Building effective planning support systems for green urban water infrastructure – practitioners' perceptions

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Abstract: The multiple benefits of adopting distributed, green stormwater technologies in the local environment are increasingly recognised, particularly in relation to water quality, flood mitigation, amenity and aesthetics. To advance the integration of these systems into everyday decision-making practices, Planning Support Systems (PSS) are considered vital. Despite several PSS available to support planners and key decision-makers, their uptake remains constrained; a phenomenon known as the 'implementation gap'. While scholars have hypothesised why the adoption of PSS is limited, there remains little empirical investigation regarding the reasons why. This paper tests the hypotheses underlying the implementation gap in relation to water sensitive urban design (WSUD) planning. Drawing on the tacit experience of 24 key urban water planning professionals in the front-runner city of Melbourne, Australia, in-depth semi-structured interviews were undertaken to unpack the contemporary planning processes used and reveal characteristics leading to success and failure of PSS application. Data analysis revealed WSUD planning professionals regard the adoption of PSS as a significant step towards improving contemporary decision-making practices, which are regarded as opportunistic rather than strategic. PSS use was widespread, though the type, intensity and sophistication of use varied among interview participants. Confirming the hypotheses from planning literature, practitioners suggested PSS need to be user-friendly and align closely to planning practice. Additionally, however, it was found that it is crucial for PSS to meet industry conventions. Suggested improvements to current PSS included incorporating socio-economic factors alongside biophysical and planning factors, hence the role for GIS-based suitability analysis tools. Overall, this study provides current and future PSS-developers with critical insights regarding the type, function and characteristics of an 'ideal' PSS aimed at

enhancing the usefulness and uptake of PSS, and thus improve planning that supports expediting green infrastructure implementation.

Keywords: Water Sensitive Urban Design; Low Impact Development; Planning Support Systems; Urban Planning; Implementation Gap; Strategic Planning

1. Introduction

1.1 Background

Cities around the world are confronted with the negative impacts of increasing urbanisation and climate change. Impervious surfaces and changing weather patterns cause urban waterway degradation and increase flooding risks (Gill et al., 2007). Responding to this situation, Water Sensitive Urban Design (WSUD) in Australia, and similar concepts such as Low Impact Development (LID) in the US, Sustainable Urban Drainage Systems (SUDS) in the UK and Sponge Cities in China, have gained attention over the past decades as an adaptation and mitigation strategy that increases the liveability and resilience of cities (Fletcher et al., 2014). At the core of this strategy are distributed 'green' drainage infrastructures, such as raingardens and constructed wetlands. The application of varied multi-functional green infrastructures is aimed at protecting water quality, mitigating flood risks and providing additional benefits, such as improved amenity values, micro-climate and ecological habitat (Wong and Brown, 2009). Globally, the number of WSUD systems being adopted is growing. To ensure that technologies perform to their full capacity and deliver the full suite of benefits, due attention to their context is required to achieve successful integration into the urban landscape (Kuller et al., 2017).

WSUD departs from large scale, centralised single-objective urban drainage systems that are predominantly hidden from the public eye. However, the multi-functionality of WSUD technologies widen the policy and decision-making contexts, for well-designed and well-situated WSUD assets can go beyond just urban drainage, to incorporate biodiversity targets, improved aesthetics and amenity and potential micro-climate benefits, among others (Fletcher et al., 2014; Sharma et al., 2016). With this in mind, strategic planning practices are required to incorporate all aspects of the urban context for WSUD integration: biophysical, socio-economic and urban form (Kuller et al., 2017). The multitude of relevant aspects and considerations make WSUD planning a complex task that calls for vertical (between different levels of government) and horizontal (among municipalities) alignment and integration of key policy and decision-making contexts. Indeed, Morison et al. (2010) highlight the importance of high levels of internal (between departments within an organisation) and external (between organisations) collaboration required to accomplish this integration (Morison et al., 2010). Currently, vertical misalignment of high-level policy is exacerbated by differences between municipalities in their levels of capacity and commitment to WSUD planning (Morison and Brown, 2011).

Effective planning for integrating WSUD technologies into the landscape requires an understanding of the varying functionalities associated with different WSUD approaches, a high-level of planning expertise and readily available data. Yet, current WSUD scholarship continues to highlight how the internal capacity of municipalities, where the majority of detailed WSUD planning is undertaken, is constrained by factors such as insufficient technical skills, high levels of staff turnover and lack of dedicated resources, among others (e.g. Brown et al., 2009a; Morison and Brown, 2011). To overcome these internal challenges, external expertise from engineering consultancies is typically sought. This has led to ad-hoc and opportunistic planning practices, which may result in long-term, sub-optimal outcomes (Kuller et al., 2018). Indeed, as Malekpour et al. (2015) highlight, reactive and incremental approaches

to planning are ill-suited to guide a transition towards widespread adoption of WSUD approaches.

1.2 WSUD: urban planning and Planning Support Systems

Planning Support Systems (PSS) may be well suited to aid urban planning practitioners (Klosterman, 1997) and may help to overcome the challenges associated with collaboration and alignment of goals and interests in the water sector (Crona and Parker, 2012; Gibson et al., 2017). A myriad of PSS is available to planning practitioners (Kuller et al., 2017), including several recent PSS focussed on supporting WSUD implementation, such as UrbanBEATS (Bach, 2014) and SUDSLOC (Ellis and Viavattene, 2014) (see also Figure 1). The application of PSS is widely promoted in academic scholarship (e.g. Geertman and Stillwell, 2012; Klosterman, 1997; te Brömmelstroet, 2013) based on the recognised value of PSS in dealing with the growing complexities of urban planning tasks (Geertman, 2016; Poch et al., 2004). Nevertheless, the reported level of PSS uptake among planning professionals remains low (e.g. Gibson et al., 2017; te Brömmelstroet, 2013; Uran and Janssen, 2003; Vonk et al., 2005). The causes of this 'implementation gap' have been widely hypothesised over the past two decades. Although still the subject of academic debate, there is a growing consensus the implementation gap is the result of: limited exposure to and experience with PSS, a lack of data availability and quality, low user friendliness, and the simplicity and limited usefulness of outputs (te Brömmelstroet, 2013; Vonk et al., 2005). Despite these insights, there remains a lack of empirical research focussing on practitioner perceptions regarding the causes of this WSUD planning the implementation gap (McIntosh et al., 2007).

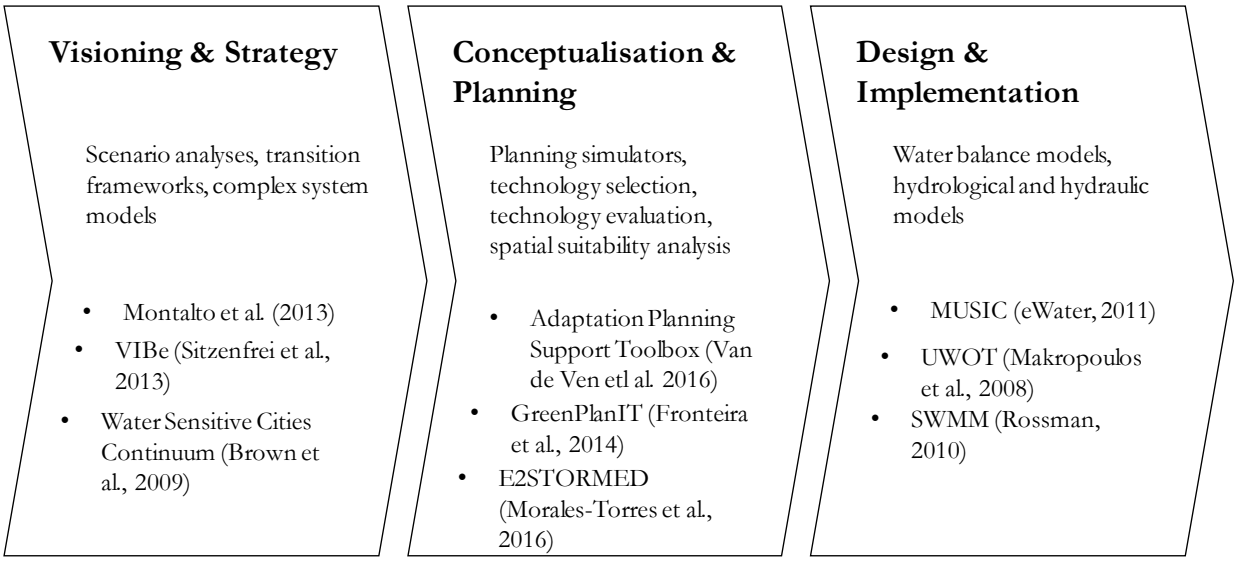

Figure 1 Planning stages (top) and with associated PSS types (middle) and examples (bottom). Adapted from Kuller et al. (2017).

(Brown et al., 2009b; eWater, 2011; Fronteira et al., 2014; Makropoulos et al., 2008; Montalto et al., 2013; Morales-Torres et al., 2016; Rossman, 2010; Sitzenfrei et al., 2013; van de Ven et al., 2016)

Contemporary PSS scholars point to a lack of direct engagement between PSS developers and everyday planning practices and practitioners, as the core of the implementation gap (e.g.

Crona and Parker, 2012; McIntosh et al., 2007; Pelzer et al., 2015; Rodela et al., 2017; te Brömmelstroet, 2013; Vonk et al., 2005). Indeed, the failure to directly engage with PSS end-users has led to a range of weaknesses in PSS design, which ultimately act as barriers to uptake, which are summarised in Table 1. Reflecting the temporal challenge in relation to advancing PSS uptake, Table 1 reveals how similar challenges to those identified by Lee Jr (1973) almost half a century ago are still relevant. Lee Jr's (1973, p.164) "seven sins of large scale models" p. 164: Lee Jr (1973) closely mirror the contemporary barriers, including, among others: "hyper-comprehensiveness" (the drive to include too much detail in models), "hungriness" (the need for data inputs), "complicatedness" (high number of variables and relationships) and "mechanicalness" (deterministic, inflexible, inhumane thinking process of computers). Geertman (2016) concedes that many of these challenges are present today, though does acknowledge they vary depending on the domain of planning.

Table 1 Barriers to a wider uptake of PSS, as identified in contemporary PSS literature.

Category	Issue	Description	References
Inputs	Data availability	Existence and availability of required data	Vonk et al. 2005
	Data quality	Quality of available data	Vonk et al. 2005
Outputs	Relevance	Outputs useful to the planner. Special emphasis on the need for spatial outputs	Vonk et al. 2005, Uran and Janssen 2002, te Brommelstroet 2013, (Hajer et al., 2010), Gibson et al. 2017
Design	Complexity	The dichotomy between complexity and useability	te Brommelstroet 2013, Geertman 2016, te Brommelstroet et al. 2014, Gibson et al. 2017
	Transparency	Openness about processes and assumptions	Vonk et al. 2005, te Brommelstroet 2013, (te Brömmelstroet et al., 2014)
	Flexibility	Capacity to deal with different inputs, requirements and link to other tools	Vonk et al. 2005, te Brommelstroet 2013
	User friendliness	Ease of use, graphical interface	Vonk et al. 2005, te Brommelstroet 2013
Scope	Too technical	Focus on technical issues rather than planning process and 'soft values'	te Brommelstroet 2013, te Brommelstroet et al 2014, Pelzer et al 2015
	Meeting planners needs	Supply focussed rather than demand focussed. Strong need to engage more with the planning practice	Vonk et al. 2005, (te Brömmelstroet and Bertolini, 2008), Uran and Janssen 2002, te Brommelstroet 2013, Geertman 2016, te Brommelstroet et al. 2014, Pelzer et al 2015, Gibson et al. 2017
User	Experience	Experience with PSS of individuals and organisations	Vonk et al. 2005, te Brommelstroet and Bertolini 2008, Gibson et al. 2017
	Awareness	Awareness of the existence and potential of PSS	Vonk et al. 2005
	Capacity and support	Expertise within the organisation and support (manuals, online help, etc.) to user of PSS	Vonk et al. 2005

1.3 Aims and objectives

To advance WSUD implementation and avoid opportunistic implementation, this paper characterises practitioner's perceptions regarding the underlying issues associated with PSS adoption within the Australian urban context of metropolitan Melbourne. Drawing on the tacit experiences of contemporary planning practitioners engaged in WSUD practices, this qualitative research seeks to: (i) identify the perceived strengths and weaknesses of current WSUD planning processes, (ii) assess the current level and scope of PSS uptake and how this could be improved into the future to expedite WSUD implementation and (iii) compare the barriers to PSS uptake from literature with those found for WSUD planning. For the first time,

the implementation gap is empirically tested for WSUD planning. It is one of the few attempts, to date, to empirically test the hypotheses for the PSS implementation gap in urban planning in general. Many important causes hypothesised to underlie the implementation gap were confirmed by our findings, such as user friendliness and relevance to the planning process. However, some other issues were found that were not before described to play a role in PSS uptake, most notably whether a PSS is industry convention. This research is undertaken in the context of the development of a novel planning support tool and will inform its design. In addition, it is anticipated that this research will provide PSS developers with critical insights regarding success factors for PSS uptake, enabling them to develop more successful models and tools to further urban planning practices.

2. Research approach

To explore how PSS can improve WSUD planning, two overarching research questions were formulated: (1) How are the characteristics of current WSUD planning practices and their outcomes perceived by planning practitioners? (2) What is the current and potential role that PSS can play to improve WSUD planning and (3) how can we improve the suitability of PSS towards this strategic planning for WSUD? While the answers to questions 1 and 2 are captured in the interview data, the discussion posits key design feature that might be necessary to improve PSS for WSUD planning (question 3). This qualitative research adopts a single case study design Creswell (2012) across multiple scales. Melbourne (Australia) was selected as our case study location. Melbourne has been on the journey towards WSUD for over a decade (CSIRO, 1999), gaining experience with WSUD implementation on the ground (e.g. Melbourne Water, 2005) as well as in policy throughout all levels of government (Brown et al., 2013). A strategic commitment towards WSUD is expressed from state (DELWP, 2016a, b), as well as local levels of government (e.g. City of Melbourne, 2017; City of Whittlesea, 2012), shaping an enabling context for ongoing WSUD development. We focussed on both state and local levels of government, where policy and implementation of WSUD occurs. Furthermore, our focus extends to private engineering consultants, to whom parts of the planning process are outsourced by government organisations.

Data collection included in-depth semi-structured interviews of between 45 and 90 minutes each (Creswell, 2012). Research participants were selected to represent practitioners typically involved in WSUD planning from the state context, through to municipal governments, utility services and engineering consultants, which provided a vertical representation sample (Figure 2). Horizontal representation was achieved by selecting individuals from across the metropolitan area: inner, middle and outer municipalities. This was considered necessary for across greater metropolitan Melbourne there is a large variance in urban form, age, demographics and socio-economic characteristics, planning priorities and commitment to WSUD (Morison et al., 2010). A total of 24 practitioners were interviewed across 19 interviews.

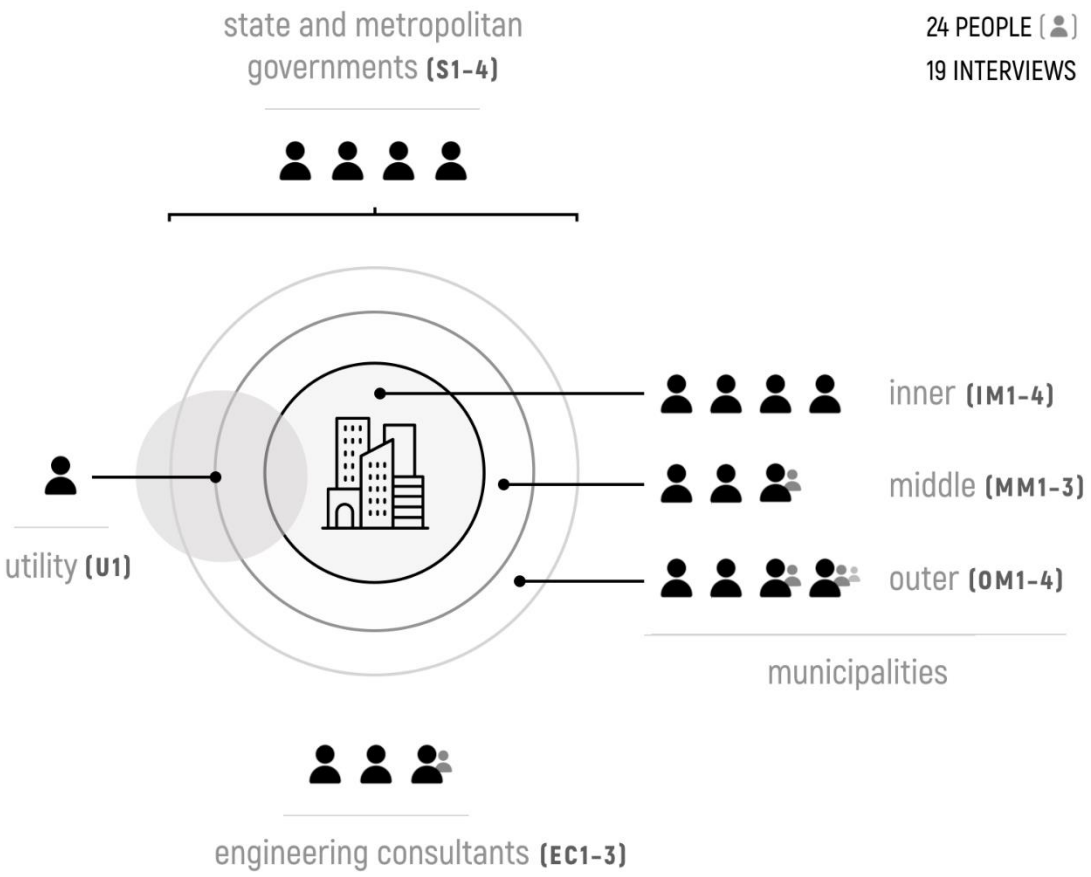

Figure 2 Representation of research participants from the interviews.

Interview questions were grouped in two broad themes, aligned with the main research objectives. Participants were asked: (i) to identify what aspects within their organisation may improve the planning process, (ii) if they had ever used PSS and why (not), and (iii) to suggest a list of good/bad characteristics related to PSS that they are aware of. To form a reliable and balanced insight regarding participant's tacit knowledge and experiences, questions were formulated both negatively and positively (e.g.: "What are the success factors of your organisation's planning process?" and "What could improve in your organisation to make the planning process more successful?"). Further probing questions were used to encourage deeper conversation regarding the subject's detailed experience and opinion.

Interviews were analysed through using transcription, followed by an iterative process of coding and grouping answers into emerging 'themes', in line with the interview questions. Themes were assessed for their relative importance through quantification of occurrence and compared between municipal and non-municipal respondents. Further grouping of different and opposing answers within themes was performed, to uncover story lines across the interviews. Although descriptive statistics were gathered about issue mentions to build evidence for relative importance of the emerging themes, no further quantitative or statistical analysis was performed as this study's set-up was qualitative in nature.

The findings from the interviews were validated through a stakeholder workshop and analysis of relevant secondary data. The workshop involved 16 people from similar organisations as the interviewees (state government, water utility, councils, private consultant) and was designed to cross-check (validate) the answers provided by interviewees, assist in deepening our understanding and to consolidate the results. In addition, secondary data, including government policy documentation and municipal strategies and planning documents, were examined to provide context and insight regarding the enabling context for WSUD planning and decision-making.

3. Results

3.1 Contemporary planning processes

Considerable experience with WSUD planning has been gained by planning practitioners in Melbourne over the past decade. Nevertheless, it is still regarded as a relatively novel concept. Important to note is the difference between planning for greenfield- (development of rural land) and infill (development of existing urban land) developments. While the former is relatively well structured and set in policy (e.g. clause 56.07 of the Victorian Planning Provisions, which sets the requirement for integrated water management in residential subdivisions: DELWP, 2017), the latter is significantly more challenging. Greenfield developments occur in the outer municipalities, while infill is done mostly in the inner and middle municipalities.

Across all stakeholder groups, respondents identified internal (between departments within the organisation) and external (between organisations) collaboration as key for advancing WSUD planning (Table 2). Despite this recognition, insufficient levels of external collaboration were identified, particularly between municipalities. This was found to be caused by restrictive differences between municipalities in levels of commitment to WSUD and the sophistication of internal planning processes. Individual respondents, who self-identified as being less committed to WSUD, highlighted organisational rigidity and risk-averse management styles, hindered process and practice innovation. A recent initiative by state government, called *Water for Victoria*, facilitates regional collaboration through platforms that aim to bring together planning professionals from all municipalities within an urban catchment (DELWP, 2016a). This initiative illustrates the growing recognition of the need for increased collaboration at catchment scales and the potential for PSS to facilitate this.

While reactive, opportunistic and ad-hoc approaches were identified as the greatest threats to good WSUD planning, most respondents indicated the need for local water strategies to address this. Municipal respondents noted that these would be useless without the backing of legislation and policies across all levels of government, to mitigate against the challenges of changes in government and resulting priority setting. Another barrier identified by some respondents was long turnaround times (of up to 10 years, according to respondent OM3) between the conception and implementation of WSUD strategies.

Finally, the challenge of building a business-case reflecting the benefits of green systems was identified as a significant challenge by respondents across organisations. These benefits are very difficult to measure and translate into dollar values. Although an increasing amount of

research is emerging (e.g. Boyer and Polasky, 2004; Niu et al., 2010; Tapsuwan et al., 2014), its application is not currently apparent in practice. One potential solution according to our participants was the development of better ‘tools’ and models. Tools were furthermore identified as important to aid strategic planning by optimising locations for WSUD.

Despite the challenges and barriers to contemporary planning practices identified above, there was a feeling of optimism among participants, along with a strong sense that progress has been made in WSUD planning and implementation over the past decade. Participants showed great willingness to learn and work towards removing the remaining barriers.

Table 2 Issues with current planning processes for WSUD, as identified by Melbourne planning practitioners. Ordered from high to low frequency.

Issue[1]	Qualitative explanation examples[2]
Internal and external collaboration (6,9)	• It is good that we are here to negotiate between stakeholders (S4) • "Collaboration is not always happening, it is easy to just focus on your own core business. Collaboration is ad-hoc, not formalised. That's why we're starting [inter municipal] forums." (S1) • "Every organisation has its own role and goals and agenda. Sometimes they conflict. Melbourne Water is most important for WSUD." (U1) • "There is a lot of talk about Integrated Urban Water Management, but it is not happening. Everybody is chasing their own KPI's." (EC3) • "To improve between departments, we try to publish together. Having young people also helps." (OM3) • "What is good is that everyone in the water sector talks to each other." (MM2) • "Our project steering team worked really well to get buy-in from the entire municipality." (OM1) • "We still work together with other departments, but that is more about managing existing [WSUD] assets." (IM4)
Opportunistic and ad-hoc planning (5,8)	• "Municipalities used to be very opportunistic, following road renewal, which is poor in terms of strategy." (S3) • "Planning is opportunistic, putting assets whenever they [municipalities] have money, wherever they can." (EC1) • "We are too reactive. We may be throwing money at things we don't want." (MM2) • "[We use] mostly opportunistic and ad-hoc planning. We are not being holistic about WSUD, now only focussing on flood." (MM1) • "We are not comparing locations or looking at catchments strategically." (IM1) • "For new developments, developers usually just chuck WSUD in, and I have to go out and check it." (MM3) • "We need to plan them [WSUD] better, where they suit, where they're needed." (IM3)
Presence/absence of local strategy or water plan (3,8)	• "The urban water cycle is integrated, so should planning be." (S1) • "We need our systematic approach back." (IM3) • "We have an in-house strategic plan that drives our commitments to WSUD. We have guidelines though for WSUD covering the whole process, which helps." (OM1) • "Recently we have moved to a more strategic approach, with priority catchments based on Directly Connected Impervious, ... Early stages, trying to do it such that projects don't delay too much." (OM3) • "We have no strategic plan anymore, and no money anymore either." (IM4)
Justification, business case (4,6)	• "Furthermore, we don't have proper ways to measure costs and benefits." (S2) • "[Our new framework shows] where to allocate risks, costs and benefits. Where and who are benefitting and paying. Also [it enables] to see extra benefits." (S1) • "We need a better way to strategically balance different priorities..., we don't integrate the extra benefits or compare between department wishes but consider them separately." (IM1) • "Problem is that the drivers aren't necessarily economic, it doesn't financially stack up 'cause the extra benefits are amenity, draught [mitigation], bbq's etc." (MM3)
Presence/absence of legislation and policies (2,6)	• "…but mainly it is all about legislation, and the legislation has to change to incorporate incentives for municipalities and developers… Standards accepted by industry like the guidelines and 80-45-45 [reduction targets] really help." (S4) • "We've streamlined statutory planning and got all experts we need." (IM2) • "We need organisational policy to take the discretionary element out of it [planning]." (OM1) • "Our guidelines should have WSUD as a requirement." (MM1) • "We hold the hands of developers to design it [WSUD], and we have the backing of our policy, which is very important. Before it was very hard to make them do what we wanted." (MM3)
Community issues (0,8)	• "The 'will' needs to be there with all the people involved [including community] to do things. This is what I found worked so well in The Netherlands." (OM2) • "Smaller systems are less accepted when not maintained…. Acceptance is also an issue for [water] recycling." (MM2) • "People hate raingardens." (IM3) • "Residents have a stake as they pay [for WSUD], and they're not always in favour. Lot of what I do is communication therefore." (OM4)
Differences between municipalities (1,7)	• "There's some municipalities that are ahead of others." (OM3) • "We are not as advanced as IM2." (MM2) • "…we're far ahead of other municipalities." (IM2) • "We're different from other municipalities in that we do more with infiltration." (OM4)
Need for tools/models (2,4)	• "Limited models and tools [available] for infill planning." (S2) • "A tool could be incredibly helpful. We are trying to do a 4-year planning thing and make that more visual. Trying to find a way with our GIS." (IM4)

	• "Also a graphic DSS approach for finding the locations [for WSUD] in catchments is important." (MM1) • "[My role is] opportunity mapping, finding locations [for WSUD]." (IM2)
Organisational rigidity (2,4)	• "[There is] limited innovation, especially for brownfields." (S2) • "[A problem is] rigidity and the amount of rules, no freedom or out of the box thinking, which leads to just ticking boxes. If you only want simple assets that are easy to maintain, it is difficult to innovate." (EC3) • "WSUD is a novelty, but planners are comfortable with the risk it brings and accept failure." (OM3) • "I was surprised how hesitant they [managers at municipality] were [towards WSUD]." (MM1) • "People do what they're used to [traditional drainage]." (IM4)
Progress (1,5)	• "In 50 years from now, sustainability will be the norm, and everything will be changed and accepted." (S4) • "Appreciation for WSUD is growing." (MM3) • "We are learning. Over the years our engineers became more skilled with MUSIC [model]." (MM2) • "Info for decision making is growing the past five years." (OM3)
Time constraints (2,2)	• "…tough timeframes, which lead to suboptimal results and cutting corners." (S4) • "Consultants are asked a lot for little money, especially with rate capping [decreased municipal income]." (EC1) • "Bigger team would be good." (IM4)
Turnaround times (1,3)	• "The time between plan and implementation is 10 years." (OM3) • "Implementation takes 1-2 years. Wetlands take longer, about 5 years. Processes are slow moving." (MM2)
Reliance on personnel's expertise (0,4)	• "Our planning is risky, as it relies on people's experience." (OM1) • "We've been losing expertise after restructuring." (MM1) • "…but up to now decision making is done manually, depending on people's knowledge." (IM1)
Costs (2,1)	• "Race to the bottom for getting the cheapest consultancy." (EC1) • "With rate-capping our budgets are constrained, pushing towards traditional drainage." (IM4)

[1]Between brackets: (# non-municipal respondents, # municipal respondents)

[2]IM: Inner Municipality, MM: Middle Municipality, OM: Outer Municipality, S: State government, U: Utility, EC: Engineering consultancy.

3.2 Planning Support Systems in WSUD planning

Interviews revealed that tools and models are commonly used by municipal and non-municipal practitioners. MUSIC (Model for Urban Stormwater Improvement Conceptualisation) (eWater, 2011) and spatial software such as ArcGIS are most commonly used. These PSS are so well integrated into existing planning processes through state-based regulation (i.e. MUSIC) and standard industry practice (i.e. spatial software), that municipality respondents often forgot to mention these when they were asked about PSS usage. Other widely applied PSS included Cost-Benefit Analysis (CBA) and spreadsheet-based tools (Figure 3). The main driver behind adopting a PSS is the requirement from a manager or outside organisation (e.g. client for a consultancy). Furthermore, individual choice and industry convention play a big role. Even though a certain level of engagement with PSS is common, their application tends to be limited to WSUD functional design and asset management. Specialised PSS, designed to aid strategic planning for WSUD, were rarely used and limited to non-municipal stakeholders, due to the barriers listed in Table 3, including user friendliness and training requirements.

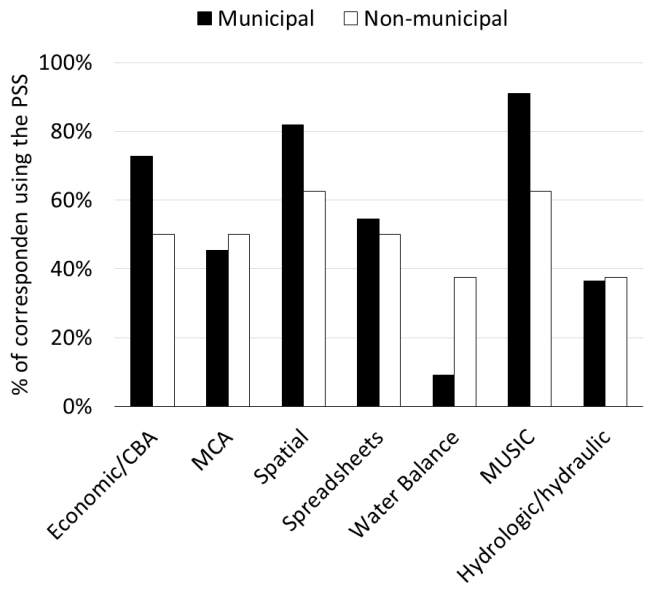

Figure 3 Types of WSUD-PSS used by planning practitioners in Melbourne. CBA: Cost-Benefit Analysis, MCDA: Multi-Criteria Decision Analysis.

Simplicity within a PSS was identified as paramount for planning practitioners to start utilising it. Key aspects such as: user-friendliness, minimal training requirements and low complexity (i.e. a heuristic rather than accurate) were identified as critical success factors for PSS (Table 3). Whilst non-municipal respondents acknowledged the need for PSS to adequately reflect the complex nature of reality within the tools, benefits were also recognised in the trade-off between complexity and usability. Tools that are considered “industry convention”, such as MUSIC, were generally preferred, enjoying higher levels of confidence amongst users in the sector. As is the case with MUSIC, the process of becoming an industry convention is often driven by their position as a requirement in policy and regulations. However, MUSIC alone is

not enough to facilitate strategic planning of WSUD, as its focus is limited to technical design and sizing of infrastructures (see Figure 1). Furthermore, interviewees noted the relevance of output generated by tools as important, with emphases being placed on producing visual outputs such as maps. Such outputs are easily understood by non-experts and provide a strong vehicle for communication of ideas and opportunities both within as well as between organisations. Technical specifications, including the availability and quality of required input data, flexibility, transparency and accuracy also play a role, albeit to a lesser extent.

Table 3 Characteristics inhibiting and promoting PSS uptake as identified by planning practitioners in Melbourne. Ordered from high to low frequency of mention.

Issue[1]	Qualitative experience examples[2]
User friendliness (5,7)	• "MUSIC is simple and easy to run, without technical skills." (S3) • "Intuitiveness is important, not even simplicity." (U1) • "Functionality rather than ease of use. We don't care about the looks." (EC3) • "Models need to be simple to use for planners, as there is a large turnover." (OM3) • "Needs to be super, super simple for people to use it." (OM2) • "It needs a good user interface and manual, so you can learn it yourself. MUSIC is great, very intuitive." (OM4)
Training, time investments (4,8)	• "MUSIC is a good example, it seems to work, easy to use and training is provided." (S2) • "Training time it takes [to learn a tool] is important." (U1) • "We don't use tools because we don't have time [to learn them]." (MM2) • "It [MUSIC] is complex and you need training. Colleagues struggle, so do developers." (MM3)
Complexity dichotomy (5,5)	• "Although complex tools are useful, 90% of the users will only use the basic functionality." (S2) • "Tools that do more than their core, become too cumbersome to use." (S1) • "Complexity is a trade-off, depending on the task at hand…Only adding complexity where it adds rigour." (EC1) • "Don't put too much in one too. Simple enough to use, but robust enough to drive a wide range of outcomes." (IM2) • "I prefer not to use a too complex model, as I don't know how to do or interpret it." (IM1)
Industry convention (5,5)	• "People rely too much on MUSIC. There is no competition, so there's a monopoly." (S3) • "If everybody uses them and trusts the results, a community builds around it that keeps it being developed further." (U1) • "…but there needs to be a critical mass of users." (IM2) • "If it's a requirement, it makes it easier." (IM3) • "...but also how it syncs with what other municipalities do." (MM1)
Clean, relevant, compatible output (4,5)	• "…and the effectiveness of output it generates that is easy to interpret." (EC3) • "Making the message clear, simple and quick to understand by using visuals makes the likelihood of it going up with directors or funders higher." (IM1) • "Storm [a WSUD PSS] is simple to assess [the output], you get a score. People who don't know WSUD can still use it." (MM3)
Costs* (3,5)	• "…but if we really need it, paying shouldn't be a problem." (S1) • "To a degree cost and open source are important. I am a huge open source fan." (U1) • "Money not so much [of an issue], I am happy to fund that from a strategic point of view." (OM1)
Input data (quality, quantity) (3,4)	• "The value of the answer should justify the effort of inputting, so the less input the better." (S2) • "On a detailed scale, data is very limited, which is a big problem." (IM2) • "…low level of data input and no expertise needed. ...control over inputs." (IM1)
Flexibility (3,4)	• "Source is very flexible, you can tweak it to do what you want." (U1) • "I like to be able to access command line interfaces, so I can do batch running." (EC1) • "...customisability, so it can be used in the local context." (OM4)
Trust (4,3)	• "the problem with a tool when it is not scientifically sound is that sceptics with shoot it down." (S2) • "Trust of the data is very important, especially to engineers." (IM3) • "I trust MUSIC, so much money has gone into development. It's robust, doesn't need replication." (MM3)
Transparency (5,0)	• "Jargon is another problem. …difficult to navigate, not transparent, black box is not used by people." (S3) • "MUSIC is well documented and transparent, so I trust it." (U1) • "Transparency is generally important…but if it is too complex, you don't need to know the algorithms." (EC1)
Accuracy (2,1)	• "GIS need to be geographically accurate." (S4) • "Making it as simple as you can without losing too much accuracy, because there is no point in coming up with a simple, but wrong answer." (EC1)
Familiarity (1,1)	• "There's lots of them [PSS] out there, but municipalities just don't know about them." (S3) • "We don't know about them and don't have them." (MM2)

[1]Between brackets: (# non-municipal respondents, # municipal respondents)

[2]IM: Inner Municipality, MM: Middle Municipality, OM: Outer Municipality, S: State government, U: Utility, EC: Engineering consultancy.

*Even though costs were mentioned reasonably frequently, with only one exception these mentions were dismissing its role.

Familiarity with tools and their potential to aid planning practices was only occasionally put forward. However, limited awareness of the PSS available to practitioners, particularly among municipality respondents, indicated this is an important barrier to PSS uptake as well. Costs

associated with acquiring PSS were found to play a very limited or no role in the decision to use them. In fact, whenever costs were mentioned, they were specifically denied to play a role. This may partly be due to the cost of adopted PSS being relatively insignificant. Important to note with each of the barriers identified in this study is that they reflect the perception of the practitioners interviewed. This reality may not always resemble the actual limitations of PSS, as pointed out by Gibson et al. (2017).

When discussing key facets a PSS needs to possess, interviewees agreed that a variety of biophysical, socio-economic and urban form factors should be considered. Notably, while all three were considered important by most respondents (urban form: n=17, biophysical: n=16 and socio-economic: n=14), a clear hierarchy of importance emerged based on the frequency of interviewees' responses. While about half of the responses related to urban form and a third to biophysical factors, less than a fifth of factors mentioned were socio-economic. Although socio-economic factors being recorded less, many participants highlighted that these factors, such as environmental awareness and socio-economic status, were important components in the overall planning process and, to date, have been largely overlooked.

3.3 Comparing barriers to PSS uptake

Comparing WSUD planning with other urban planning practices, the relative novelty of WSUD is reflected in both the development and uptake of PSS. A small number of fundamental tools are widely utilised, but the development of tools aimed at strategic planning is recent and their uptake still limited. If we compare the causes of the implementation gap from Table 1, with our barriers to PSS uptake in WSUD planning from Table 3 (see Table 4), great similarities are apparent in the issues that can stifle and promote the uptake of PSS, as all but one of the topics identified in Table 1 also play a role for WSUD planning.

Notably, WSUD planners did not identify a focus on technical outcomes as a negative issue of PSS. As the process of WSUD planning inherently integrates water engineering with urban planning, this points towards a greater need for technical details. Furthermore, whether or not a tool is industry convention has a great impact on its use for WSUD planners, as illustrated by the success of MUSIC (eWater, 2011). This is closely related with the amount of trust that planners put in PSS. Neither issue was encountered by planners from other fields.

In response to the call by Geertman (2016) to focus on success stories rather than barriers to the uptake of PSS in order to close the implementation gap, we extend our focus on MUSIC. This tool used for WSUD sizing and design was widely seen as a hallmark of success by the Melbourne planning community. Although it certainly is not free of criticism, it is widely used and well appreciated. Multiple qualities, as identified by its users, are at the base of this success and include the perception that the tool is: (i) industry convention, (ii) a requirement in policy, (iii) relatively simple to use and intuitive, (iv) well supported and transparent through training and documentation, (v) robust and trustworthy. These findings, and the other findings from Table 4 are crucial lessons in the context of the development of novel PSS approaches to support WSUD planning in the future.

Table 4 Comparing barriers to uptake of PSS as recognised with the planning literature (Table 1) and WSUD planning respondents (Table 3). The size of the circle indicates the level of importance. No circle means this issue wasn't identified to play a role.

General urban planning	Issue	WSUD planning
	Inputs	
●	Data availability	●
●	Data quality	●
	Outputs	
●	Relevance	●
	Accuracy	●
	Trust	●
	Design	
●	Transparency	●
●	Flexibility	●
●	User Friendliness	●
	Scope	
●	Complexity dichotomy	●
●	Too technical	
●	Meeting planner's needs	●
	User	
●	Experience	●
●	Awareness/ familiarity	●
●	Capacity	●
	Industry convention	●

4. Discussion

4.1 Challenges to WSUD planning

Despite the proven benefits of, and ongoing commitment towards WSUD, the planning and implementation of WSUD still faces challenges. These challenges, as identified by our research participants, are not exclusive to the WSUD planning process. For example, need for collaboration to mobilise knowledge and increase the capacity of local planning actors is widely recognised (e.g. Allmendinger and Tewdwr-Jones, 2002; Healey, 1998). Indeed, Brand and Gaffikin (2007) argue that as our world becomes increasingly complex and unpredictable, collaborative planning becomes essential. WSUD planning provides a fitting example of such increased complexity for at least two reasons: it responds to multiple objectives (e.g. water quality improvements, flood mitigation and amenity) and has a reciprocal relationship with the urban landscape, of which it is an integral part (Kuller et al., 2017). Although planning practitioners acknowledged the fact that governance structures around urban water

management in Melbourne are relatively advanced, they emphasise the need for ongoing improvement of collaborative practices, particularly within their organisation. PSS provide a great potential to support and enable collaborative approaches by providing a platform for discussions and a vehicle for communication of ideas among stakeholders of diverse backgrounds and views (Kahila and Kyttä, 2009). Particularly GIS-based PSS with visual outputs have proven beneficial to planning (e.g. Balram and Dragićević, 2005; Smith et al., 2013)

Opportunistic planning practices dominate WSUD implementation. Although participants accept the importance of strategic, integrated planning when it concerns the complexity of water management, ad-hoc decision making still prevails, as illustrated by the following quote from a state government participant (S3):

-- "It [the *living rivers* project, a WSUD implementation project in Melbourne] started off at a very opportunistic basis, so we went to councils [municipalities] and say: *Are you planning any road renewal projects….?* […] *Would you put a raingarden in as you're doing it?* You know, it's cheaper once you're ripping up the road to do it, but that's um, in terms of a strategic approach that's very poor." --

Commonly, systems are implemented as part of road renewal, which provides a window of opportunity for cheap integration – thereby ignoring the need to consider a variety of context-specific factors crucial for their success. The negative consequences of these opportunistic practices are increasingly felt: failing systems, high maintenance costs and deteriorating public attitudes towards WSUD. Despite the strong and continuing emphasis of planning literature on the need for strategic planning and policies (Albrechts, 2004; Solesbury, 2013), opportunistic planning practices are still prevalent. Fortunately, its negative outcomes are triggering the realisation in the WSUD planning community that strategic approaches are called for, embedded in clearly targeted policies. After collaboration, strategic approaches and policies are the most widely identified solutions to current planning issues.

Strategic planning is aided by PSS through tools such as Multi-Criteria Decision Analysis (MCDA) and Cost-Benefit Analysis (CBA) (Nijkamp and van Delft, 1977; Shefer and Kaess, 1990). They allows us to integrate what Lee Jr (1973) called "soft values", such as socio-economic factors, with hard values of biophysical and urban form factors. MCDA and CBA also play a crucial role in building the business case for 'alternative' stormwater management practices (e.g. Urrutiaguer et al., 2010). Building a business case for WSUD was often perceived as problematic, since many benefits of green systems are indirect, public and difficult to measure. CBA and MCDA are particularly well equipped to deal with the high number of competing needs that inner-city municipalities face in their land-use planning. When coupled with GIS, MCDA has additional potential and a wide application towards strategic and spatially explicit forms of urban planning (Malczewski and Rinner, 2015).

Our findings confirm previous work done by Roy et al. (2008) regarding the limitations and variations in organisational capacities between municipalities and their organisational rigidity. They specifically emphasise "fragmented responsibilities, lack of institutional capacity, lack of

legislative mandate, lack of funding and effective market incentives, and resistance to change" (Roy et al., 2008, pp 344) among the most important impediments towards sustainable urban water management. Evidently, these impediments are persistent, as we still found them to be topical a decade onwards.

4.2 PSS for WSUD planning: an implementation gap?

Moving forward, it is suggested WSUD planning become increasingly (i) collaborative: connecting people and interests within as well as between organisations responsible for delivering WSUD; (ii) strategic: targeting measures that are sensitive to their environment and bring the greatest overall benefit and supported by enabling policies and local as well as regional strategies; and (iii) accountable: drawing from clear, communicable and quantified evidence on benefits to justify investments and incorporating community voices, preferences and interests in the process. An increased uptake of PSS could greatly stimulate a move towards better planning outcomes by addressing all three issues outlined above. It is therefore encouraging to find that most participants were positive and eager to learn and most claimed that improvements in the understanding of, and planning approach to WSUD were made in the past five to ten years.

It would be premature to declare the existence of the 'implementation gap' that was identified to exist for PSS uptake in other fields of urban planning. However, many of the ingredients identified in PSS literature regarding the "cause" of the implementation gap were present in WSUD planning (Table 4). Critical review of literature reveals the need for new tools that can support strategic planning for WSUD (e.g: Kuller et al., 2017; Lerer et al., 2015) . In recent years, an encouraging trend towards the development of such tools is observed, with MCDA and GIS-based methods coming to the fore.

5. Conclusion

While urban planning practices greatly benefit from PSS, their uptake remains low. This phenomenon, known as the 'implementation gap', has emerged as a result of the lack of engagement from the developers of such tools with the planning practice. PSS development has become supply, rather than demand driven. Our research responds to this trend by deeply engaging with planning practice and the role of PSS through the analysis of planner's experiences and assessment of the existence, potential causes and solutions to the implementation gap for WSUD planning. For the first time, the implementation gap and its hypothesised causes are empirically studied for WSUD planning. Thus, it paves the road towards the development of more successful planning tools to support WSUD implementation.

Despite the more than 25-year history of development in this area, WSUD practices have not reached maturity yet. Most importantly, ad-hoc and opportunistic planning practices lead to sub-optimal outcomes. Eminent enthusiasm and goodwill from local practitioners is challenged by disappointing performance of WSUD systems. Processes are slowly improving through adaptive management resultant from practitioners' reflective learning. Some of the greatest room for improvement is to be made in inter and intra organisational collaboration, while bridging differences in capacity and sophistication between planning agents. Furthermore,

strategic approaches to WSUD placement and justification for business cases are urgently required.

Although they should not be regarded as a panacea, certain PSS can be well-suited to assist these improvements. Indeed, a selected number of PSS is commonly used by WSUD planners, but their focus is mostly on technical design. Although isolated cases of strategic PSS application exist, their wider uptake is lacking. Therefore, great benefits are expected from the implementation of more tools aiding with strategic planning.

The infancy state of WSUD planning and the fact that PSS development is only starting to take off render it too early to diagnose an implementation gap. However, most of the ingredients (causes) for this gap to occur were found to be eminent, such as data availability and quality issues, user friendliness and relevance to the planning practice. Therefore, action is needed from PSS developers, who need to actively engage with on-the-ground practices to tailor and shape their planning tools. The findings of this study should be taken to heart, to prevent the implementation gap from opening in the field of WSUD planning.

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