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A comparative socio-technical discourse analysis of Water Sensitive Urban Design for Melbourne, Australia and Copenhagen, Denmark

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Abstract

This paper presents a comparative socio-technical discourse analysis of WUSD for Melbourne and Copenhagen. Despite Melbourne appearing to have progressed further, the technology pathways are very similar, suggesting significant potential for transfer of insights and policy mechanisms. However, there are some fundamental differences in the underpinning ontology of WUSD policy makers and practitioners, which provides more nuanced insights into how best to adapt the knowledge transfer process.

Introduction

Motivation

In the past few decades, and throughout the world, issues with the management of the urban water cycle such as drought, floods and poor water quality, have arisen. In several places, including Copenhagen and Melbourne, local, natural and sustainable technologies are being tried as possible solutions to these issues. In Melbourne these technologies are called Water Sensitive Urban Design (WSUD) and in Denmark they are called Lokal Afledning af Regnvand (Local Rainwater Drainage—LAR).

This study has investigated the stabilization process of the alternative urban stormwater management technologies and the actors connected to these in the two cities. The main macro-level drivers behind these technologies differ for the two cities and the purpose of the research is therefore to discover what the two cities can learn from each other? Is stabilization possible?

Cases

Two locations have been compared in this study, Melbourne Australia and Copenhagen Denmark. The two cities currently both experience changing conditions, such as growing population, urbanization and climate changes.

The first location investigated in this study is Melbourne in Australia. Melbourne is located on the south-east coast of Australia and is the second largest city of Australia (Australian Bureau of Statistics, 2012) covering 9990.5 km2 with a population of 4.2 million residents in 2010 (City of Melbourne, 2013). Melbourne is located in a temperate climate (City of Melbourne, 2013). The annual rainfall of Melbourne is distributed to the natural storage of waterways and groundwater and to the manmade storages of the stormwater system and the water reservoirs. Melbourne has a separated sewerage system. The water reservoirs are the main source for the water supply in Melbourne, which

also contains harvested stormwater and recycled wastewater. The water from the water supply either enters the stormwater system or the wastewater treatment system. The water from the stormwater system ends up in the waterways and is then transported to the ocean, while the water from the wastewater treatment system is either discharged for recycling or to the ocean or the waterways. From the oceans and the reservoirs there is evaporation that refills the storages for the rainfall.

The second location investigated in this study is Copenhagen. Copenhagen is the capital of Denmark, a country located in northern Europe. The population of the greater Copenhagen is 1.24 million residents in 2013 (Statistics Denmark, 2013). The climate of Denmark is temperate (Danmarks Meteorologiske Institut, 2013).

See Figure 1 for concept descriptions of the urban water systems of the two cities. Please note that Copenhagen's water supply is groundwater and Melbourne's is surface water reservoirs; furthermore, Copenhagen has a combined sewage system, while Melbourne has a separated system.

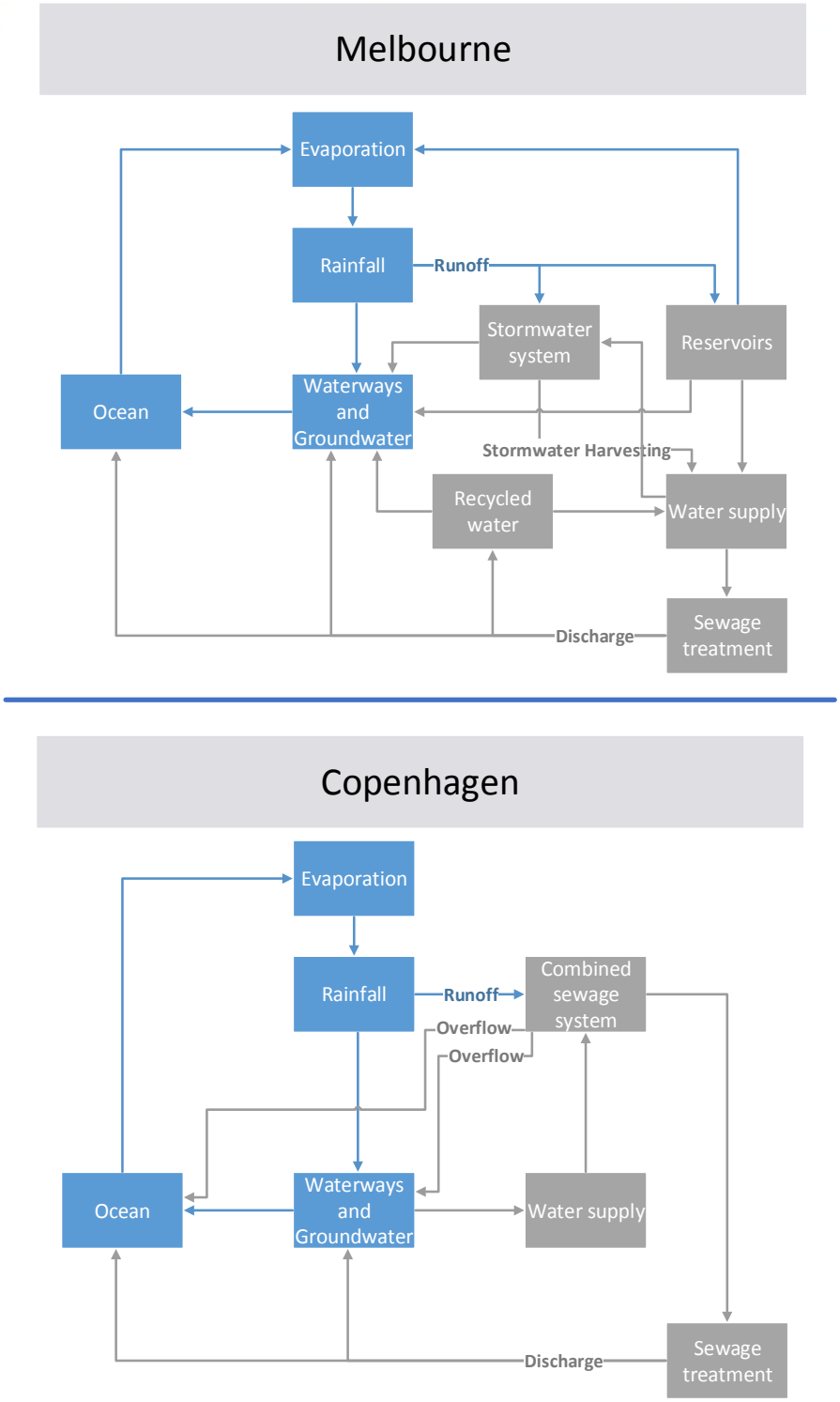


Figure 1. Concept Urban Water Systems for Melbourne and Copenhagen.

Method

Structure

In order to examine the stabilization process of WSUD/LAR in Melbourne and Copenhagen the socio-technical analysis method, Social Construction of Technology (SCOT), has been adapted. The SCOT analysis primary data is semi-structured qualitative interviews of actors connected to the technologies. This is supported by literature as secondary data. The research structure has been as follows:

- Literature study
- Interview structuring
- Qualitative interviews in Melbourne
- Data analysis of the Melbourne case
- Qualitative interviews in Copenhagen
- Data analysis of the Copenhagen case
- Comparative analysis of Melbourne and Copenhagen

The initial literature study analysed newspapers, technical descriptions, reports and other journals as well as scientific papers concerning WSUD/LAR in Melbourne and Copenhagen. This resulted in an incipient conceptual framework, which founded the basis of the analysis and was refined throughout the study. Following the initial literature study was an interview structuring based on the conceptual framework. Following this the qualitative interviews of actors in Melbourne was conducted. The interviews referenced the specific WSUD implementation case of The Darling Street Stormwater Harvesting Project. Hereafter followed the analysis of the stabilization process of WSUD in Melbourne, with a basis in the conceptual framework. An identical approach was taken in Copenhagen, where the qualitative interviews of actors resulted in the analysis of the stabilization process of LAR. The interviews in Copenhagen referenced the specific LAR implementation case of Vilhelm Thomsens Allé. Finally was the comparison of the stabilization process of WSUD and LAR in Melbourne and Copenhagen, respectively.

Theory

SCOT analysis a change in a socio-technical system and originates in Science and Technology Studies (STS). However, it can also be related to the newer scientific field of Transition Science (TS); 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 proposes a series of terms that forms a framework in the socio-technical analysis. The aim of the SCOT analysis is to describe the development of the technology in focus towards a more stable situation, the stabilization process.

Stabilization, as used in SCOT, involves settling arguments between different actors involved with a technology, closure (Pinch and Bijker, 1984). This closure does not necessarily mean that the foundation for all arguments are gone, the actors just need to feel that they are gone. 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.

If or when a technology is stable, it does not mean that it is mainstreamed or they are part of a new socio-technical regime. The stabilization is therefore a sub-set of a transition and might result in a transformation or in a lock-in, backlash and system breakdown, as described in the well-recognized s-curve of transition-science.

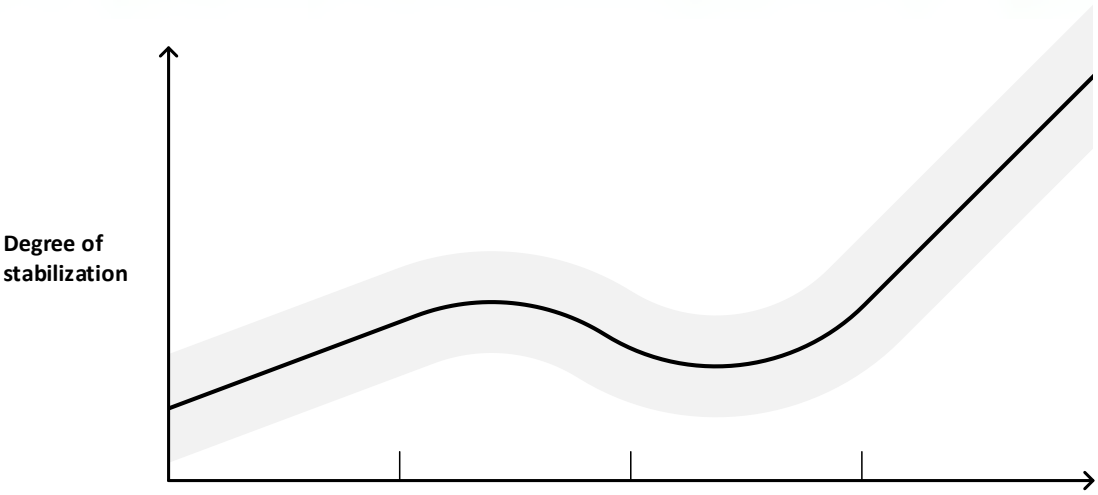
Conceptual framework

A conceptual framework has been used to describe the stabilization processes. The conceptual framework is based on following things: the research questions and the preliminary literature study, the SCOT framework and transition theory and its well-recognized s-curve for transition.

A conceptual framework (Figure 2) has been used to describe the stabilization processes. It is based on the study's purpose, the preliminary literature study, the SCOT framework, and on transition theory and its well-recognized s-curve for transition, and it outlines four periods that technologies go through:

1. New Technology, where the technology emerges as a result of a conflict with the current system.
2. Testing, where test cases are used to improve the technology and only few actors are involved.
3. Opportunity, where new actors are involved because of new dissatisfaction, this leads to new confrontations that need to be settled.
4. Agreement, where the confrontations has been settled over time, and agreement among the actors arises.

The conceptual framework forms the basis of the SCOT analysis and the general table is therefore later specified in detail for both Melbourne and Copenhagen. In each period it is specified what actors and meanings are in play and what the relative degree of stabilization is.



	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 2. Conceptual framework, describing the stabilization process of WSUD/LAR in Melbourne and Copenhagen.

Data

The primary data was collected through semi-structured qualitative interviews performed in the two cities. Two types of interviewees were selected: Interviewees related to a specific case and a few industry interviewees that are considered frontrunners in relation to the WSUD/LAR technologies. The interviews performed in relation to a specific case had the objective of getting an in-depth narrative of the case and the objective of substantiating other literary sources in the process of investigating the research questions. The case was then part of the overall aim of investigating the overall research questions of this study. The industry interviews only had the objective of substantiating other literary sources like (Anthonisen et al., 1992; Brown et al., 2013; Brown and Clarke, 2007; Københavns Kommune, 2010; Lützen et al., 1994; Melbourne Water, 2005) in the process of investigating the research questions of this study.

The aim in selection of interviewees was to get as wide a range of different actors as possible. In both Melbourne and Copenhagen were eight interviews conducted, 16 in total, of which three in each city were with frontrunners and therefore had a more general focus (Bourke, 18/02-2013; Burgdorf Nielsen, 25/04-2013; Deletic, 11/02-2013; Gabriel, 17/04-2013; Grigg, 13/01-2013; Hansen, 19/04-2013; Jensen, 30/04-2013; Lerer, 30/04-2013; Lützen, 23/04-2013; Madsen, 17/04-2013; Noyce, 06/02-2013; Oke, 22/02-2013; Pfleiderer, 06/02-2013; Shears, 04/02-2013; Wong, 08/02-2013).

Table 1. Qualitative interviews performed in Melbourne and in Copenhagen

Actor type	Number of interviews in Melbourne	Number of interviews in Copenhagen
Public authority	2	1
Industry	2	3
Research	2	2
Citizen	1	1
Politician	1	0
Other	0	1
Total	**8**	**8**

Results

Melbourne

The first period in the stabilization process in Melbourne (Figure 3) is the phase New Technology, which spans from the early 1980'ties to early1990'ties, but the period also has roots as far back as the 1960'ties (Brown et al., 2013; Brown and Clarke, 2007). The period is characterized by the fact that the technology emerges as a result of dissatisfaction with the current system. In the case of Melbourne there is a major dissatisfaction with water quality of the waterways in Melbourne (Wong, 08/02-2013). The all-important meanings and actor groups of this period is therefore Water Quality, whom argues that WSUD can reduce the pollution loads from urban stormwater; but also Environmental Protection, whom argues that WSUD will help protect the environment, appears in this period.

The governmental institutions reacted to the public pressure in several ways including the passing of the Water Act 1989, which tried to meet the new sustainability demands for water management (Brown and Clarke, 2007). The focus of this act was on an integrated approach, and is an early sign of the meaning Integrated.

The public and governmental focus on Water Quality and Environmental Protection led to new scientific research discipline with a focus on water quality, as mentioned by (Wong, 08/02-2013): "Well in the early 1990'ties, I was very fortunate to be part of a small group that started to look at the notion of using green infrastructure for improving the quality of stormwater.". The group focused on

adding physical representations of WSUD to the terminology and concept, which was developed in Perth in the early 1980'ties (Wong, 08/02-2013).

The focus of the actor group of Water Quality was especially on gross pollutants and nutrients causing algae blooms. The focus of the group leads to the development of technologies including Gross Pollutant Traps for catching litter and wetlands for nutrient removal (Brown and Clarke, 2007; Wong, 08/02-2013). Both technologies are end-of-pipe solutions, with treatment located near or in the outlet of the stormwater system. Furthermore, both technologies focuses on stormwater treatment and other water types are not part of the picture.

There is in this period a large dissatisfaction with the current system and little knowledge about the emerging WSUD technologies, and it is therefore a relative unstable situation.

The second period in the stabilization process is testing. The focus of this period is on improvement of the technologies. The technologies that now have emerged are weighed, tested and improved. The period spans from the early 1990'ties to around year 2000. The main actor groups are still Water Quality and to a lesser degree Environmental Protection, that both now can be considered to be well established.

Water Quality is at this point still focused on both litter and nutrients. Litter was considered the main pollution source in the public space (Brown and Clarke, 2007) but in the industry and in research the focus was on nutrients. The public perception is connected to the fact that litter is a visible pollutant, while nutrients and toxicants are invisible to the naked eye. The scientific community had a different view on the water quality issues. There arose a shared perception between the industry frontrunners and researchers that nitrogen loads was the major water quality problem (Brown et al., 2013).

Because of this new shared perception that nutrients from stormwater (a diffuse source) were the major culprit, the focus in the research also changed. The research concentrated on wetland research and source control and non-structural measures, like education and planning emerged as solutions (Brown and Clarke, 2007; Wong, 08/02-2013). The main actors in this group were researchers and industry frontrunners, especially Melbourne Water (Brown et al., 2013; Brown and Clarke, 2007). The relationship between these two actor groups was strengthened by the two previously established CRC's, The CRC for Catchment Hydrology and the CRC for Freshwater Ecology (Brown and Clarke, 2007).

However, a major issue in this period is that it initially was uncertain whether Melbourne Water had the regulatory power to act and spend money on water quality issues. But eventually Melbourne Water took the risk of implementing new systems. Several wetlands projects were approved in The Healthy Bay Initiative (Brown and Clarke, 2007). Furthermore the first WSUD project on a smaller scale was implemented by the CRC for Catchment Health and Melbourne Water on the Lynbrook Estate. This project was a successful collaboration of the actors and it improved not only water quality but also the aesthetics of the estate and added community values (Brown and Clarke, 2007). This shows that the two meanings of Aesthetics and Community are present in this period.

The period involved a lower level of actors, almost exclusively industry frontrunners, like Melbourne Water, and researchers connected to the CRC. Furthermore, these actors very much agreed on the direction of the technology: The water quality must be improved and the environment must be protected. The general agreement indicates an increase in the degree of stabilization. The increased stabilization also has something to do with a lack in governmental focus on the issue, because there was a larger focus on economic growth and privatization (Brown et al., 2013).

The third period is Opportunity, where an opportunity arises for the technologies to influence the current regime. In the case of Melbourne the opportunity is connected both to the 13-year drought (1997-2010) and to the work the actors developing and promoting the technology. The period spans from around year 2000 to around year 2010. In this period an important RSG of Water Harvesting enters the picture, furthermore the period is characterized by a strengthening of the meaning Integrated.

The work of the actors in promoting WSUD includes a wide range of actions. In supporting the implementation of technologies modelling software and appertaining design guidelines was developed by the CRC for Catchment Hydrology and Melbourne Water. The first release of MUSIC (Model for Urban Stormwater Improvement Conceptualization) was in 2001 (Brown and Clarke, 2007). MUSIC is still today used as a way of conceptualizing design and design outcomes of WSUD and it is an important tool in the decision making process of potential projects, as exemplified by (Noyce, 06/02-2013): "…once you submit a MUSIC model, that is it. Everyone just accepts that it works."

Another way the actors supported the technology was in promoting and building on the knowledge sharing already present in the industry. This was among other things done by establishing the first national WSUD conference in Melbourne in 2000 (Brown and Clarke, 2007). The conference was an initiative from the same group of actors that was part of the Lynbrook estate (Brown and Clarke, 2007).

A third way the implementation of the technology was supported was though demonstration projects. Following the successful project at the Lynbrook estate was the redevelopment of the Docklands, a high socio-economic development west of Melbourne's CBD (Brown et al., 2013; Brown and Clarke, 2007). The Docklands was redeveloped with the principles of WSUD and served with the Lynbrook estate as an inspiration for councils to start smaller scale projects (Brown et al., 2013). These smaller scale projects, often involved WSUD technologies integrated into the roadscape. The developed technologies in this period is therefore bioretention raingardens (Brown and Clarke, 2007; Pfleiderer, 06/02-2013). The main focus was still on stormwater, but other water sources for WSUD was also being investigated (Wong, 08/02-2013).

Finally a major support from the actors was in promoting the technology in policy making. The result of this advocating is among other things the successful Clearwater Program, which main objective is industry capacity building through industry and local governmental education and training (Brown and Clarke, 2007). The Clearwater is a result of a state wide funding program from the newly elected government in 2000, for developing a more responsible stormwater program. This focus in this program is still on water quality and pollution treatment and control (Brown and Clarke, 2007).

By 2003 the drought is widely recognized (Brown and Clarke, 2007; Pfleiderer, 06/02/2013; Shears, 04/02/2013). There was however still a dissatisfaction of the actors with the level attention that WSUD was getting (Brown et al., 2013). This lack in focus is also seen in the degree of stabilization of the period. Because of the drought becoming so significant, more actors re-enters the process and the actor-network is diluted. The dilution represents a higher interpretive flexibility which in this case also results in a less stable period, where it is unclear where WSUD fits into the future regimes. The dilution is illustrated by (Shears, 04/02/2013) : "The state government put water restrictions on, so that our ability to deliver water to our landscape was just somewhat curtailed. And people were recognizing the value of moving way from doing business as usual."

The focus of the government is on finding a secure way of supplying water and the decision is made that desalination is the way to go. However, there is significant community opposition for this solution, and the desalination solution falls through. However, in the meantime the actors connected to WSUD have found time to adapt their arguments. The new meaning and actor group of Water Harvesting is born. The main argument is that WSUD can be used as a way of harvesting water for reuse. This is highly supported by the group of Economic Efficiency, which has numbers that shows stormwater harvesting is a cheaper solution than desalination (Oke, 22/02/2013; Pfleiderer, 2013). These numbers are used as a rhetorical closure, because they are strong logical arguments (Wong, 08/02-2013). The adapted focus is illustrated by (Wong, 08/02/2013): "It was a logical step to say: Well if we improve the quality of the water we might as well see how we can use that as a resource."; and by (Pfleiderer, 06/02/2013): "And because it was some dry years, we were also thinking that in theory the water is much cleaner once we let it go through these systems, why are we just letting it go back to the Yarra.". The initial reaction from the public was that water harvesting from stormwater was a bad thing, because it would take water from the waterways. However, the WSUD champions closed that uncertainty and it was accepted that a natural system wouldn't let that much was enter the waterways

as illustrated by (Grigg, 13/01/2013): “So in other words it is a double plus. Because we are stopping the water. Because everything is so cemented now, well if you say it is natural that it goes into our seas, it is not. It is because if everything wasn’t paved it wouldn’t be going into the sea it would be soaking into the ground all along.”.

This adaptation in argument illustrates the concept of Closure by redefinition, there are several meanings getting connected to each other. It also illustrates the strengthening of the group Integrated, which advocates that WSUD can provides multiple benefits and that the two major groups of Water Harvesting and Water Quality can work together.

The main arguments against WSUD are also present in this period. Firstly the actor group of No Need focuses most of its arguments against the strongest group of the period, Water Harvesting. No Need argues that stormwater harvesting is not needed because climate change is not going to happen; they hereby attack the main argumentation of Water Harvesting. The group does get some attention from governmental institutions, especially in connection to specific projects (Pfleiderer, 06/02/2013; Shears, 04/02/2013). The effects of the drought do however overshadow their arguments, and the group has little traction. A second group that argues against WSUD emerges in this period, Economic Inefficiency. The group finds that many of especially the smaller scale WSUD, like raingardens, are hard and expensive to maintain, furthermore they are also expensive in construction cost (Pfleiderer, 06/02/2013). There is a clear and direct conflict established between the arguments of Economic Inefficiency and Economic Efficiency.

In this period the meanings of Community and Aesthetic is strengthened in the sense that their arguments are supported by the drought and the new strong group of Water Harvesting: “And the residents in Melbourne are very aware of the drought, 12 years of it, they are calling out to councils to do something about it. Sporting clubs didn’t have anywhere to play football or cricket and the street trees are dying. Nothing like having a 12 years drought for having residents understanding the importance of spending money on capturing water.” (Oke, 22/02-2013).

With the new wider range of meanings in play, with Water Harvesting in the centre, there is an governmental institutional reaction and the National Water Initiative is established in 2004, which marks a national policy promoting WSUD and the national policy is followed by several guidelines from for example Melbourne City (Brown and Clarke, 2007) and Engineers Australia (Engineers Australia, 2007) and Melbourne Water (Melbourne Water, 2005). During this period, in 2005, the CRC for Catchment Hydrology and the CRC for Ecology, comes to an end (Brown et al., 2013). The research is however continued though other research programs, including a new establish Centre for Water Sensitive Cities (Brown et al., 2013). Which demonstrates the future prominent meaning Integrated: “… WSUD didn’t really capture the imagination of many people in the community and in the government because it has always been viewed as a simple piece of technology to be put on the ground. So in the mid 2000’ence the concept of Water Sensitive Cities [WSC] came about. Where we basically say WSUD is the process and WSC is the outcome.” (Wong, 08/02/2013).

The fourth period is agreement, where the larger majority of the actors have agreed on a direction for the technology, there is a high degree of stabilization. The period in Melbourne spans from around year 2010 to present day. In this period there is a strong focus on the meaning Integrated in combination with Economic Efficiency, the other groups take a more withdrawn position.

The meaning of Integrated includes many different actors from citizens to politicians; however the degree of inclusion into the group varies. Some of the actors will know about all the different benefits WSUD can bring, but further questioning will show that their main focus might still be on Water Harvesting or Water Quality. The group argues that an integrated approach to managing the urban water cycle will result in multiple benefits (Oke, 22/02/2013; Pfleiderer, 06/02/2013; Shears, 04/02-2013). Furthermore the argument is that there exist significant future challenges for cities and they therefore need to be sustainable, resilient and liveable: “Because for the current time the challenges in a lot of our minds is how the future cities look like. Dealing with growing population, limiting resources and higher levels of climatic extremes—that a city needs to cope with.”(Wong, 08/02/2013).

Strongly leaning on the arguments of Integrated is the group of Economic Efficiency. Many actors that are included to a high degree in Integrated will also be part of the group of Economic Efficiency, this includes (Oke, 22/02/2013), (Pfleiderer, 06/02/2013) and (Wong, 08/02/2013). The two groups are also connected in the sense that they are both in conflict with the group of Economic Inefficiency. As a response to the main argument, that WSUD is an economically inefficient way of managing the urban water cycle, the two groups are now trying to gain arguments to a rhetorical closure. This they will do with arguing for all benefits with reduced cost. Therefore many of them feel that an economic model relating all benefits to cost are an important and necessary future development. It is important for the two groups to deal with the conflict of the group of Economic Inefficiency because it attacks central arguments, but the arguments from the group No Need doesn't directly attack the main arguments and they are therefore not that influential in the debate as illustrated by (Pfleiderer, 06/02/2013): "… whatever you do, you would have one or two people who has a problem with it. And you try to accommodate them, but you don't have to stop the project just for that."

The institutional developments during this period includes the establishment of the Office for Living Victoria that will implement a new policy: Living Melbourne, Living Victoria, which includes an integrated water cycle management (Brown et al., 2013). The organization will guide the interplay between different organizations related to water management (Brown et al., 2013). Another institutional development is the establishment of a new Melbourne based CRC: CRC for Water Sensitive Cities, which focuses on changing Australian cities towards becoming more water sensitive (Brown et al., 2013). The focus of the CRC and the two groups of Integrated and Economic Efficiency are also shown in the current focus in the technologies, which are on WSUD treatment trains and integrated approaches, see also "3.1 Water Sensitive Urban Design—WSUD".

Future institutional challenges include a current debate on stormwater property rights (Gordon, 2013; Oke, 22/02-2013; Wong, 08/02-2013) and a change in institutions and co-investment and sharing of risks, because of today's narrow focus on core businesses clash with the multiple benefits connected to WSUD (Oke, 22/02-2013; Wong, 08/02-2013), illustrated by (Wong, 08/02-2013): "…the institutions at the moment can often be an impediment to realizing all the objectives—unless you can change the institution for it to have a much broader objective of all the benefits.".

	New technology	Testing	Opportunity	Agreement
	~1980	~1990	~2000	~2010
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	Gross Pollutant Traps Early wetland techonology	Wetlands	Bioretention raingardens	WSUD treatment train
Main actors in play	Researchers Industry frontrunners Government Citizen	Researchers Industry frontrunners	Researchers Industry Government Citizens	Government Industry Citizens
Meanings in play	WSUD can reduce the pollution loads from urban stormwater WSUD will help protect the environment	WSUD can reduce the pollution loads from urban stormwater	WSUD can be used as a way of harvesting water for reuse WSUD integrates many benefits from managing an sustainable water cycle WSUD is an economic efficient way of managing the urban water cycle WSUD is an economic inefficient way of managing the urban water cycle	WSUD integrates many benefits from managing an sustainable water cycle WSUD is an economic efficient way of managing the urban water cycle

Figure 1. The stabilization process for WSUD technologies in Melbourne.

Copenhagen

The first period in the stabilization process in Copenhagen (Figure 4) is New Technology, which spans from around 1990 to around 1995. In this period the LAR technologies emerges as a result of dissatisfaction with the current system. In Denmark there is dissatisfaction with both the state of the waterways and of the groundwater (Andersen and Carstensen, 2011) and the culprit is deemed to be both farming runoff and infiltration and overflow of untreated sewage (Andersen and Carstensen, 2011; Anthonisen et al., 1992). The major actor groups of this period are Water Quality, Groundwater Recharging and Economic Efficiency. Many of the LAR technologies have been around for several years before this period, as they have been used for drainage especially in rural areas (Gabriel, 17/04/2013; Hansen, 19/04-2013). The term Lokal Afledning af Regnvand, LAR, is however introduced through a translation of the Swedish term Lokal Omhandling af Dagvatten (LOD) (Jensen, 30/04-2013). This translation happens early in this period, and has one of the first major appearances in (Anthonisen et al., 1992).

The term LAR has at this point in time a relationship with urban ecology, which is clearly visible in (Lützen et al., 1994), but also is mentioned by (Madsen, 17/04/2013) and (Lützen, 23/04/2013). The group of Environmental Protection is prominent and related to general environmentalism of earlier years, including urban ecology. In (Lützen et al., 1994) the term urban ecology is even defined in the

introduction and it is stated that LAR can help create better conditions for vegetation in that will more closely simulate the water cycle of the open landscape. Another central thinking from this group is considering rainwater and stormwater a resource, which broke with the previous ideas of treating it like a waste product (Anthonisen et al., 1992; Jensen, 30/04/2013; Lützen et al., 1994). Related to Environmental Protection is Aesthetics and Community. The group of Aesthetics finds that LAR through water and vegetation improves the urban landscape (Lützen et al., 1994). Some might even think of water as art element (Lützen et al., 1994; Lützen, 23/04-2013). The group of Community argues that LAR improves the opportunities for the local citizens for outdoor activities though a more interesting urban landscape (Lützen et al., 1994). The three actor groups of Environmental Protection, Aesthetics and Community especially promote permeable pavements and vegetated trenches and swales.

The RSG of Water Quality presents LAR as one of the solutions to the problems with the state of the waterways. This is especially clear in (Anthonisen et al., 1992), where LAR is even explained as: "LAR covers some of the techniques, that can be used to lower or even out the stress that the sewerage system experiences during rain." LAR will therefore reduce the overflow volumes from sewerage pipes (Anthonisen et al., 1992), which has proved to be a problem for the waterways (Andersen and Carstensen, 2011). However, LAR is only one of the measures presented as the solution to the problems with water quality. Another solution is regulation, a non-structural measure, and in already in force since 1987 is the first Action Plan for the Aquatic Environment (Miljøstyrelsen, 2012). The action plans enforces planning of fertilization for farmers and proposes actions for improving sewage handling from treatment plants and industry (Miljøstyrelsen, 2012). In 1991 the regulation for fertilization from farming is further restricted though the implementation of the nitrate directive from EU.

A third very important meaning and group is that of Economic Efficiency, that argues for that LAR is a cheap alternative to the traditional sewerage systems (Gabriel, 17/04-2013; Hansen, 19/04/2013; Lützen et al., 1994; Ritzaus Bureau, 1994). The argumentation is that the construction cost in some cases are lower and that there are multiple benefits related to a lesser demand for expansion of the sewerage system and treatment of smaller volumes of sewerage together with many other benefits related to for example aesthetics and environmental benefits (Lützen et al., 1994). The group supports the implementation of a large range of LAR element both related to infiltration and surface systems. There is however a large uncertainty related to the numbers presented by the group of Economic Efficiency (Lützen et al., 1994) and the group of Economic Inefficiency therefore tries to use a rhetorical closure, by arguing that especially the surface systems are expensive in construction and maintenance (Jørgensen, 1996; Lützen et al., 1994).

The period of New Technology present with an emerging field of multiple RSGs and technologies and the period lack a collective direction for the development of the technologies. Furthermore the period is characterized by a series of uncertainties and conflicting meanings. The LAR that is being implemented is: "…backyard projects, decentralised, something you wanted for yourself and driven by champions." (Jensen, 30/04/2013). It is mainly individual LAR elements being implemented out of context to the Waste Water Plans. The period therefore has a high level of interpretive flexibility and a low degree of stabilization.

The second period of Testing is characterized by a lower level of activities and a lessened public focus on LAR. The period spans from around 1995 to around 2005. In this period the industry frontrunners and researchers are focused on bettering the technology and the meanings that are most prominent during this period is Groundwater Recharging and Water Quality, while the other meaning gets a less important role.

In this period there is an economic recovery from the difficult 1980'ties (Lützen, 23/04/2013) and there is a lessened focus on LAR, which was from the previous period characterized by general environmentalism. This results in a lessened public focus on LAR (Lützen, 23/04-2013) and little implementation of the technologies: "We talked too much and acted too little" (Lützen, 23/04/2013). The lessened focus from the public regarding water quality can have something to do with the

success of the non-structural measures of the Action Plan for the Aquatic Environment, which was published as a second version in 1998 and a third in 2004 with a stronger focus on nutrients washing out from farmers (Miljøstyrelsen, 2012) since there already was a large reduction in the loads from sewage (Andersen and Carstensen, 2011).

LAR was still a focus of some researchers and industry frontrunners: “A solid engineering company, they have been working with this even though it wasn’t in the everyday politics.” (Lützen, 23/04-2013). The focus in this period was on Groundwater Recharging and Water Quality, which shares a focus on reducing the volumes of water entering the sewerage system. The main technologies in play are therefore soakaway and wet and dry basins (Gabriel, 17/04/2013; Jensen, 30/04/2013). Water Quality was focus on bettering the water treatment with LAR technologies so that emissions to waterways were acceptable (Jensen, 30/04/2013).

There is in this period therefore a relative higher degree of stabilization and a constant level of interpretive flexibility. The higher degree of stabilization is due to a lessened public focus on LAR and little action from industry frontrunners and researchers, who still was focused on LAR.

The third period, opportunity, spans from around 2005 to present day, here an opportunity arises for the technologies to influence the current regime. In Denmark this opportunity is connected both to the work of a group of actors in developing and promoting the technology and to a series of large rain events causing severe floods. In this period there is therefore several new and some of them also prominent meaning: Nuisance Flooding, Cloudburst Flooding, No need and Integrated.

The work of some of the actors in promoting and developing the technology was mainly focused around three interdisciplinary organizations, Black, Blue & Green (2BG), 19K in reference to the 19 Municipalities that participated and the newest one VandiByer (WaterinCities). These projects has developed the understanding of the term LAR, so that there now is a stronger focus on surface solutions like raingardens. The projects have furthermore developed some technologies, for instance doubleporous filtering (Gabriel, 17/04/2013; Jensen, 30/04/2013). Furthermore the projects helped by putting LAR on the political and public agenda (Jensen, 30/04/2013; Lützen, 23/04-2013).

Around 2007–2008 the utilities was privatized, however still owned by the municipalities. This led to new people was introduced to water management both in the municipalities and the utilities (Burgdorf Nielsen, 25/04/2013), this also introduced new ideas and a main focus of many of the new actors was that LAR is an economically efficient way of managing the water in city. This is primarily connected to the reduced water volumes in the sewerage system, but also the many other benefits related to LAR (Jensen, 30/04/2013). The actor group of Economically Efficiency shares a close relationship to other groups like Environmental Protection, Cloudburst Flooding, Water Quality, Groundwater Recharging and Integrated. The close relationship with the new group of Integrated is related to the fact that a main argument for both groups is the multiple benefits related to LAR: “And that [the traditional piped system] isn’t a very ambitious way of spending 250 billion. It could be more exciting getting something more out of the climate adaptation.” (Gabriel, 17/04/2013). Both groups use words like synergy, sustainability and environment (Gabriel, 17/04/2013; Holm, 2013; Jensen, 30/04/2013). And both groups support a wide range of LAR elements in combination, treatment trains (Holm, 2013).

In the later years several extreme rain events has hit Denmark, on the 5th of July 2007 southern Zealand is hit by a cloudburst, August 2010 also included a cloudburst and is one of the wettest months recorded and on the 2nd of July 2011 central Copenhagen is severely flooded with 135 mm of rain (Jensen and Fryd, 2012). The 2nd of July caused a lot of damages to private citizens’ property and brought the traffic in Copenhagen to a standstill with central roads and public transport flooded (Jensen, 30/04/2013). The response from citizens was strong, described by (Burgdorf Nielsen, 25/04/2013): “It was almost chaotic conditions afterwards, when we were at public meetings. The citizens were wildly agitated.” The response from the politicians is equally strong, the mayor of Copenhagen stated that this should never happen again in his city (Jensen, 30/04-2013). The politicians decided that immediate action was needed (Burgdorf Nielsen, 25/04/2013; Jensen, 30/04-

2013; Lützen, 23/04/2013). The municipalities reacted by creating climate adaptation plans, and in the case of Copenhagen also a cloudburst plan (Københavns Kommune, 2012). There is therefore an increase in investment in climate adaptation through a renewal of the sewerage system (Jensen, 30/04/2013; Jørgensen, 2010) and new laws for co-funding of projects (Jensen, 30/04/2013) and insurance benefits for private citizens if they adapt to cloudbursts (Gabriel, 17/04/2013). The new meaning and actor group of Cloudburst Flooding is born. The group argues that LAR can help prevent damages causes by cloudbursts and extreme rain events. By disconnecting stormwater from the sewerage system there will a reduced water volume in the sewerage system during rain events, furthermore can LAR elements detain water and either discharge it later or infiltrate it (Christensen, 2011; Hansen, 19/04/2013; Jensen and Fryd, 2012; Jensen, 30/04/2013). The group defines LAR also by storage on terrain, both more natural storage and more urban storage possibilities as reported in (Daugaard, 2013): “Skate parks in rainwater basins, paddling pools in roundabouts and rainwater as a decoration instead of a challenge?” However, there is also a focus on rainwater tanks and soakaways as a remnant from previous times (Jensen, 30/04/2013).

In conflict with the definitions of LAR by the group Cloudburst Flooding is Nuisance Flooding, who argues that LAR only can manage nuisance flooding. There simply is not the storage volume in the LAR elements to manage the water from the larger rain events (Gabriel, 17/04/2013; Paludan and Arnbjerg-Nielsen, 2011). The RSG is not against implementing LAR, they just argue that they shouldn’t be used as flood prevention in relation to climate adaptation (Lerer, 30/04/2013). In close relationship to the group of Nuisance Flooding is that of Economic Inefficiency, which argues that LAR is an economic inefficient way of managing the urban water cycle. The arguments both related to high construction and maintenance costs (Burgdorf Nielsen, 25/04-2013) and the lack of storage volume and therefore the amount of LAR elements needed to manage the water (Marfelt and Andersen, 2012). The group of Nuisance Flooding defines LAR more traditionally as soakways and other infiltration measures, raingardens and green roofs (HOFOR, 2013; Marfelt and Andersen, 2012). Both Nuisance Flooding and Cloudburst Flooding, Economic Efficiency, and Economic Inefficiency are trying to use rhetorical closure to convince the other group of their view point, and both argue with numbers and rationales, as in (Marfelt and Andersen, 2012), (Jensen and Fryd, 2012) and (Paludan and Arnbjerg-Nielsen, 2011). The rational arguments include statements like: “It is kind of frustrating, that he has made all these economic calculations and then they don’t match with what we see in our projects in real life, not on construction cost or societal costs” (Gabriel, 17/04-2013) and “When we are paying the citizens to disconnect from the sewerage system by installing a soakaway in their backyard, aren’t we lowering the risk of flooding, but it will be an expensive and badly functioning solution.” (Marfelt and Andersen, 2012).

As it can be read above this period displays a more complex picture of actor groups and technologies. The groups have a lot of conflicts in their vision of the technologies and there are several uncertainties in the ontology of LAR. There is a very high interpretive flexibility and a low degree of stabilization.

	New technology	Testing	Opportunity
	~1990	~1995	~2005
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.
Technologies in play	Soakaways Wet and dry basins Vegetated elements Permeable pavements	Soakaways Wet and dry basins	Raingardens Soakaways Treatment trains Detention on terrain
Main actors in play	Researchers Industry frontrunners Government Citizens	Researchers Industry frontrunners	Researchers Industry Government Citizens
Meanings in play	LAR can help improving water quality of waterways and ocean LAR can refill groundwater aquifers LAR will help protect the environment LAR is an economically efficient way of managing the urban water cycle	LAR can help improving water quality of waterways and ocean LAR can refill groundwater aquifers	LAR can help improving water quality of waterways and ocean LAR can refill groundwater aquifers LAR will help protect the environment LAR is an economically efficient way of managing the urban water cycle LAR can be used as cloudburst flood protection LAR can only be used to prevent nuisance flooding

Figure 2. The stabilization process for LAR technologies in Copenhagen

Comparative discussion

Differences between Melbourne and Copenhagen in macro-level components promote different drivers for changes in the stabilization process and therefore different applications of the technology. The macro-level differences include differences in culture and politics, but also the physical environment including the water infrastructure and the natural environment.

Copenhagen and Melbourne have some fundamental difference in their water infrastructure. Melbourne has a separate sewage system; while most parts of Copenhagen has a combined sewage system. Both systems have led to problems with eutrophication and water quality has therefore been a major driver in both cities. In Copenhagen there is a very strong tradition for regulation and politics

and culture therefore have had a significant influence in addressing this driver; the driver of water quality has therefore led to little change in the LAR technologies.

Finally there are differences in the natural environment that have led to different drivers and different applications of WSUD. In Melbourne there has been a 13-year drought and water is generally scarce in the dry climate, water scarcity has therefore been a main driver for the development and implementation of the WSUD technologies. A major driver in Copenhagen in recent years has been extensive floodings due to cloudbursts. The floodings and climate change adaptation is now the major driver for developing and implementing LAR technologies. Since the pressures from natural environments are so different, almost diametrical opposites, there have also been significant differences in what has been the focus of the implementation of WSUD. There has been a focus on volume reduction /detention in Denmark, while there has been a focus on treatment before harvesting in Melbourne.

Currently in Copenhagen LAR is being implemented as part of a climate change adaptation to reduce the damages related to flooding as a result of cloudburst. However, not everybody agrees with the reasoning behind this implementation. Some actors find that LAR should only be implemented in relation to nuisance flooding, because it can't prevent floodings from cloudbursts. There is therefore a strong public debate between different actors related to the two actor groups of Cloudburst Flooding and Nuisance Flooding. The origin of this debate can be related to fundamental differences in belief, world views and definitions; the ontology of the actors.

Both groups argue against reacting in panic and both agree that LAR has multiple benefits and therefore has a place in society. However, at the base of both groups' arguments in the conflict lies their ontology: the prerequisites for their theories, work and their academic disciplines. The differences in their ontology are expressed both in different world views and in their definition of the term LAR, what LAR physically is. The group of Nuisance Flooding does not define detention on terrain and larger basins etc. as LAR and therefore cannot see how LAR could handle larger volumes of water. Furthermore, the group's academic knowledge is often based in traditional engineering and utilitarianism. The group of Cloudburst Flooding has a different view on LAR and also includes a wider range of technologies like detention on terrain and other landscape based solutions. The group's academic knowledge is often related to landscape design and environmentalism.

This debate and its origin in the ontology of the actors, and the lack of a common definition of the terminology and therefore technology are important for the future stabilization process in Copenhagen. It is something that definitely needs to be solved before the stabilization process can move forward.

The stabilization processes of Copenhagen and Melbourne are very similar, they go through the same overall phases with the same overall actions and actors. Because of this it is possible to make a series of recommendations for supportive activities that could promote the further development and implementation of LAR in Copenhagen and Denmark. The activities are inspired by the successful activities from the stabilization and transition in Melbourne:

- Niche actors providing institutionalization in the form of design tools, guidelines and standards that will help the implementation of the technologies
- Supportive policies across several governmental levels will provide incentive for implementation of the technologies
- A strong cooperative institutional approach across several actors and institutions.
- Successful full scale demonstration projects, which are supported and developed by a wider range of actors, will help building a common vision for the technologies and provide proof that implementation is possible
- Knowledge building and sharing activities across the entire industry will help building a common vision for the technologies
- A linking of the technologies to a main societal problem (landscape pressure) will create societal incentive for implementation

- Inclusive actions in the closure process, closure by redefinition, will provide a sense of ownership and help a common vision. However, rhetorical closure is also needed if the controversies are too big

Similarly there are some things inspired by the development in Copenhagen that can support the further development of WSUD in Melbourne.

- Non-structural measures and regulation can provide a valid solution for some problems, for example water quality
- It is possible to incorporate flood protection into the LAR/WSUD technologies, for example through detention on terrain
- Infiltration in urban areas is possible and can provide passive irrigation of urban green elements if not groundwater refilling. It only requires consideration for and moist proofing of the nearby foundations

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 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 above should therefore be seen as preliminary findings when focusing specifically on the two terms WSUD (in Melbourne) and LAR (in Copenhagen); further interviews in the future are expected to facilitate an expansion of the scope of the comparison.

Conclusions

It can be concluded that the technical elements of WSUD and LAR are very similar. Both technologies 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 or treatment. The similarities in the theoretical technical elements can rapidly be contributed 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 institutional organization, culture and physical environment.

In Melbourne the stabilization has gone through three phases, New Technology, Testing and Opportunity, and has now reached the period of Agreement. The focus has been on the meanings of Environmental Protection, Water Quality, Water Harvesting and Integrated. In Copenhagen the stabilization has gone through two periods, New Technology and Testing, and has now reached the period of Opportunity. The focus in the stabilization process has been on the meanings of Water Quality, Groundwater Recharging, Environmental Protection, Economic Efficiency, Nuisance Flooding and Cloudburst Flooding.

Because of the similarities in the technologies and the overall phases in the stabilization processes, one can make a series of recommendations, inspired by the process in Melbourne, to Copenhagen and Denmark in order to facilitate a further stabilization and transition. However, it might be that stabilization and transition is not possible, as the discussion in Denmark is rooted in differences in the fundamental different core believes and definitions of LAR, the ontology, of different actor groups.

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