Decision Support Tools of Sustainability Assessment for Urban Stormwater Management

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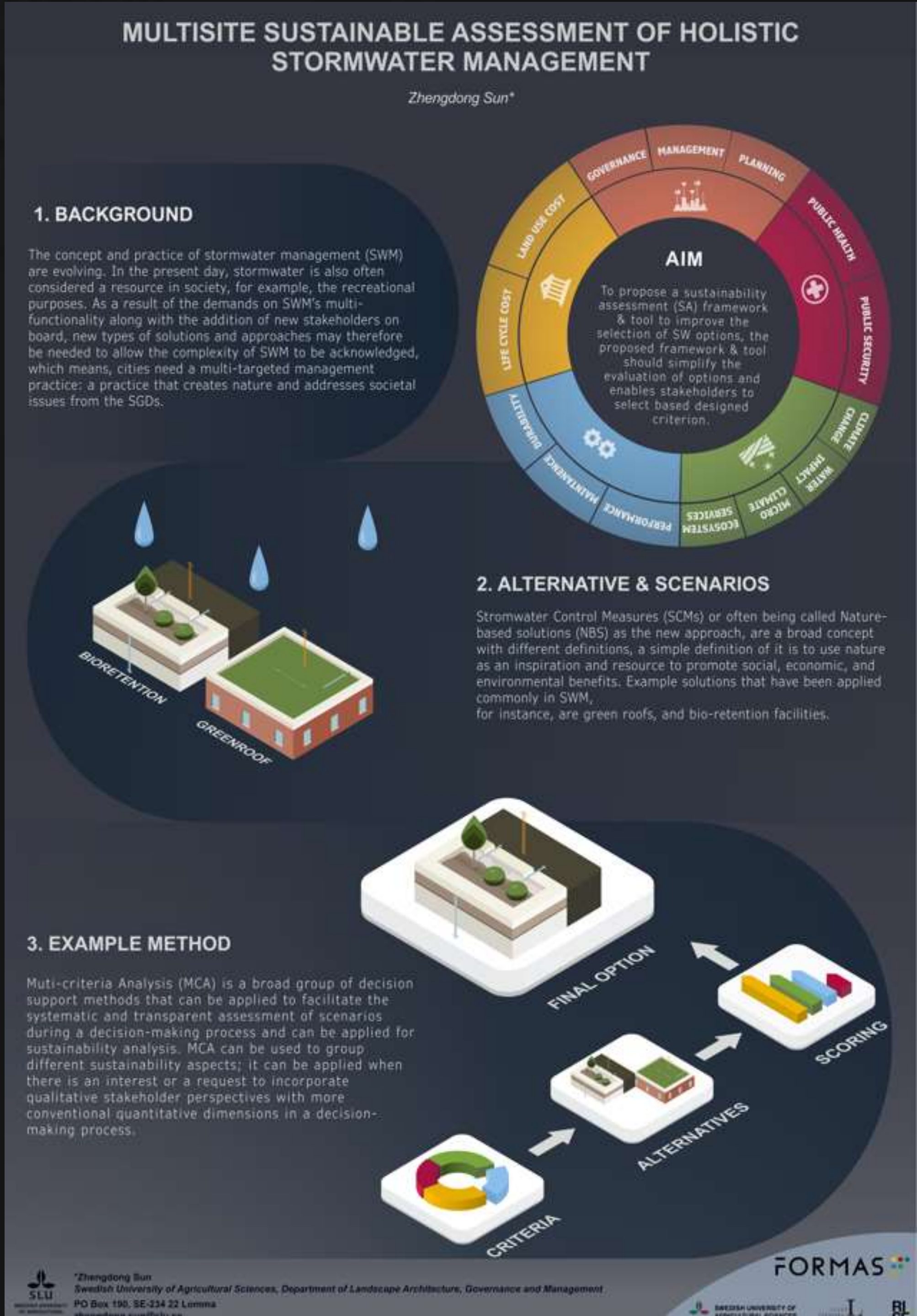
FORMAS PROJECT

Achieving Multifunctional,
Holistic & Sustainable
Stormwater Management in
Existing Development

SLU

PH.D. PROJECT

Sustainability Assessment Of Holistic Stormwater Management



CONCEPTS & BACKGROUND

Stormwater Management

Governance and Management

Sustainability Assessment

Decision Support Tools of Sustainability Assessment for Urban Stormwater Management

– a review of their roles in governance and management

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Review

Decision support tools of sustainability assessment for urban stormwater management – A review of their roles in governance and management

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ABSTRACT

Urban areas face growing sustainable challenges arising from stormwater issues, necessitating the evolution of stormwater management concept and practice. This transformation not only entails the adoption of a multi-functional, holistic, and sustainable approach but also involves the integration of water quality and quantity considerations with governance and management aspects. A means to do so is via decision support tools. However, whilst existing studies using the tools by employing sustainability assessment principles or as indicators to plan blue-green infrastructures and strategies, uncertainties remain regarding how decision support tools encompass governance and management dimensions. The aim of this review study is to provide much-needed clarity on this aspect; in doing so, a systematic review of decision support tools used in sustainability assessment within the stormwater management context is conducted, focusing on their abilities to include governance and management. Findings encompass governance aspects, such as actors, discourses, rules, and resources considered, and explore how these relate to long-term management. The results reveal the recognized potential of decision support tools in facilitating governance and management for sustainable stormwater management, however, future research and efforts need to be allocated in: (i) Exploring practical challenges in integrating all sustainability assessment pillars with consistent criteria into decision support tools, to determine the optimal use of all criteria in fostering open and informed stormwater governance and management. (ii) Understanding how to engage diverse stormwater actors with future decision support tools, to secure ownership and relevance. (iii) Using retrospective (ex-post) sustainability assessments to provide more tangible knowledge and to support long-term management.

1. Introduction

1.1. Sustainable stormwater management

The concept of sustainable development is at the core of urban stormwater management (SWM) by designating that this task is not exclusively underscoring the traditional engineering approach of runoff retention, conveyance, flood control, and quality treatment. Rather, SWM is increasingly considered a holistic and integrated approach to complex urban challenges. As such, SWM addresses environmental concerns of ecological, socio-technological, and social-economical magnitudes where technical means to abate flooding, stormwater discharges, and pollution control are integrated into a wider and comprehensive sustainable context and adopted as sustainable SWM (Flynn and Traver, 2013; Mell and Clement, 2020; Porse, 2013). Such demands are creating an ever-challenging task, as the already complicated existing hyetographic, topographic, hydrological, and engineering information for stormwater control, needs to be added with quantitative and qualitative data from technological, social, environmental, and economic perspectives to be fully acknowledged as sustainable SWM (Depietri and McPhearson, 2017; Makropoulos et al., 2008).

To comprehend such complexities, several concepts have been developed over the past decades, e.g., Water Sensitive Urban Design (Wong, 2006), Low Impact Development (USEPA, 2000), and Sustainable Urban Drainage Systems (Fletcher et al., 2015). These concepts have been ascribed not only to mitigate pluvial flooding and water quality treatment but also to support heat mitigation, biodiversity, health, recreation, etc. (Gettner et al., 2014). As such, these concepts are to varying degrees including nature processes in the development of specific measures to tackle stormwater, such as Nature-based Solutions

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STUDY BACKGROUND & AIM

Sustainable SWM

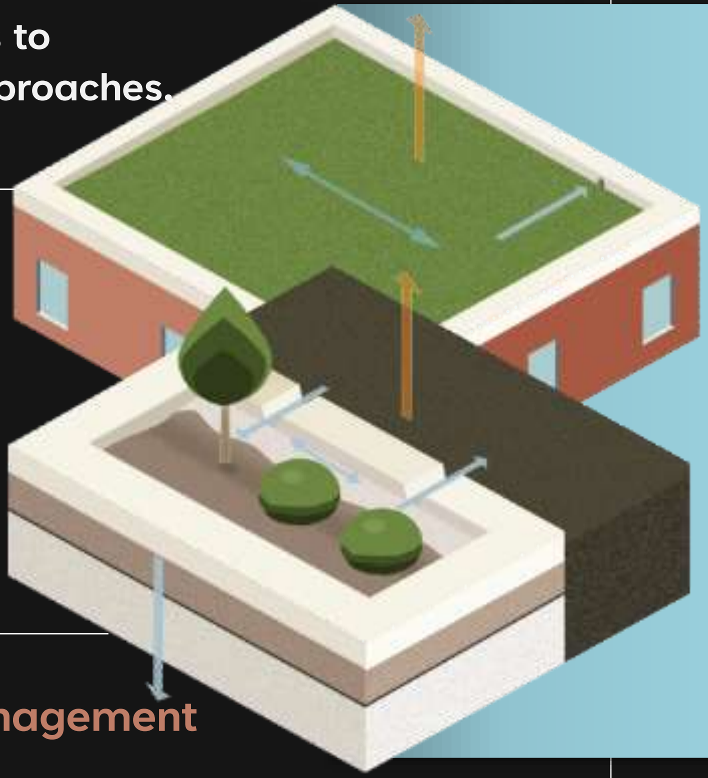
Urban SWM has evolved from traditional practices to embrace holistic approaches.

Decision support

DSTs are used to assess impacts of SWM measures and strategies.

Governance & management

Sustainable SWM needs collective actions with effective governance across various actors.



AIM

How DSTs can support decision-making for holistic and integrated governance and management of sustainable SWM ?

Objective 1

How are DSTs used in sustainability assessment of SWM?

Objective 2

What SWM themes are DSTs applied for?

Objective 3

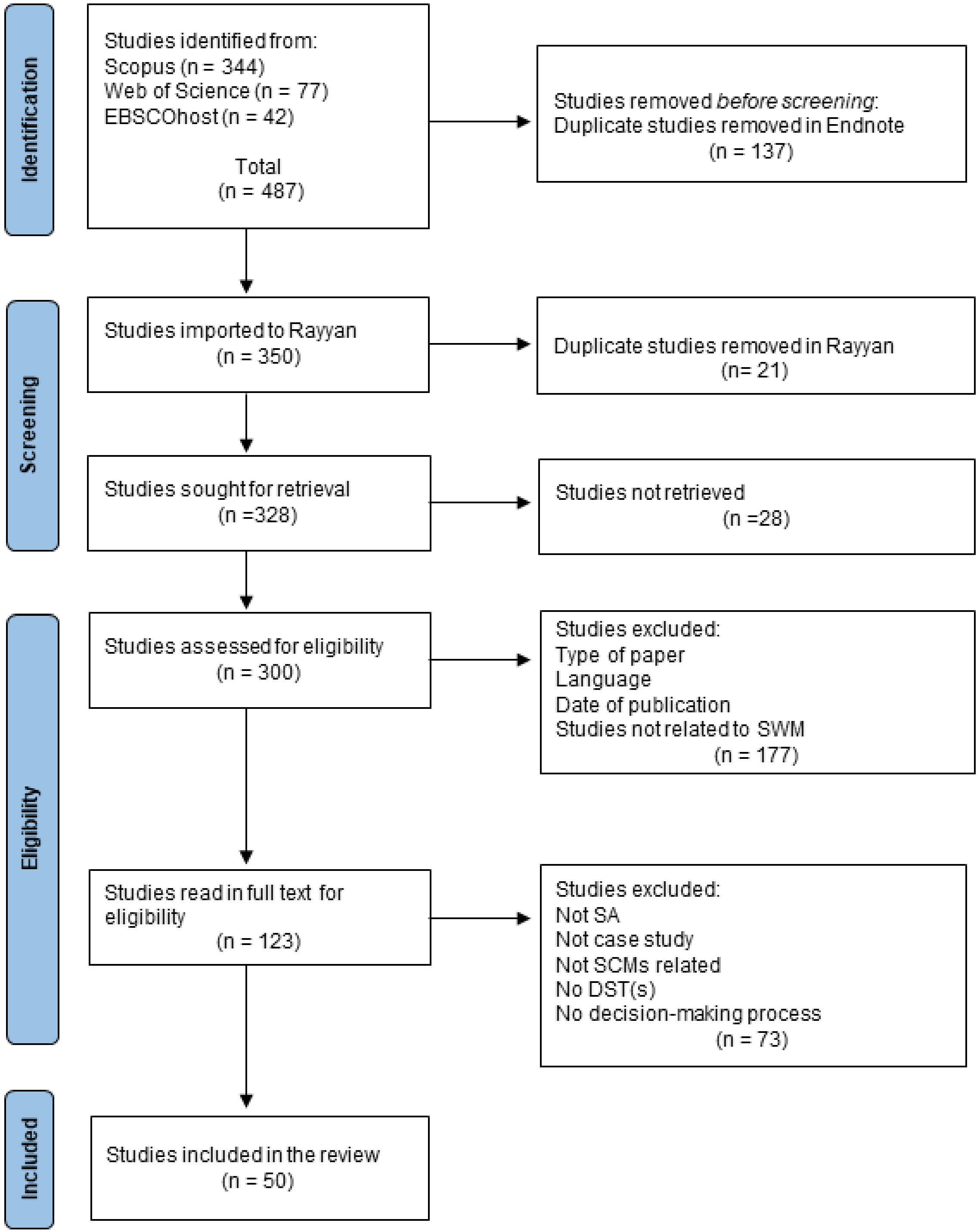
How do DSTs assist sustainable stormwater governance and management based on the policy arrangement model?

OBJECTIVES & METHOD

i. How are decision support tools used in sustainability assessment of stormwater management?

ii. What stormwater management themes are decision support tools applied for?

iii. How do existing decision support tools assist sustainable stormwater governance and management perspectives based on the policy arrangement model?



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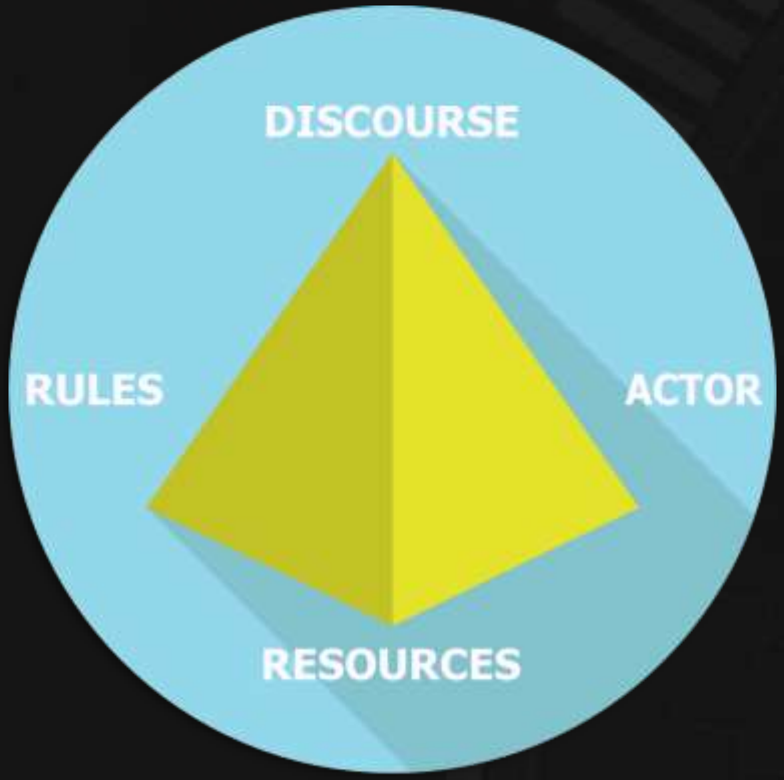
ANALYTICAL FRAMWORK

i. **Discourse:** represents the "pre-defined" problems and the intentions behind the SWM approach.

ii. **Rule(s) of the game**: refers to both legally and non-legally binding documents, reports, guidelines

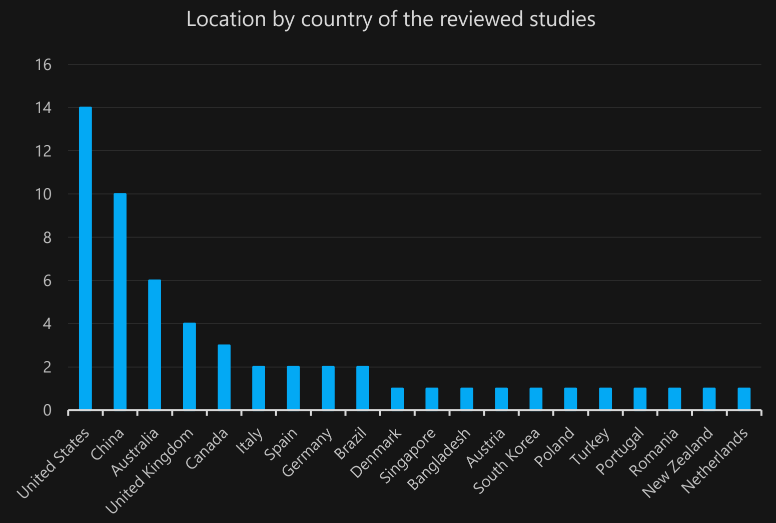
iii. **Actors:** stand for both stakeholders who are actively involved, and those who are indirectly affected.

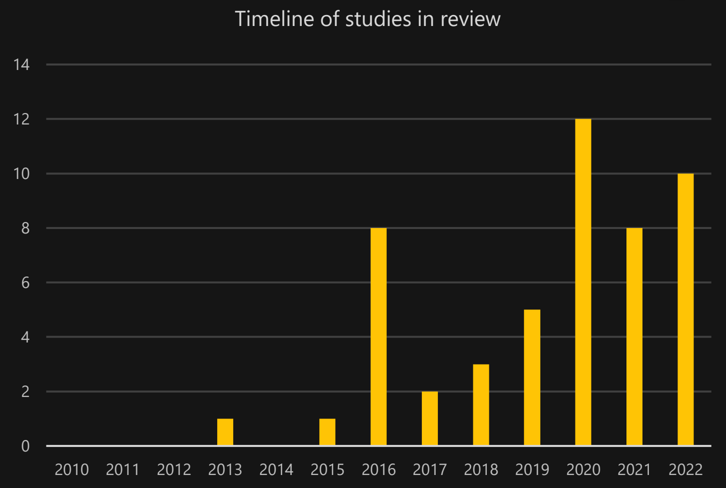
iv. **Resources:** denote knowledge, finance, data, time input, *etc*., influencing the selection and utilization of DSTs.



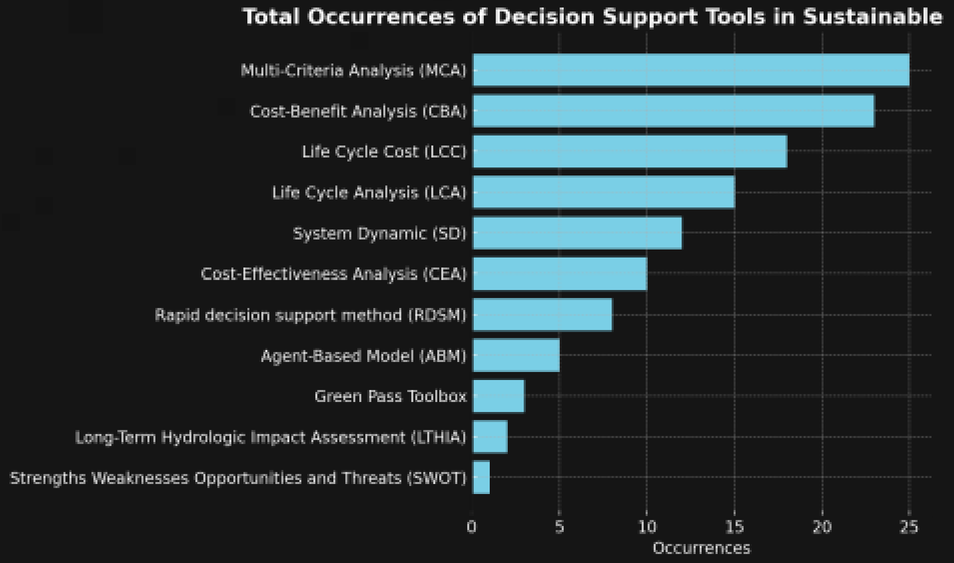
Policy Arrengement Model (Arts et al., 2006)

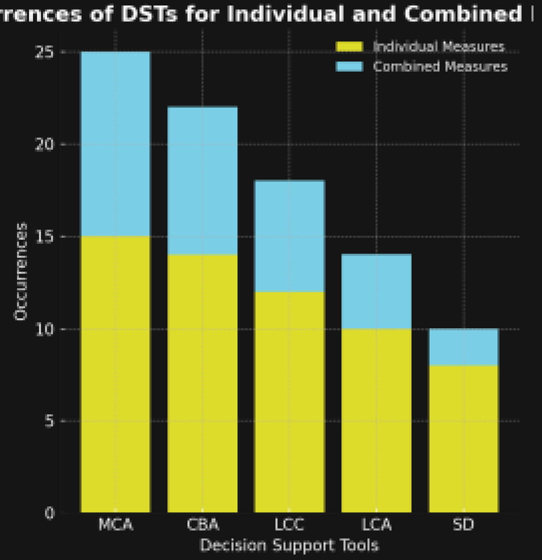
Result 1: Geographic, Timeline & Pillar





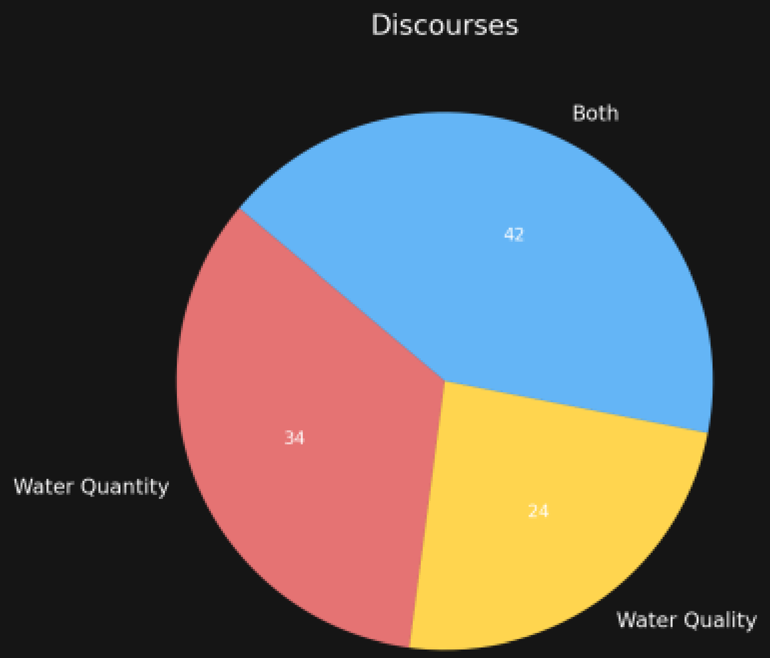
RESULT 2: DSTs





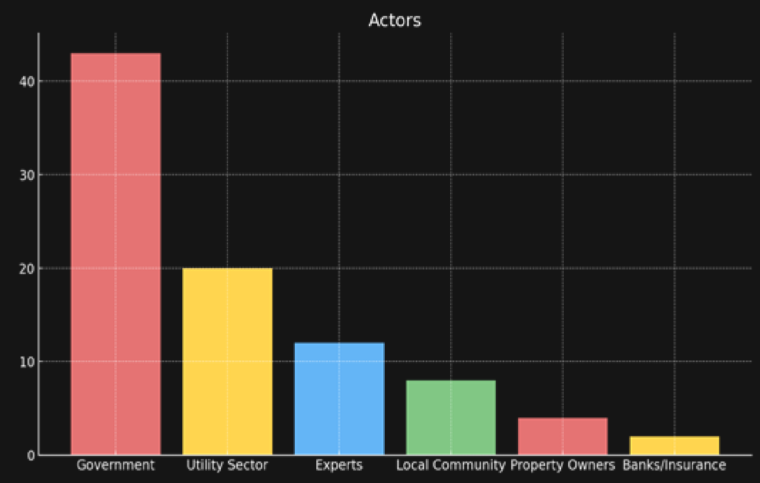
DST	Description	Techniques		Individual (I) or Combined (C)	Occurrences
Multi-Criteria Analysis (MCA)	MCA is a family of methods that enables the evaluation of alternatives based on multiple criteria. It utilizes various approaches and techniques to assess different SWM practices and stormwater control measures within the various frameworks, while also being able to engage stakeholders and decision-makers.	- Analytic hierarchy process - Fuzzy-based approach - Technique for order of preference by similarity to ideal solution - Preference ranking organization method for enrichment evaluations - Optimization approaches	- Shapley choquet aggregation - Delphi method - Scoring (Likert scale) - Parameter ESTimation - Multi-attribute value - Bayesian belief networks	I or C	26
Cost-Benefit Analysis (CBA)	CBA is a tool used to evaluate the costs and benefits associated with different SWM strategies. It is a valuable tool for decision-makers to determine the most cost-effective solution while considering multiple objectives, such as monetized environmental and social benefits. It can help to identify the best management practices that deliver the greatest benefits and maximize the return on investment.	- Benefits Estimation Tool (B £ST) - I-DST - Net present value - Average service life span - The economics of ecosystems and biodiversity - Benefit cost ratio	- System for urban stormwater treatment and analysis integration - Willingness to pay - Investment framework for economics of water sensitive cities	I or C	11
Life Cycle Cost (LCC)	LCC can evaluate the cost of stormwater control measures over its entire life cycle, including initial capital costs, maintenance costs, and end-of-life disposal costs. It can help decision-makers compare the cost-effectiveness of different SWM strategies and identify the most cost-effective option.	- Net present value - Benefit cost ratio - Internal rate of return		I or C	7
Life Cycle Analysis (LCA)	LCA can be used to assess the environmental impacts of a stormwater control measure over its entire life cycle. It can provide value to compare different design options and identify areas for improvement in terms of reducing the measure's environmental impact.	- International Organization for Standardization (ISO) protocols. - Cumulative energy demand - Carbon footprint - ReCiPe midpoint hierarchist		I	3
System Dynamic (SD)	SD is a modelling tool used to understand the behavior of complex systems over time, such as combined stormwater control measures. It supports evaluating long-term performance, predicting future impacts, and developing adaptive strategies that are resilient to changes.	- Casual loop diagram - Fuzzy cognitive mapping - Participatory modeling		C	3
Cost-Effectiveness Analysis (CEA)	CEA is a tool or sometimes a technique for LCC that is used to compare the costs of different strategies in SWM that achieve similar outcomes. It assists decision-makers to identify the most efficient and cost-effective solution, such as reducing stormwater runoff or improving water quality.	- Monte Carlo simulation - System for urban stormwater treatment and analysis integration - Benefit cost ratio - Cost effectiveness ratio		I or C	2
Rapid decision support method (RDSM)	RDSM is a structured and participatory decision-making approach that helps to identify and evaluate alternative solutions to complex problems promptly. It is based on the Ecosystem Services' variables.	- Ecosystem Services' variables		I	1
Agent-Based Model (ABM)	ABM is a tool that models the behavior of individual agents and their interactions in a complex system. It is commonly used to study complex social, economic, and ecological systems and to explore the impacts of different policies and interventions.	- UrbanBEATS & DynaMind		C	1
Green pass Toolbox	Greenpass Toolbox is a web-based platform that supports decision-making in the management of green infrastructure, such as urban parks, green roofs, and wetlands. It provides tools and data for planning, designing, and assessing the performance of green infrastructure projects.	- GIS with Simulation & Evaluation System		C	1
Long-Term Hydrologic Impact Assessment (L-THIA)	L-THIA is a model that estimates the long-term hydrologic impacts of land use changes on a watershed. It can be used to assess the impacts of urbanization, agricultural practices, and other land use changes on water quality and quantity.	- Modeling with curve number method		I	1
Strengths, Weaknesses, Opportunities, and Threats (SWOT)	SWOT is a framework for assessing the internal and external factors that affect the performance of an organization or project in strategic planning and management to identify potential risks and opportunities	- Analytic hierarchy process		I	1

Result 3.1: Discourse



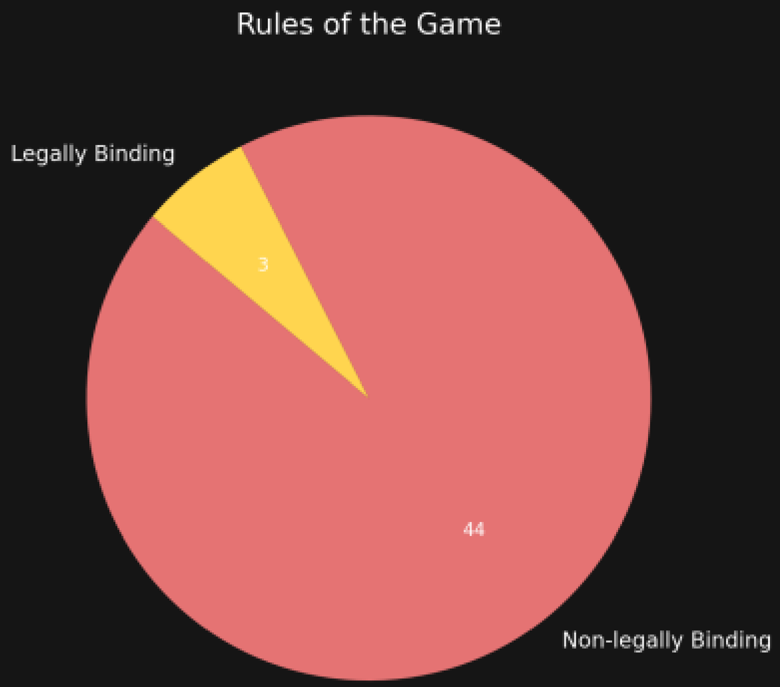
THEMES	OBJECTIVE	OCCURRENCES
Performance of Stormwater Control Measures	Functions & configuration; combination mode; spatial layout; spatial scale; and spatial distribution	29
Benefits and Values	Direct or indirect benefits trade-off & synergies	21
SWM Strategies	Policies; regulations; and schemes/scenarios	11

Result 3.2: Actors



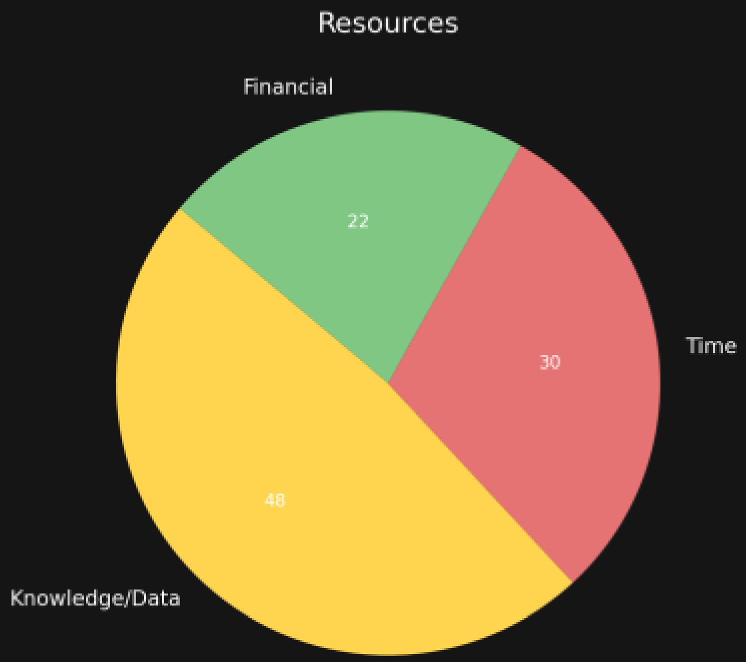
ACTOR ROLE	DESCRIPTION	WHO
Proponent	who undertake the assessment and develop, apply, or demonstrate the DSTs to propose resolutions either with (engaged) or without (distance) other actors	*Researcher* *Government*
Decision Agency	who have the power or are empowered by the proponents to make decisions and are directly involved in the decision-making process	*Government Authorities* *Utilities* *Property Owners* *Decision-makers*
End User	who may not have a direct role or stake in the decision-making process but are impacted by SWM outcomes	*Commerce* *Contractors* *Bank And Insurance* *Public/Citizens,* *Residences/Community*

Result 3.3: Rules



- Define SWM & decision problems
- Set motivations, rationales, objectives for SWM assessment
- Guide establishment of SWM requirements, alternatives, functions, benefits
- Determine indicator, criteria, input data
- Identify DSTs, conduct scenario analysis

Result 3.4: Resources



INTEGRATED DSTS	DETAILS AND RATIONALES
LCA & SD	Integrated LCA & SD in assessing and evaluating different nutrient treatment efficiencies under various spatial and temporal settings, this dynamic framework can be generalized to different environmental and system conditions to inform the future design and optimization of green infrastructures applications
MCA & LCC	LCC as auxiliary to many-objective optimization approaches*, allowed stormwater best management practices to be evaluated by stakeholders before the portfolio selection process.
	MCA for assessing alternative solutions on hydro benefits was incorporated with LCC, with regard to enhancing planning-level analyses by expanding information for decision-makers.
LCC & CBA	LCC and CBA as the integrated DST were utilized due to the quantitative and comparative purpose for the assessment of green infrastructure performance.
	Monetized climate impacts by LCC and community rainwater harvesting benefits with CBA to propose a community rainwater harvesting system as an alternative water supply solution for supporting policy decision-making.
LCA & LCC	Integrated LCA and LCC models were used to evaluate the cost and environmental impacts of permeable highway pavements.
MCA & CBA	MCA to compare grey and green infrastructure alternatives for the management of a combined sewer overflow, in which the criteria related to ESS were monetized with an adjusted value transfer (VT) method (B£ST software)**.
	Developed Modelling of the attractiveness of Green Infrastructure through a combined approach (MAGIGA) with MCA and CBA for assessing the value of green roofs and walls, so as to overcome the limitation of CBA.
MCA & SD	Synergized SD with MCA to compare different alternatives based on performance as revealed by the SD simulation and the judgment of decision makers.

How can future DST best include governance aspects?

- DST Capacity and input criteria
- Comprehensive and Holistic
- Consistencies and Integration
- Social Criteria Gap

Social value & benefits	Numbers of instances
• Environmental justice and green space accessibility	10
• Civic engagement (the public/local community)	9
• Education	6
• Green economy (new enterprising)	4
• Health & recreation	16
• Aesthetics	11
• Tourism	2

How can future DST best include long-term management?

- **Long term perspective**

  The capability of DSTs, with or without hydrological models, can facilitate long-term simulation & planning in SWM. The tools are well-equipped for assessments ranging from 10 to 50 years, with some even up to 100 years.

How can future DST best include long-term management?

- **Long term viability and monitoring**

  Successful long-term viability needs empirical data, having long term data such as from raingardens and bio-swales to be compiled into DSTs is essential for ensuring their functionality. We found that, real-world , particularly nature related monitoring and input data is under-researched.

How can future DST best include long-term management?

- **Long term effectiveness**

  This echoes what I mentioned in the previous slide about the comprehensiveness, there is a need is for holistic assessment, not just economic value and benefits, but also the social and other qualitative indicators to secure real-world long-term effectivenss

How can future DST best include long-term management?

- **Ex-post assessment**

Almost all studies in our study were ex-ante assessment that looked into the future pathway, there is a need to apply ex-post or retropestive assessment to provide more historical insight & data , this again, very relevant to nature related management.

CONCLUSION & KEY INSIGHT

Sense Making

Our study connects sustainability assessment, sustainable SWM, and governance & management through the role of DSTs.

Decision Making

There is significant potential for DSTs to serve as a facilitative role in supporting management practices and deliberative governance.

LIMITATIONS

Analytical Framework

Complex Actor Dynamics

Urban SWM Practice

RECOMMENDATIONS

- Exploring practical challenges in integrating **all sustainability assessment pillars** with **consistent criteria** into DSTs. This is crucial in **fostering open and informed** stormwater governance and management.

- Understanding **when**, **where**, and **how** to engage **who** with future DST, to secure ownership and relevance.

- Use of **retrospective (ex-post)** sustainability assessments are needed to provide more tangible knowledge and to support long-term management.

THANK YOU

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