in pipes in the soil, but the result is green and pretty, some hard surfaces which are adapted to the existing architecture."*
No need	*"… he thinks it is a total waste of money, a total waste of time – he doesn't believe in climate change."*	*"There are some wastewater engineers that don't care for it, and the fact that it [LAR] isn't reliable. And we have used pipes for 150 years and knows all about how to dimension them"*
Marketing	*"There are some peers, some developers and some clients there see marketing value in pushing the envelope. They see marketing value in terms of being a leader."*	*"The best thing that can happen after a separation [of the sewerage system] is that contractors work isn't visible. How much fun is it living with that? A LAR project is the complete opposite"*
Integrated	*"So you asked if it is the best solution out there - I would say that if you capture everything that WSUD is then I guess it is the best solution. It is localized, it is designed for purpose and for sight"*	*"And then getting an understanding this being more than just sewerage - that is synergy."*

3.3 WSUD stabilization in Melbourne

In Melbourne the WSUD stabilization has gone through three phases, New Technology, Testing, and Opportunity, and the stabilization process has now reached the period of Agreement cf. Figure 3.

In the period of New Technology (~1980-1990) WSUD was first clearly articulated in Perth in the 1980'ties. The WSUD idea and terminology travelled to Melbourne in the 1990'ties with a small group of actors working with stormwater quality. This group of actors drew on the public focus of the 1960'ties and 1970'ties on the state of the environment (Brown and Clarke, 2007; Brown et al., 2013). Specifically the problem of sewage outlets discharging into the Yarra River that flows right next to Melbourne's Central Business District (CBD) and into Port Phillip Bay (Brown and Clarke, 2007) was in focus, and *Environmental Protection* and *Water Quality* therefore were the important meanings. The corresponding technologies developed and implemented were end-of-pipe solutions: gross pollutant traps and artificial wetlands for litter and nutrients removal. The governmental response to the public pressure included the creation of The Victorian Environment Protection Authority (EPA) in 1970, as well as the following Catchment Management Committees and The Water Act 1989 (Brown and Clarke, 2007), which tried to meet new sustainability demands with an integrated approach to water management. The Water Act and surrounding actors represent early signs of the meaning *Integrated.* Later governmental responses include the creation of the two important Cooperate Research Centres (CRCs) for Freshwater Ecology and Catchment Health (Brown and Clarke, 2007), which helped the further development of emerging technologies and created a link between the universities of Melbourne, industry partners and politicians.

From the early 1990'ties to around 2000 there was a quiet period of Testing in the development and implantation of WSUD. There was still a focus on WSUD technologies with reference to the meaning *Water Quality* but it no longer had public focus. Researchers and a few industry partners shared the perception that nutrient loads from stormwater runoff and sewage outlets were the main culprit to the city's water quality issues. The dominant technologies therefore became artificial wetlands and source control measures including structural and non-structural measures implemented near the pollutant source like citizen education and water reuse (Engineers Australia, 2007). The main actors in this period were connected through the two CRC's: Melbourne Water, the main water utility of the City of Melbourne, as well as researchers and industry partners. A major issue in this period was the uncertainty of Melbourne Water's regulatory power with regard to water quality issues (Brown et al., 2013). Eventually Melbourne Water ignored the unresolved power issues and implemented several wetlands in The Healthy Bay Initiative as well as smaller WSUD projects in the residential Lynbrook Estate together with the CRC for Catchment Health (Brown et al., 2013). The Lynbrook estate showed that the meanings *Aesthetics* and *Community* also had influence on WSUD projects. An important institutional development during this period includes the forming of the Stormwater

Committee in 1996 (Brown and Clarke, 2007), which published the first recommended stormwater targets for new developments.

The third period provided an Opportunity for WSUD champions to push for implementation and development of WSUD. The period spanned from around 2000-2010 and essential for this opportunity was the Millennium drought, the thirteen year drought from 1997-2010. The champions were themselves promoting the WSUD concept and the associated technologies with the development of "MUSIC", a model for conceptualizing designs and design outcomes especially useful in the WSUD planning process. The actors also had the first annual national WSUD conference in Melbourne in 2000 (Brown and Clarke, 2007). These activities were both knowledge building and opportunities for knowledge sharing, further supporting the development of WSUD. Finally the actors supported the implementation of WSUD with new demonstration projects at the Docklands, a development close to the city's CBD and other council's smaller WSUD roadscape projects. The dominant technologies in these projects were bioretention rain gardens. Lastly the actors promoted WSUD technologies in policy making. The result was among other things the Clearwater Program, which is a state funded industry supporting organisation still existing. By 2003 the drought was widely recognised and there was a wide political and public focus on water use and security of supply. The first governmental response was to build a desalination plant. However, the plant received significant community opposition and was upon completion put in standby mode. The WSUD champions used this momentum and adapted their argumentation, and the meaning of *Water Harvesting* was born. The main argumentation was that WSUD can be used to harvest stormwater for reuse. This was supported by the meaning of *Economic Efficiency* that provided numbers showing that stormwater harvesting was cheaper than desalination. This adaptation of argumentation from *Water Quality* to *Water Harvesting* is in SCOT terms called closure by redefinition, which connects different meanings through adaptation of arguments. It also illustrates the strengthening of the meaning *Integrated* that advocates for the multiple benefits of WSUD. Arguments against WSUD were also present in this period. The meaning *No Need* argued that there was no need for water harvesting since climate change was disbelieved. This meaning had some connection to governmental institutions especially in connection to specific projects. The effects of the drought were however so visible that the *No Need* meaning gained little traction. This indicates that interpretive flexibility still existed. However because of lack of traction, this meaning had little influence in the closure process. Another meaning arguing against WSUD was *Economic Inefficiency*, which argued that especially smaller decentralised WSUD projects were hard and expensive to construct and maintain. There is a clear and direct conflict between the arguments of *Economic Efficiency* and *Economic Inefficiency*, which existed in parallel during this period. The governmental reaction to the pressure from the drought and the push for these meanings from a range of actors was the creation of the National Water Initiative in 2004, the first national policy promoting WSUD (Brown and Clarke, 2007). The national policy was followed by several guidelines from the City of Melbourne, Melbourne Water and Engineers Australia. The two former CRC's ended in this period, but research continued in the new CRC for Water Sensitive Cities, which was established in 2012.

The fourth period, Agreement, spans from around 2010 to the present day. There has been real progress in the implementation of WSUD in Melbourne in this period. A series of actors from politicians to citizens have agreed that WSUD has multiple benefits ranging from water harvesting to aesthetic, community and economic benefits. Figure 6 shows the dominant technologies and meanings in this period. A vision has been created about "The Water Sensitive City", which both is climate resilient, sustainable and liveable. This vision is supported and promoted by the CRC for Water Sensitive Cities, and another governmental institution has also been founded, The Office for Living Victoria, which also promotes an *Integrated* approach to water management (Brown et al., 2013; de Haan et al., 2014). The dominant technologies are now more local solutions in treatment trains but also the conversion of larger squares and parks to water reservoirs. Until 2013 there has been little focus on *Flooding* and WSUD potential regarding flooding. However, Melbourne is now also experiencing pluvial, fluvial and coastal flooding. Several residential areas have since 2011 been flooded and are in risk of flooding. This new development and the connected public focus has put WSUD and its champions under pressure. New discussions of risk acceptance, responsibilities and potentials have arisen.

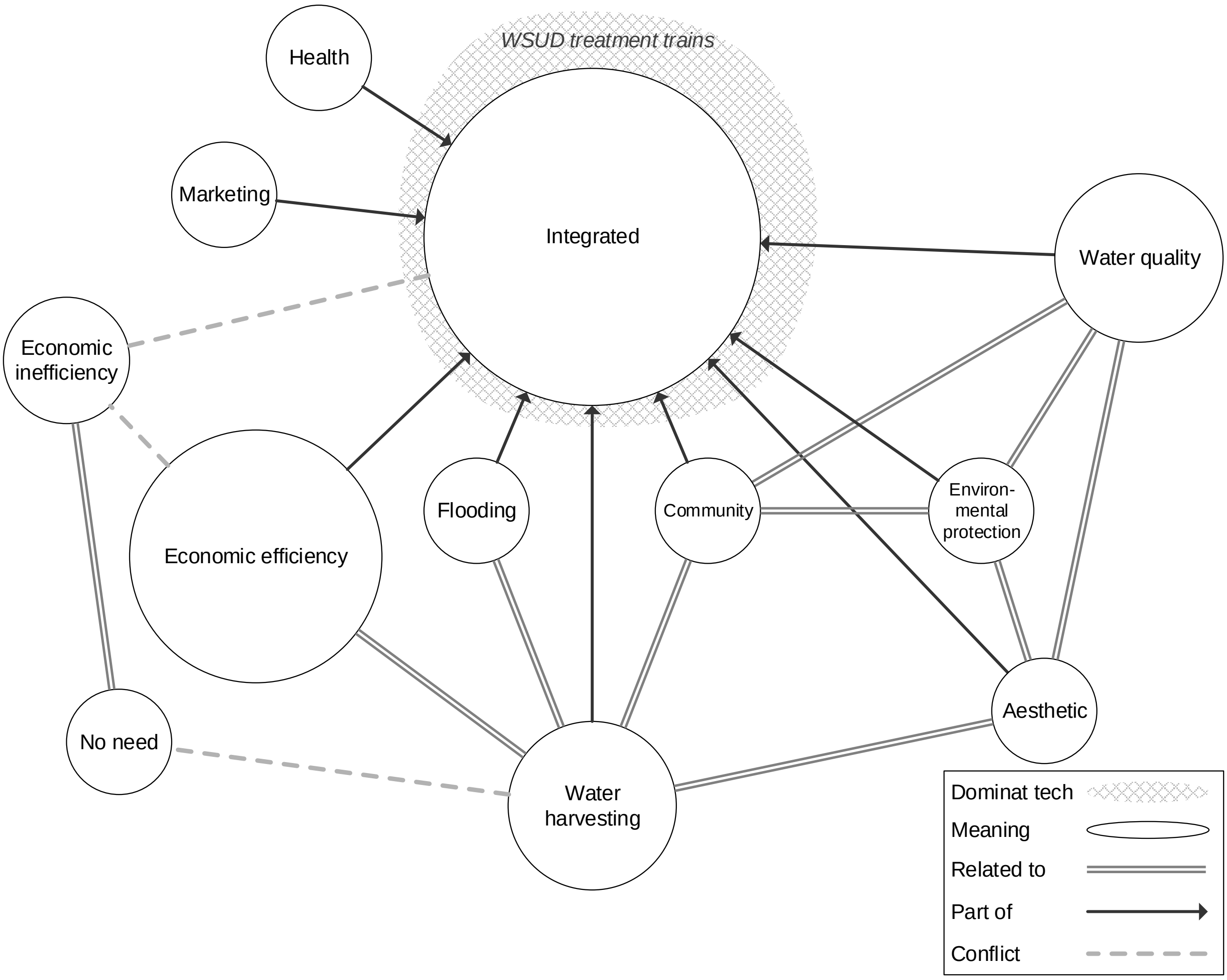


Figure 6. Dominant technologies and meanings of the Agreement period in Melbourne (~2010-2015)

3.4 LAR stabilization in Copenhagen

In Copenhagen the stabilization has gone through the first two periods outlined in Figure 3, New Technology and Testing, and has now reached the period of Opportunity, see Figure 7.

The New Technology period spanned from around 1990 to 1995, where there was public dissatisfaction with the state of waterways and groundwater and the culprit was considered to be runoff from farmland as well as infiltration and overflow of untreated sewage (Anthonisen et al., 1992). LAR technologies had existed for decades before 1990, but the Danish term LAR was introduced in this period (Fletcher et al., 2015). Numerous meanings and technologies existed, though most champions advocated strongly for one single or a few meanings and technologies. Some LAR champions advocated for the meaning *Environmental Protection*, arguing that LAR systems can deliver a more natural water cycle and improved habitats for flora and fauna. This group of actors were related to the urban ecology movement as well as to greening of cities, and therefore also to the meanings *Aesthetic* and *Community.* A second strong meaning in this period was

Water Quality, which argued that LAR reduces the amount of water entering the combined sewage system and therefore reduces overflow volumes during rain, which was a proven water quality problem in this period. LAR was however not the only solution presented to this problem. The First Action Plan for the Aquatic Environment (Regeringen, 1987) enforced planning of fertilizer use for farmers and improvements of sewage treatment plants and industry, and the regulation of fertilizer use was further restricted through the implementation of The Nitrate Directive from the EU (European Commision, 1991). A third meaning from the LAR champions was *Groundwater Recharge*, which argued for further infiltration of rainwater to recharge groundwater aquifers. *Water Harvesting* also argued for reducing the use of groundwater and supplementing with stormwater. However, this meaning was less prominent since the groundwater resource was considered sufficient. The dominant technologies were therefore connected to infiltration and mainly included soakaways and to a smaller degree wet and dry stormwater ponds and rainwater tanks. Supplementing these technologies were permeable pavements and vegetated trenches and swales promoted through the meaning *Environmental Protection.* Finally, the meaning *Economic Efficiency* argued that LAR had lower construction costs than traditional sewer systems and multiple additional benefits. Opposition also existed in this early stage mainly from the two sides *Economic Inefficiency* and *Groundwater Threat. Economic Inefficiency* argued directly against the financial cases presented by the *Economic Efficiency* advocates, focusing especially on maintenance costs. *Groundwater Threat* represented a group of actors worried about the quality of the stormwater infiltrating into the soil and further pollution from percolation through polluted soil.

The second period, Testing, spanned from around 1995 to 2005 in Copenhagen and was characterized by a lessened public focus on LAR and fewer research and industry activities. The lessened focus can both be attributed to a public focus on economic growth in the period and to the success of the Action Plan for the Aquatic Environment, which was released in a second and third version in this period (Regeringen, 2004, 1998). LAR was still present in engineering consultancies and in some research groups. Here the focus was on reducing the volumes of stormwater entering combined sewer systems, arguing for both *Groundwater Recharge* and *Water Quality.* Stormwater soakaways and detention basins in combined sewer systems were therefore the main technologies.

The third and so far last fully characterized period is Opportunity, which spans from around 2005 to the present day. The opportunity for LAR was in the beginning connected to a group of actors working on promoting and developing LAR and later to a series of large rain events causing severe floods, referred to as cloudbursts. The actor work was mainly focused around three interdisciplinary research, innovation and networking initiatives: Black, Blue & Green – Integrated infrastructure planning as key to sustainable urban water systems (2BG) (Institut for Geovidenskab og Naturforvaltning, 2011) 19K – Innovative solution to stormwater management, in reference to the 19 Municipalities participating (Naturstyrelsen, 2010), and the innovation network VandiByer (Vand i Byer, 2015). These initiatives have through knowledge development and sharing activities, including workshops and conferences, contributed to further developing the understanding of the term LAR, so that currently there is a stronger focus on above-ground solutions like rain gardens. They have furthermore contributed to developing some stormwater filtering technologies and a catalog of technologies and helped to put LAR on the public and political agenda. The main meanings of these actors are *Environmental Protection, Aesthetic* and *Community*. *Aesthetic* and *Community* argue that LAR offers exciting solutions that provide better urban, natural and green expressions and better opportunities for community activities than conventional underground solutions. This is also related to the more nature-based expression of many LAR systems, which is a main element in the biodiversity argument of the *Environmental Protection* meaning. Around 2007-08 the water utilities were corporatized in Denmark (enacted by law in 2009), which led to new institutional structures in both municipalities and the newly formed public utility companies (Regeringen, 2009). A new interest in the meanings of *Economic Efficiency* and *Integrated* arose arguing that LAR is an economically efficient holistic water management method. These meanings share a close relationship to a new meaning that has arisen in this period, *Cloudburst Flooding*. From around 2007 and onwards Denmark has been hit by a series of very extreme rain events. The most publicly noted event occurred 2nd July 2011, where flooding of central parts of Copenhagen caused damages corresponding to more than 800 million EUR in insurance claims (Institut for Beredskabsevaluering, 2012) and damage of about 30 million EUR to property owned by the City of Copenhagen (Koncernservice, 2012). This flooding furthermore closed down both public transport and central roads and threatened critical infrastructure including hospitals. There was a strong citizen outcry and a strong political response. The municipalities of Denmark were ordered to complete Climate Adaptation Plans, the City of Copenhagen also published a Cloudburst Plan (Københavns Kommune, 2012, 2010a; Regeringen, 2012), and the City Council recently approved a budget of 12 billion DKK for investment by the city and it's utility company in grey and green public infrastructure for cloudburst mitigation over the next 25 years (Københavns Kommune, 2015). Institutional responses have included a national co-financing decree for utility companies to help finance climate adaption, which traditionally is a municipal responsibility, and the Water Pollution Committee of the Danish Society for Engineers has publishes design guides for some types of LAR technologies (Aabling et al., 2011). The meaning *Cloudburst Flooding* ceases this opportunity and lobbies for LAR to help reduce stormwater runoff volumes. This meaning includes detention on terrain as a LAR technology and therefore argues that LAR can help mitigating large and rare cloudburst events. In direct conflict with this meaning is that of *Nuisance Flooding*, which argues that LAR can only manage small and frequent events that lead to "nuisance floods" and that LAR does not provide enough storage volume to mitigate large cloudburst events. The dominant technologies included in the LAR concept by this group are soakaways and other infiltration measures. The arguments between the actors from these two groups are connected to economic models and the meanings *Economic Inefficiency* and *Economic*

Efficiency, and they mainly try to win the debate with rhetorical closure by directly attacking each other's arguments. The general debate is not centered on whether LAR is a good water management solution providing multiple benefits to water utilities and society, but solely on whether LAR can mitigate large rain events. The general picture as seen in Figure 7 is scatted and unstable with a high interpretive flexibility. However, there is a low degree of stabilization and a high level of actor activity, with many possible solutions and meanings interacting and both differentiating and correlating.

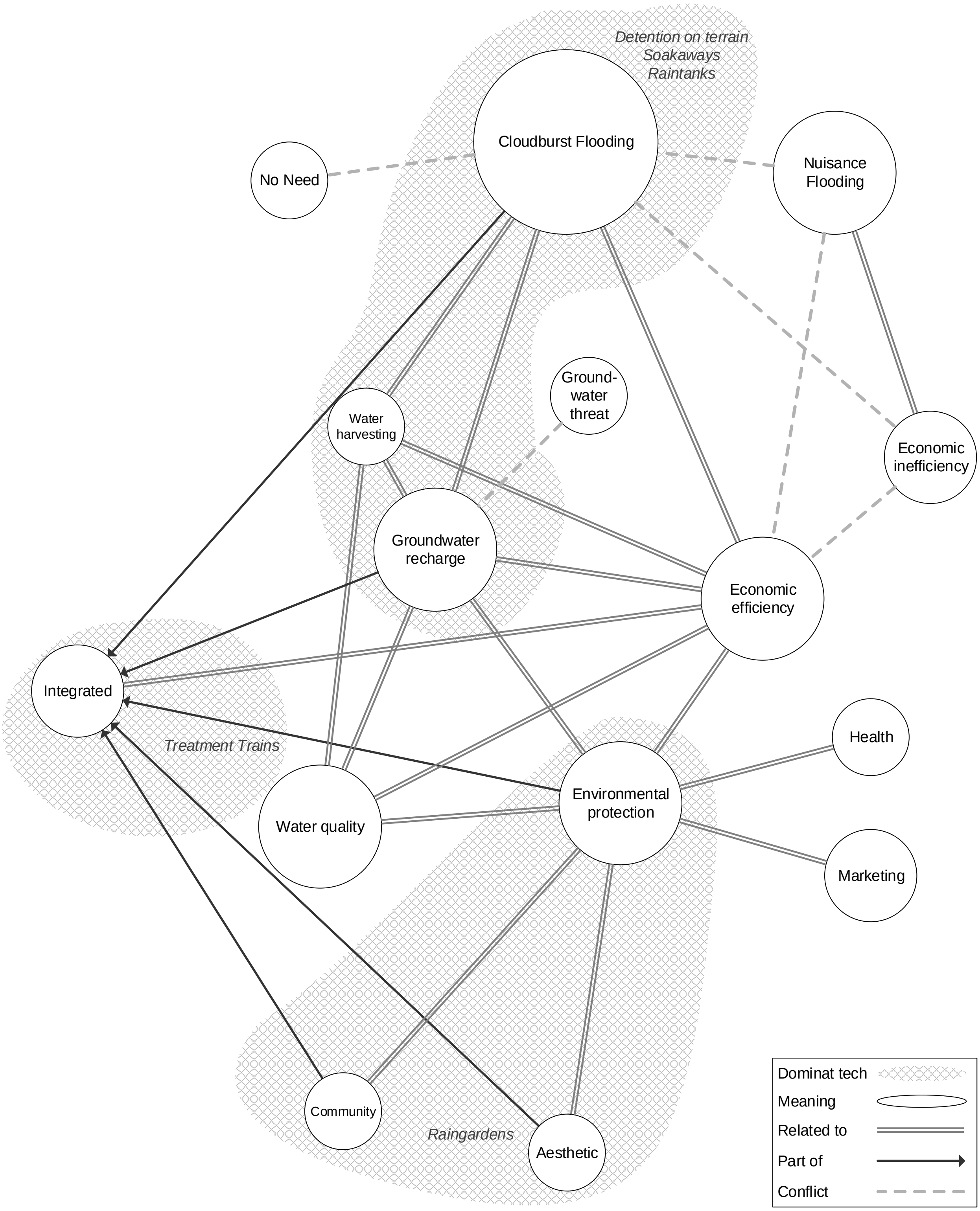


Figure 7. Dominant technologies and meanings of the Opportunity period in Copenhagen (~2005-2015).

3.5 Comparative discussion

The stabilization processes of Melbourne and Copenhagen have gone through parts of the same sequence of phases with the same overall types of actions and actors; however with different drivers, mainly drought in Melbourne and pluvial flooding in Copenhagen. Several successful elements can be found in both stabilization processes:

- Actors provide SCM institutionalization in the form of design tools, guidelines and standards that help the implementation of the technologies.
- Knowledge building and sharing activities across the entire industry help building a common vision for the technologies.
- Linking of the technologies to a main societal problem creates societal incentive for implementation.

The analysis shows that Copenhagen is at a different place in the stabilization process than Melbourne. Melbourne appears to have a more stable system with a lower interpretive flexibility, with a strong integrated understanding of WSUD, see Figure 6. However, Melbourne may at the current point in time be gaining interpretive flexibility, due to the newly arisen flooding issues. Copenhagen appears to be at a critical point with a high interpretive flexibility, with multiple conflicting understandings of LAR, public debate and several different technical solutions being advocated, see Figure 7. This instability and public focus provides opportunity for further development and implementation. Copenhagen presently shows signs of an emerging integrated approach to water management including a linking of LAR to multiple benefits and climate adaptation. When placing the two cities on the S-curve of transition, both can be placed in the acceleration phase, however Copenhagen seems to be just leaving the *take-off* phase while Melbourne seems to be approaching the phase where either a *transformation* or a *lock-in* may follow.

Copenhagen cannot follow the same path as Melbourne, because the two cities are in completely different environmental, institutional and cultural contexts. However, that does not mean that lessons cannot be learned. It is clear from Melbourne's history that:

- Successful full scale demonstration projects, which are supported and developed by a wide range of actors, will help building a common vision for the technologies and provide proof that implementation is possible.
- Supportive policies across several governmental levels will provide incentive for implementation of the technologies.
- Inclusive actions in the closure process, closure by redefinition, will provide a sense of ownership and help to build a common vision.

- Stabilization does not necessarily imply a full consensus as long as the actor groups in opposition are not gaining too much traction.

The first point is increasingly happening now in Copenhagen. Implementations of both small and large scale LAR projects currently take place, and the Climate Neighbourhood of Copenhagen is worth mentioning as an example of a full scale demonstration project implemented in collaboration between the City of Copenhagen and the main utility company HOFOR (Områdefornyelsen Skt. Kjelds Kvarter, 2013). The debate between different actor groups around whether or not LAR should be part of solutions to cloudbursts is fading. Instead more and more LAR systems are being implemented in Copenhagen every month. The actors: private residential associations, the municipality and the utility company are implementing LAR as part of a climate adaptation of the city. In most cases the actual LAR will control "everyday events" and "design events" by providing mainly storage and infiltration, corresponding to the idea of *minor drainage system design* (Fratini et al., 2012b) and further solutions are then added for cloudburst, corresponding to *major drainage system design*. However, the whole system including the cloudburst solution is by many actors often referred to as LAR. The actual cloudburst solutions often include both detention on terrain, sometimes called landscape based solutions, and large underground cloudburst tunnels, and these features are combined with an overall strategy to expand the detention basins of the underground combined sewer system.

This implementation trend can result in successful full-scale LAR demonstration projects helping to build a common vision for LAR technologies and providing proof that successful implementation of LAR is possible. The trend has two special features that also can be found in the history of Melbourne:

- Linking of the technologies to a main societal problem creates societal incentive for implementation.
- Inclusive actions in the closure process, closure by redefinition, provide a sense of ownership and help to build a common vision.

However, in Copenhagen these features also mean that there is a risk of lock-in or backlash happening. Everyone in the city has experienced the effects of climate change in the form of more frequent and intense extreme rain events causing pluvial flooding, and therefore LAR projects that make public response to climate change and in particular cloudbursts visible are generally popular. Nonetheless, climate adaptation involving stormwater volume reduction is not the only benefit of LAR. Many LAR systems have other added benefits and multifunctionality at their core. When connecting LAR strongly to climate adaption and cloudburst mitigation there is a risk that the added value of multifunctionality gets lost in the political prioritisation and resource allocation and therefore doesn't find way into the implemented projects. Furthermore, the meaning *Integrated* is gaining foothold and it advocates closure by redefinition as a strategy, i.e. including other meanings in their own meaning. This provides the stabilization needed for gaining momentum in implementation of systems. However the emerging *Integrated* definition of LAR is broad and partly unclear and vague involving arguments that are not generally accepted. This vagueness gives room for different definitions of LAR emerging in the implementation phase, restarting the debate on purpose and aim.

The risk of multifunctionality getting lost in Copenhagen in the vague *Integrated* definition of LAR and the connection to Cloudburst can possibly be related to the general lack of regulation and standardisation in Copenhagen. The story of Melbourne shows that regulation and standardisation are beneficial and that both normative, cognitive and regulative institutions are needed (Bettini et al., 2014; Ferguson et al., 2013). In Copenhagen and Denmark regulation and standardisation is emerging in the form of the newly published co-financing decree (Regeringen, 2014) as well as design guides published by the Water Pollution Control Committee of the Society of Danish Engineers and the Vand i Byer network. There is however a need for more regulation to match the real life distribution of human and financial capital. Furthermore there is the need for regulation on more precise water quality and quantity aims for the systems.

4 Conclusions

We conclude that the Stormwater Control Measures (SCMs) included in LAR in Copenhagen and WSUD in Melbourne are similar. Both WSUD and LAR champions apply an integrated approach to implementing more sustainable and environmentally friendly solutions and both groups of technologies retain parts of the features of: detention, infiltration or harvesting, evaporation, transport and treatment. The similarities in the technical elements can readily be attributed to a global research community with fast knowledge sharing. However, the applications of the technologies differ because of the different contexts in the two cities, including differences in physical environment, institutional organization, and culture.

Both cities have a temperate climate, but Melbourne is served by surface water reservoirs, has a separate wastewater and storm drainage infrastructure and has suffered from a decade of drought (1997-2010), while Copenhagen is served by groundwater pumping and a combined sewer system and has suffered from a decade of pluvial flooding incidents (2007-). There are however clear similarities in the SCM technologies and the overall phases in the stabilization processes of the two cities. However, Copenhagen is at a different place in the stabilization process than Melbourne. Melbourne appears at the current point in time to have reached the “agreement” stage, i.e. the innovation system is stable and there is low interpretive flexibility and a strong integrated understanding of WSUD. In Melbourne a number of positive aspects, including aspects outside the water sector, have become included in the dominant integrated approach.. Copenhagen appears to have reached the “opportunity” stage, i.e. a critical point with high interpretive flexibility, intense public debate, multiple separated understandings of LAR and several different proposed technical solutions.

Nevertheless, this instability and public focus provides opportunity for further development and implementation by niche actors. The story of Melbourne provides a lesson of closure by redefinition, which the actors promoting the integrated approach can learn from. In a situation of opportunity several niche processes can provide closure: institutionalization in the form of design tools, guidelines and standards, knowledge building and sharing activities, and successful full-scale demonstration projects supported by a wide range of actors. Furthermore, strong institutions, including regulative institutions, are needed for an anchoring of the development. However, because of a different context Copenhagen cannot follow the exact same path as Melbourne. At present Copenhagen shows signs of an emerging integrated approach to stormwater management including a linking of LAR and climate adaptation and an emerging regulation with a wide definition of LAR. This linking is among other things created by closure by redefinition, where several meanings are included in a wider integrated meaning. However, in Copenhagen these features also contain risks. The risk of losing the multifunctional benefits that LAR embodies; and the risk of a broad and partly unclear and vague LAR concept that is hard to handle in the implementation projects. The current technologies and meaning(s) associated with LAR, most prominently Detention on terrain and *Cloudburst Flooding*, may in the end not provide a foundation for stabilization; instead other technologies such as cloudburst tunnels could become prominent, which would again increase the interpretive flexibility and result in a situation of decreased stabilization; restarting the closure process. .

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