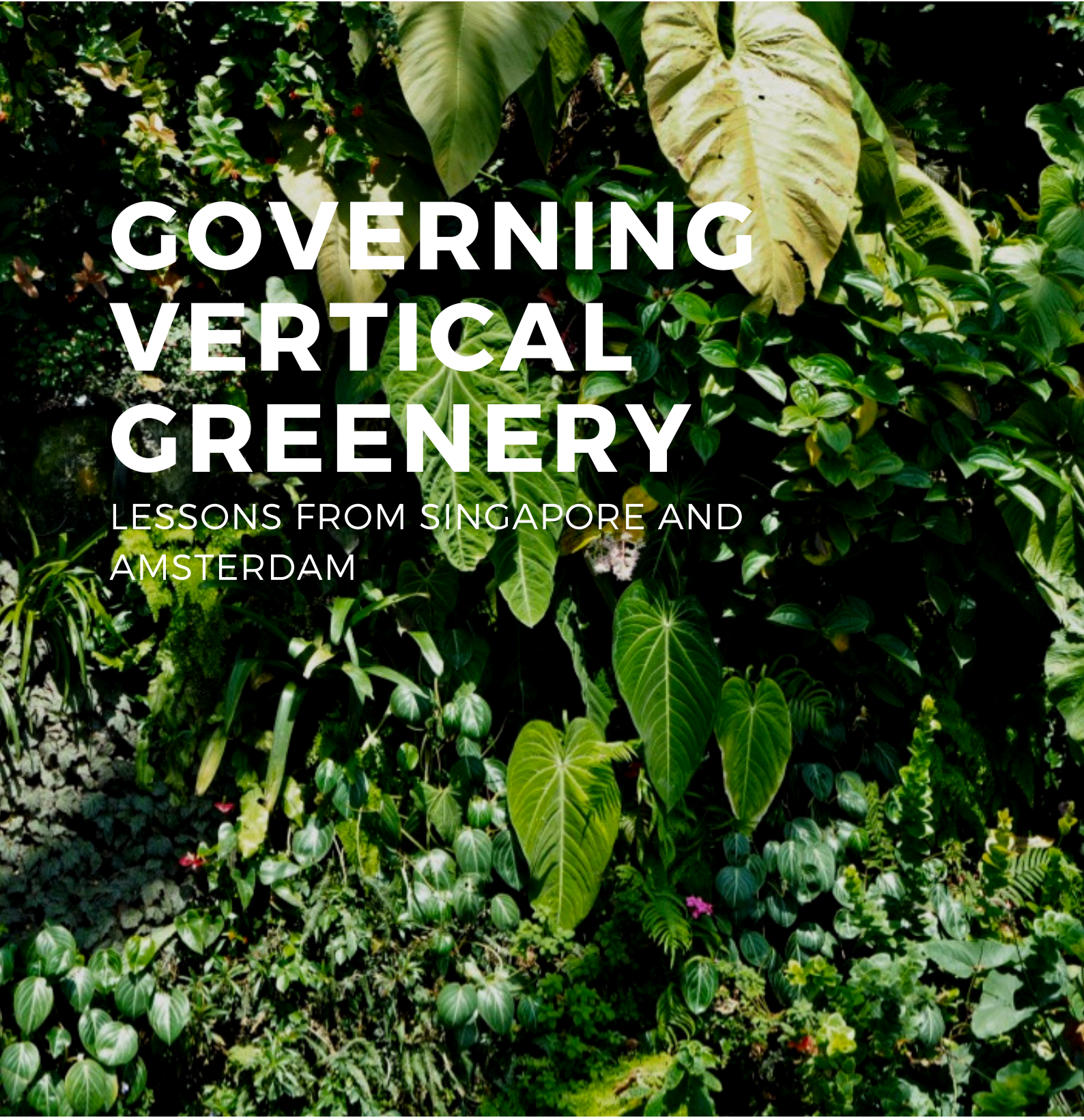

GOVERNING VERTICAL GREENERY

LESSONS FROM SINGAPORE AND AMSTERDAM

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Summary

Climate change affects the liveability of many cities around the world. The integration of greenery in the urban scape makes cities more resilient for climate change related issues and increases the well-being of citizens. However, urbanization pressures the limited space available for greenery. Vertical greenery, such as green facades or living wall systems, can successfully integrate vegetation into the built environment without composing the limited space available. Old systems and new technologies make it possible to apply vertical greenery in more ways than ever before. Despite these developments, in most places vertical greenery is an exception rather than a common practice.

This research aims to discover how vertical greenery development can be encouraged. The issues preventing development of vertical greenery, indicated by scientific literature, can be summarized in three main themes: uncertainty about scientific knowledge, complexity in the process of development, and inequality in the application of vertical greenery. Therefore, the research question is formulated as: *What governance arrangements can contribute to overcoming issues of uncertainty, complexity, and inequality in the development of vertical greenery?*

In a qualitative case study comparing Singapore and Amsterdam, features of vertical greenery governance arrangements are explored. Interviews with experts provide insights into the actors, tools, decisions, and context that shape the governance of this type of greenery. Choosing these cities, despite their differences, led to a comparison of two unique methods of vertical greenery application and adequate governance.

The results indicate that issues of uncertainty in vertical greenery development are mainly found in a lack of knowledge and diverging opinions by different stakeholders and necessitate guidance of the government. Issues of complexity, caused by the many stakeholders involved, can be addressed by both top-down and bottom-up governance arrangements resulting in different physical application of vertical greenery. Evaluating vertical greenery governance on issues of inequality, such as unequal distribution and quality, indicates that both top-down and bottom-up governance can help solve inequality issues, but both have limitations. Despite being separately discussed, issues and solutions within the themes of uncertainty, complexity, and inequality are interrelated. Overcoming issues of uncertainty has a central role in supporting vertical greenery development since knowledge and political support are necessary in both governing issues of complexity and of inequality.

Based on these results it is advised to gain more attention for vertical greenery by showing the feasibility of the systems and, in this way, gain social and political support. Besides this, strong efforts should be taken to develop a network of stakeholders which can collectively produce scientific and practical knowledge on vertical greenery. Lastly, citizens should be empowered to take part in shaping their city and establishing vertical greenery.

Preface

The natural and the urban world have grasped my attention for a long time. Both worlds have a stateliness that appears to be indomitable, expressed by mighty mountains, determined rivers and skyrocketing buildings. Both worlds are also marked by constantly evolving systems, in which small actions do have the ability to change big structures. The vastness of these ecosystems and the possibility to change them has inspired me and made me eager to bring my contribution to preserve and merge nature into the urban scape.

Therefore, this thesis 'governing vertical greenery: lessons from Singapore and Amsterdam' is my contribution to overcoming the endless dichotomy between city and nature. The thesis is written as a part of the completion of the master program Environmental Sciences, specifically focusing on policy, at the Wageningen University & Research and has been researched and written between January 2019 and July 2019.

I truly felt that this thesis brought everything together I had learned so far. During the process I grew as a researcher and as a person thanks to the many people that were available to talk with me, think with me and provided me with feedback. Therefore, I would like to thank all respondents without whose cooperation I would not have been able to do this research.

Additionally, I would like to thank my supervisor, Kris van Koppen for his guidance and positivity. He kept me motivated and on point. Also, I am grateful for the input and help of friends, family and especially Jacir in the whole process: your support has served me well. Lastly, I would like to express my gratitude for the Van Eesteren-Fluck & Van Lohuizen Foundation whom granted me their subsidy covering the travel costs to Singapore. Thank you for believing in me.

I hope you will enjoy reading.

Daan Verhorst

Amsterdam, August 1, 2019

List of Acronyms

BCA	Building and Construction Agency
BREAAM	Building Research Establishment Environmental Assessment Method
CLC	Centre for Liveable Cities
CUGE	Centre for Urban Greenery and Ecology
GnPR	Green Plot Ratio
HDB	Housing and Development Board
LEAF	Landscape Excellence Assessment Framework
LRA	Landscape Replacement Area
LWS	Living Wall System
MEWR	Ministry of Environment, Water and Resources
MND	Ministry of National Development
NGO	Non-governmental organization
NParks	National Parks Board Singapore
NUS	National University of Singapore
SEC	Singapore Environment Council
SGBC	Singapore Green Building Council
SGIS	Skyrise Greenery Incentive Scheme
SSB	Singapore Sustainable Blueprint
UHI	Urban Heat Island
URA	Urban Redevelopment Authority
GFA	Gross Floor Area
DIY	do it yourself

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1. Introduction

One of the seven wonders of the ancient world, the hanging gardens of Babylon, has inspired mankind throughout history. A 19th century interpretation depicts a vast brick structure with different terraces, upheld by pillars in the form of palms and Dade trees (Figure 1). The terraces are filled with vegetation; large trees such as cypresses, pines and a variety of palms rise in the sky, making the structure appear wild and tall. Shrubs, hanging from the various levels, cover the enormous structure in green with accents of red and orange flowers. Plants and grass cover the remaining terraces with flowers in purple, pink, and yellow. In the background, the huge constructions of the city are pictured: walls, pillars, fortresses, and houses, with the great tower of Babylon rising behind them all.

Figure 1: Nineteenth century interpretation of the hanging gardens of Babylon. Artist unknown. Source: http://www.plinia.net/wonders/gardens/hgpix1.html

However, this visual representation is more an expression of imagination than of facts. Since the hanging gardens of Babylon are inspirational, they have been extensively researched. Unfortunately, this only resulted in further questioning of its existence (Dalley, 1994).

1.1 Nature in the built environment: from urban parks to vertical greenery

Despite the lack of evidence of the garden's existence, the utopian vision of integrating nature into the built environment has been appealing for centuries. In the 1800s, this vision was first expressed by the establishment of parks in urban areas, as places where citizens could stroll, bike, picnic, row, and learn about nature based on the belief that it would benefit the urbanites' health (Cranz & Boland, 2004)

In the 20th century, these efforts continued with the garden city movement by Howard, aimed to bring nature into urban planning practices (Sharifi, 2016). The concept combined the benefits of urban and country life. Along the outskirts of the city, low density mixed neighbourhoods, surrounded by green belts and connected with strong infrastructures were to develop. Cities such as London or Amsterdam shaped areas built in the first half of the 20th century according to Howard's vision. However, after establishment, these areas faced different criticism, such as urban sprawl, unobstructed growth, and environmental degradation (Sharifi, 2016). Moreover, the green belts were often overlooked due to the high cost of land. The concept evolved throughout the 1900s, new movements like radiant city, new urbanism, and eco-urbanism left their marks on city development (Sharifi, 2016).

At the same time, shrubs were used to decorate buildings and offered a cheaper and more space efficient form of greenery than parks. In 19th-century Europe, traditional climbers and balcony

decoration were used to cover simple facades (Köhler, 2008). In mid-20th-century Germany, campaigns supporting green facades flourished (Köhler, 2008). However, in the 1980s, negative experiences and a fading enthusiasm for greenery became common, and the green facades slowly diminished in numbers.

Today, there has been renewed attention in greenery in building practices. Integrating greenery in buildings is mainly considered within the sustainability discourse for mitigating or adapting to climate change (Wolfram, van der Heijden, Juhola, & Patterson, 2019). Green roofs are especially popular, although their potential coverage area is far less than that of vertical structures (Köhler, 2008). New and old technologies, such as direct and indirect green facades and continues and modular livings walls, make it possible to integrate greenery onto structures in more ways than before (Manso & Castro-Gomes, 2015). Particularly in Singapore, which actively promotes and develops these techniques, this practice is widely applied, covering more than one million square meters of grey surface with green (National Parks Board, n.d.). Despite the wide application of vertical greenery in Singapore, in most urban areas around the world, the use of vertical greenery seems an exception rather than a common practice.

1.2 Nature to improve well-being

The rationale for bringing nature into the built environment is best described in the Biophilic thesis. This thesis, developed by psychological research, states that humans have a positive experience while being in unthreatening natural settings (R. S. Ulrich, 1993). The thesis also claims that humans have a negative experience in urban areas, which can be improved by the integration of natural elements. Many scientists have proven the benefits of nature on mental and physical health (Hartig, Mitchell, de Vries, & Frumkin, 2014; R. Ulrich, 1984). Natural environments are not only perceived as less stressful surroundings but are also found to be mentally restorative (Berto, 2014).

Other researchers describe the benefits of nature in terms of ecosystem services. These services provide support, provisions, regulations, and culture (e.g., food supply, climate regulation, pollination; Millennium Ecosystem Assessment (Program), 2005). Moreover, nature provides inspiration for education and cognitive and spiritual activities. These services have a strong influence on constituents of human well-being, such as security, health, and positive social relationships as explained by the Millennium Ecosystem Assessment (2005). Thus, nature is clearly essential to human life.

Vertical green infrastructures provide their own benefits. Studies focused on the benefits of the systems (Pérez-Urrestarazu, Fernández-Cañero, Franco-Salas, & Egea, 2015), such as climate change mitigation and adaptation (Demuzere et al., 2014; S. M. Sheweka & Mohamed, 2012), local microclimate regulation (Tavares, Calmet, & Dupont, 2015), building insolation (Schettini et al., 2016), thermal comfort (Galagoda, Jayasinghe, Halwatura, & Rupasinghe, 2018), sound absorption (Davis, Tenpierik, Ramírez, & Pérez, 2017), water (Atelier GROENBLAUW, 2018), and air purification (Dahanayake & Chow, 2015). Moreover, vertical greenery will especially benefit human and non-

human health in cities (S. Sheweka & Magdy, 2011), as well as biodiversity (Weinmaster, 2009). These systems can thus create many benefits for a city.

1.3 Changing cities by establishing vertical greenery

Cities form important nodes for humanity, offering multiple perks. The density of cities makes housing, transport, and other practices more efficient than non-urban environments. Effectively hosting a high number of people in a small area in a world which, according to the United Nations (2015), will have a population exceeding 10 billion in 2100 is a solution this population problem. Furthermore, cities are a great place to live. High quantity and quality of specialized facilities, economic, and lifestyle diversity, innovation and knowledge exchange are close to each other (CS Festival, 2012). Urban dynamics are as unique as those in the countryside and attract and inspire many.

However, these urban areas create challenges to livability. The density causes issues in infrastructure, housing, food and water supply, and sewage treatment (Cunningham & Cunningham, 2017). In addition, these places also have a poignant division between the wealthy and the poor. In terms of nature, cities are often a source of major pollution with little chance for biodiversity and ecosystems. Therefore, the current form of cities is not always appealing. This situation can change by intelligently integrating more nature into the cityscape. As explained, vertical greenery provides many benefits to city life and human well-being without using much space. Given cities' large environmental footprint, vertical greenery can create benefits beyond the local scale.

1.4 Uncertainty, complexity, and inequality

Old traditions and new innovations make it possible to create vertical green infrastructures and merge nature into a city without compromising the scarce space. The techniques and knowledge exist and are deemed more relevant than ever in a time of increased environmental attention. However, vertical greenery is still scarce in many cities.

First, vertical green infrastructures have many negative connotations. The most complaints concern maintenance issues: frequent cuts, dead leaves, gutter obstruction, and difficulties with restoration (Köhler, 2008). Other critics complain about the decreasing daylight, damage to the façade, increased insects, and additional costs. Many of these problems appear to be rooted in a lack of technical and environmental knowledge, creating uncertainties in design and installation (N. H. Wong, Tan, Tan, Sia, & Wong, 2010). Vertical greenery requires a creative and innovative approach based on transdisciplinary, integrated design and technical knowledge of construction and plants and the environment (Rakhshandehroo, Mohd Yusof, Arabi, & Jahandarfard, 2016). Additionally, the effects of vertical greenery are uncertain because they hard to measure. General knowledge of vertical greenery is necessary for development, especially for designers, entrepreneurs, and developers who create the

demand (Magliocco, 2018). Thus, according to the literature, uncertainty within the development of vertical greenery creates implementation issues.

Second, vertical greenery development creates many complex problems. Governments cannot develop and establish all vertical greenery themselves because urban land is a mosaic of private, shared, and public property (Scott & Storper, 2015), nor do they have the resources. Moreover, many stakeholders, such as citizens, developers, and architects, are involved in the development of vertical greenery, and all act in networks on various levels and scales, sometimes needing guidance (van den Biesen, 2018). Thus, many issues of complexity arise.

Third, vertical greenery is, is as all urban greenery, less accessible and lower quality for the socially deprived (Hoffimann, Barros, & Ribeiro, 2017; Wüstemann, Kalisch, & Kolbe, 2017). Creation of green facades requires financial capital, knowledge, and decision authority on property, which are often not possessed by the urban poor. Financial inventive schemes for developing vertical greenery can provide support, but, for many, greenery is still out of range. Also, lack of citizens participation in decision-making on vertical greenery is a sign of inequality (Han, 2017).

Although vertical greenery can result in a better quality of life in the city, multiple issues form a barrier for further implementation of vertical greenery. These issues concern uncertainty, complexity, and inequality.

1.5 Finding ways to bring greenery skywards: research questions

This study investigates the issues of uncertainty, complexity, and inequality in vertical greenery development and explores approaches to deal with these issues. This thesis aims to identify promising features that can help promote vertical greenery development. Based on this aim, the following sub-questions were defined:

- Which uncertainty issues are present in the development of vertical greenery, and how are governance arrangements addressing these issues?
- Which complexity issues are present in the development of vertical greenery, and how are governance arrangements addressing these issues?
- Which inequality issues are present in the development of vertical greenery, and how are governance arrangements addressing these issues?
- What is the relationship between the issues of uncertainty, complexity, inequality, and the governance arrangements addressing them, and how does this relationship obstruct or support the development of vertical greenery?

Based on the results, determining methods to improve the current vertical green infrastructure governance is possible. Therefore, the main question of this research is formulated as follows: What governance arrangements can contribute to overcoming issues of uncertainty, complexity, and inequality in the development of vertical greenery?

2. Conceptual framework: uncertainty, complexity, and inequality

To provide a better understanding of the concepts of uncertainty, complexity, and inequality, this chapter discusses these main concepts and provides a framework for analysis. Section 2.1 explores issues of uncertainty and possible ways to overcome uncertainty. Section 2.2 elaborates on issues of complexity and the modes of governance that can structure this complexity. Section 2.3 delves into research on issues of inequality in the provision of urban greenery and the potential manners to improve this problem.

2.1 Understanding, overcoming, or surpassing uncertainty

2.1.1 Understanding issues of uncertainty

Uncertainty is a central feature in many modern-day environmental problems. The ground-breaking capabilities and scale of many of these problems, and the lack of linearity in cause and effect leads to increased complexity (Fisher, 2001; Renn, Klinke, & van Asselt, 2011). In this situation, a knowledge gap can appear causing uncertainty, especially since actors identifying and dealing with these issues operate beyond the traditional disciplines.

Responses to uncertainty caused by a lack of knowledge are found in expertise and counter-expertise, both of which try to find the objective truth (Koppenjan & Klijn, 2004). In many cases, closer analysis of the content, causes, and effects leads to less certainty instead of more since acknowledged presumptions might be proven less significant. Expertise and counter-expertise therefore enrich the debate but also result in "fact shopping," creating more confusion. Thus, these responses to uncertainty in a lack of knowledge do not always lead to reduced uncertainty; instead, they can generate more uncertainty.

A lack of knowledge is not the only cause of uncertainty. Koppenjan and Klijn (2004) identified two other types of uncertainty: (1) uncertainty or conflict about the available knowledge, for instance as a result of expertise and counter-expertise and (2) uncertainty or conflict about the measurement instruments, degree of seriousness of the problem, and the proposed solution to the problem. This classification results in four types of problems (Table 1).

Table 1. Four types of problems in relation to uncertainty (Koppenjan & Klijn, 2004).

	Certainty on (scientific) knowledge	
	Large	Little
(Societal) agreement on problem formulation		
Large	Technical problems	Untamed technical problems
Little	Political problems	Wicked problems

For vertical greenery, a general consensus exists for the benefits of the resilience and well-being of urban life. Although urban greenery benefits are clear, the exact impact of vertical greenery on the city's resilience or well-being over time and scale is unclear (Kabish, Stadler, Korn, & Bonn, 2017). Moreover, there is a lack of knowledge of technical features, maintenance, and return on investment (van den Biesen, 2018; N. H. Wong et al., 2010).

In Singapore, governmental organizations appear to support vertical greenery (National Parks Board, 2017), creating political support. In Amsterdam, this support is less (or not) present. Some actors are aware of vertical greenery's positive effects (Atelier GROENBLAUW, 2018), but these effects are not widely communicated or supported. Thus, the lack of vertical greenery implementation is a technical, political and, to a lesser extent, untamed technical problem, depending on the city.

2.1.2 Overcoming issues of uncertainty

Dealing with untamed, political, or wicked problems requires a difficult approach than dealing with technical problems. Koppenjan and Klijn (2004) explain that overcoming the ambiguity of political and untamed technical problems can be achieved by producing meaning together with stakeholders in a collective process. An important factor here is that actors need to acknowledge the different frames held by other actors and need to be open to negotiate it. This step will not necessarily reduce the uncertainty but may change the requirements of knowledge. In an ideal situation, 'this would lead to a situation of mutual inter-subjective interpretations of preliminary, tentative research findings' (Koppenjan & Klijn, 2004, p. 37).

Table 2. Lack of knowledge and ambiguity as sources of uncertainty (Koppenjan & Klijn, 2004).

	Substantive uncertainty	
	Lack of knowledge	*Ambiguity*
Nature of uncertainty	Lack of information and knowledge about causal relations in a problem situation	Presence of diverging frames from where problems and solutions are judged
Adequate response	Information gathering, use of experts, conducting research	Joint production of meaning

2.1.3 Surpassing uncertainty

Uncertainty can be a problem for further development of vertical green infrastructures but does not necessarily have to be. Only when the rationales for development of vertical greenery are focused around the knowledge on the benefits it can obstruct further development. Other reasons for vertical greenery, such as aesthetics or pursuing an outstanding design, can also eliminate uncertainty as a problem. The reason vertical greenery is developed can differ per city and per actor.

Vermeulen (2002) explains the many forms of goals and target formulation. Formulation of goals can be done by the government, creating a uniform goal for the whole society, or by non-state actors, formulating goals and targets themselves. A more mixed form of target formulation is seen in situations where state and non-state actors are involved, for instance in public-private partnerships. The state can try to make their goals the company's goals through a process of internalization and influence the organization to pursue specific goals.

Examining uncertainty and incentives for vertical greenery may help approaches contribute to overcoming this problem. For instance, some authors argue that Singapore's government does not pursue vertical greenery because of the environmental benefits of vertical greenery because the state does not necessarily embody the international 'sustainable' visions, such as biological diversity and climate change (Han, 2017). Rather, the government is concerned with the economic benefits of citizens comfort and foreign capital, making Singapore less vulnerable to the issue of uncertainty. This is in contradiction with the way it is promoted by governmental organizations, which focus is on the environmental benefits (National Parks Board, 2017). In Amsterdam, the organizations concerned with vertical greenery seem driven by the environmental benefits (Atelier GROENBLAUW, 2018), which makes them vulnerable to uncertainty on the benefits of vertical greenery.

2.2 Governance arrangements dealing with complexity

2.2.1 Complexity and governance in urban environmentalism

Many developed or industrialized societies are increasingly dealing with complex and unstructured issues (Loorbach, 2010). He explains that three different aspect have become increasingly complex: society itself, the problems that society faces, and how society deals with these problems (governance). The complexity is caused by differences in social spheres, disjointed levels of opperation, and the involvement of multiple actors with distinctive mindsets and attitudes (Loorbach, 2010). Urban environmentalism and urban environmental management are also dealing with this increased complexity and requires a non-traditional approach (Loorbach, 2010).

Governance refers to a theoretical view of the relationship between the state, market, and civil society in dealing with public issues (Mees, Driessen, Runhaar, & Stamatelos, 2013). Governance is seen as a better approach than the traditional government in dealing with the complexity of current environmental challenges: from a state where the government was the main governing actor to a state of governance where, according to Rhodes, governing is accomplished 'with and through networks' (2007, p. 1246). Since it lacks a strict framework, governance is flexible and adjusts to a variety of problems (Renn et al., 2011). In addition, governance makes it possible to involve different actors, disciplines, and perspectives and operates at different levels and scales (Mees et al., 2013) necessary for vertical greenery development. Moreover, policy networks can raise efficiency and public support given the non-state actors involved. However, governing through policy networks has downsides. Some

networks can suffer from a democratic deficit, reducing the power of normal citizens (Mees et al., 2013). In addition, governance networks can also increase complexity and result in a long, inefficient policy process.

2.2.2 Identifying modes of environmental governance

There are various ways to classify environmental governance arrangements. This section classifies the modes and features by using the frameworks of Treib et al. (2007), Driessen et al. (2012), and Mees et al. (2013) (Table 3). These frameworks distinguish four modes of governance: (de)centralized governance, public-private governance, interactive governance, and self-governance. The principal designs of this typology are the roles and relationships between the state, market, and civil society as defined by Warren (2001). The four modes of governance are divided into three categories of roles and relationships between the state, market, and civil society (Driessen et al., 2012). These modes of governance are ideal for analysis; however, reality consists of more complex situations where a combination of modes can exist.

2.2.3 Features of environmental governance

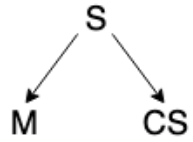
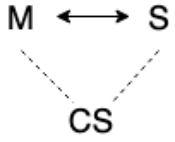
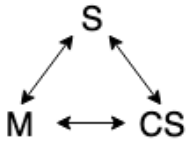
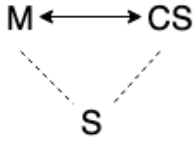
Given the study's aims and time and scale limitations, this study only distinguishes between three features: initiating actors (who), mechanisms of social interaction (how), and instruments (with what).

The initiating actor begins an action to produce a vision. As O'Toole and Montjoy (1984) explain, implementing policies often requires cooperation. Achieving a goal in society demands efforts such as the ability to coordinate, monitor, and deal with complex problems. Therefore, in many cases, the government is the initiating actor. If the government is not the initiating actor, strong coordination efforts are unlikely unless the action is in line with the involved actors' goals or worldviews.

The different actors use different mechanisms of social interaction to govern their goals and targets. These mechanisms may be shaped by authority, common interests, or negotiation and exchange (O'Toole & Montjoy, 1984). The bottom-up approach is accomplished by non-state actors, such as corporations or interest groups, aiming to influence, in this case, vertical greenery (Bovens, 't Hart, & van Twist, 2012). Bottom-up governance is thus shaped by market parties and civil society propagating values, solving problems, and seizing opportunities without or with help from the state.

Policy instruments are essential in the field on environmental policy. According to Glasbergen (1992), the government's tool contains the following policy instruments. First, prohibition, for instance, in the form of fines, can force the effected party to reduce or stop its harmful practices. Second is a subsidy to promote a certain technology or behaviour. Third, spatial regulations regulate the land use in the area. The fourth instrument is taxing environmental infraction above a certain level, creating a disincentive. Fifth is using information campaigning, which explains negative environmental characteristics and possible solutions. Sixth is an agreement between the government and private parties to achieve a standard.

Table 3. Features and modes of governance. Based on Driessen et al. (2012).

	(De)centralized governance	**Public-private governance**	**Interactive governance**	**Self-governance**
				
Initiating actors	Governmental agencies	Central government agencies; private sector is also granted a preconditioned role	Multiple actors; government, private sector, and civil society	Private sector and/or civil society
Mechanisms of social interaction	Top-down; command and control	Private actors autonomously decide collaborations	Interactive: social learning, deliberations, and negotiations	Bottom up: social learning, deliberations, and negotiations
Instruments	Legislation, permits, norms, and standards	Incentive based instruments, such as taxes and grants; performance contracts	Negotiated agreements, trading mechanisms, covenants, entitlements	Voluntary instruments; private contracts; entitlements; labelling and reporting

The six instruments can be divided into four instrument models used by governments (Glasbergen, 1992): the legal control model, the economic control model, the communication model, and the spatial control model. All approaches have their advantages and disadvantages and differ in effectiveness. Glasbergen (1992) explains that none of these instruments is the most effective in all situations. Effectiveness depends on the aspect the model deals with as well as on the circumstances under which the model is used or applied. He states that when the circumstances for all instruments are equal, physical regulation is the most effective tool. For complex circumstances and a limited capability of the application in the short term, the Norms-Taxation Stimulation (NTS) approach is the most promising. This approach tries to overcome individual limitations by combining them. The application of norms focusses on a set of regulations or prohibition that are, or will be, coming into effect. Then, taxation should be implemented as a stimulus for the development of the new technology or practices

to comply with current or future regulations. Glasbergen explains that in complex situations this approach can be the most promising when combined with information provision.

Market actors and civil society also use policy instruments. Voluntary instruments are 'a commitment from regulation agents to improve their environmental performance beyond the actual result obtained thanks to regulation and the "business as usual" scenario' (Mzoughi & Grolleau, 2003, p. 13). These instruments can be unilateral initiatives, bilateral agreements (also public-private), or public voluntary program membership.

Understanding the governance arrangement will lead to a better understanding of how the complexity surrounding vertical greenery is handled. Existing literature identifies Singapore's environmental governance as top-down and non-participatory, driven by the elite (Han, 2017). Han explains that this 'authoritarian environmentalism' is in line with the legacy of a development state. The worldwide example of Singapore as a garden city is more the result of deliberate planning efforts then an organic transition toward a green society. Han explains that involvement of NGOs was only desired when their vision was in line with economic goals, although this situation is slightly changing. This form of governance led the "garden in a city" project to more greenery in the city but not necessarily better greenery.

Amsterdam and other urban areas in Netherlands used to centralize their governing of environmental features, including indirect involvement of other actors through lobbying (Driessen et al., 2012). However, national and international targets were seldom met because the priority was urban development not environmental quality. Beginning in the mid-1990s, a new approach integrated both aspects through interactive areas specific to environmental planning involving many actors in civil society (Driessen et al., 2012). Moreover, the government started covenants with market and civil society stakeholders to improve environmental quality. The centralization was supplemented with more self- and interactive governing approaches. The latter is focused on the general environmental governance in urban areas. Specifically, exploring governance of vertical greenery will provide better insights into how the issues of complexity are managed.

2.2.4 Decision-making processes in governance

The mode and features of governance give a clear indication of who, how, with what, and why governance can take place, but this framework does not specify when and by whom decisions are made. Governance can be a complex process containing multiple decisions, without a clear beginning or end, working both on processes of problem formulation and solution implementation. This research uses the rounds model, observing decision-making as the end of a process of different decision-making rounds (Teisman, 2000). Here, problems and solutions are represented by the actors and, thus, can differ over time. As Teisman explains, 'to understand decision making, the researcher focuses on the variety of actors, objectives and solutions, their dynamics as well as the interaction between these elements' (2000, p. 943). Figure 2 illustrates the framework.

It is important to focus on what actors are present at what moment, combining the phase and stream model. The vertical classification examines the decisions in time but is not divided into time periods, functioning more as a certain decision period. Teisman (2000) identifies these periods as decision-making rounds. Horizontally, all actors are presented, and interactions concerning the decision-making rounds are identified, even when actors are not aware of others' decisions. For instance, one actor's decision could be the result of another actor's previous decision. This model explains decisions in a complex network of governance by putting them in context over time to provide a better understanding of who made decisions when and based on what.

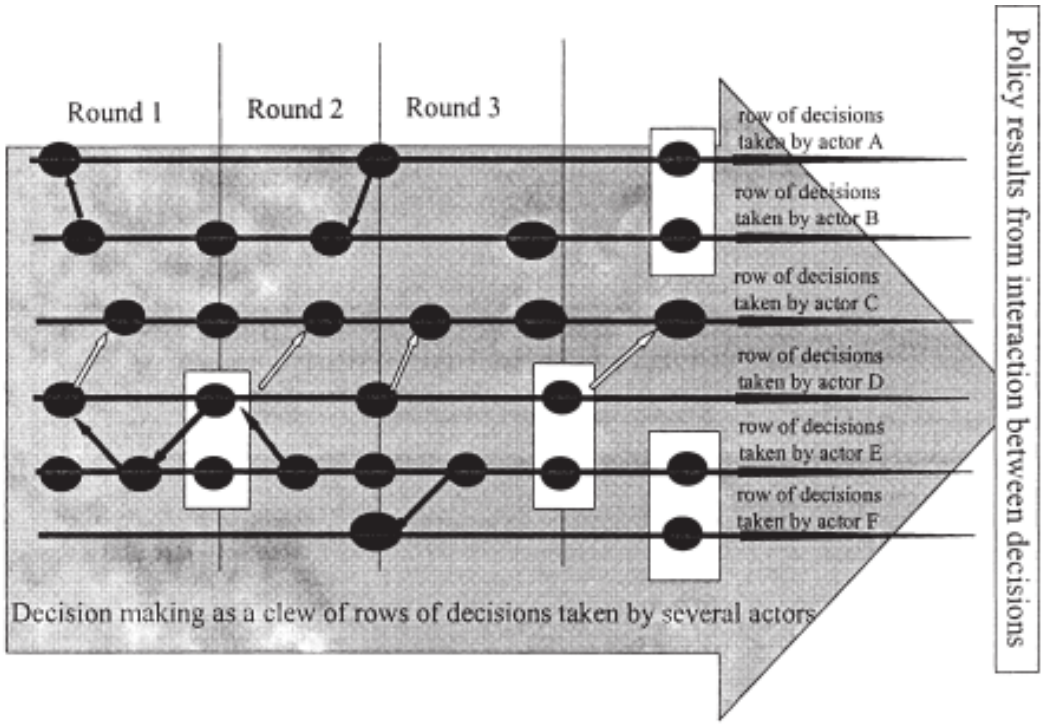


Figure 2. The concept of decision making used in the rounds model from Teisman (2000, p. 945). The grey arrow is decision making, the black dots depict decisions taken by the various actors, and the policy results stems from the interaction between decisions (building upon decisions of others is indicated by small black arrows), anticipation upon future decisions (with arrows) and covenanting results (white rectangles).

Singapore's decisions regarding vertical greenery can be traced to their development model after its independence in 1965, which led to a stable administrative state and a managed society pursuing economic growth (Han, 2017). Environmental protection was even incorporated in the development model before Singapore's independence, when founding father Lee Kuan Yew initiated tree-planting day in 1963. The following institutionalization of a garden city vision led to 55,000 new trees in the late 1970s and one of world's first Ministries of the Environment (Han, 2017). In the late 2000s, this institutionalization resulted in visions of skyrise greenery, demonstrating the long path to the development of vertical greenery. For Amsterdam, the path toward vertical greenery has been less documented and so was studied during this research.

2.3 Issues of inequality in accessibility

Thus far, this chapter has explored the basis of uncertainty in environmental problems and discussed ways to overcome this problem. Moreover, the chapter provided classifications for modes and features of environmental governance to deal with issues of complexity. In addition, a framework was provided to explore these aspects of governance and relate them decisions over time. This section discusses issues of inequality related to vertical green infrastructures.

Urban green infrastructures currently have a certain inequality, often in seen as unequal access to nature and unequal access to the benefits of nature. Research on inequality of urban green infrastructure has been mainly conducted in the US and other western countries. A study on the availability of green space in the US indicated that tree coverage in urban areas is unevenly distributed based on household income, the characteristics of the housing-market, and racial and ethnic factors (Heynen, Perkins, & Roy, 2006). Based on a study in Porto, Hoffimann, Barros, and Ribeiro (2017) found that, although most neighbourhoods have green space, socially deprived neighbourhoods are significantly further away from green space. Additionally, the quality of green space is lower in these areas.

The identified factors for unequal access to green infrastructures are different maintenance abilities, population densities, and housing densities (Heynen, Perkins, & Roy, 2006). Moreover, the increasing privatization of urban environmental management and decreasing public intervention in urban environments has increased these inequalities. Hoffimann, Barros, and Ribeiro (2017) explain that citizens from lower socio-economic status suffer from a lack of both individual and community resources.

The available scientific literature does not specify inequality in vertical greenery development. Based on the research explained in the introduction and contrary to conventional greenery, it can be noted that vertical greenery has, besides benefits for on city or neighbourhood level (e.g., climate change mitigation and adaptation) also benefits for individuals (e.g., insolation). Especially the latter requires qualitative greenery to be applied directly on the building. Therefore, this research will interpret accessibility in two forms: distribution and quality. Distribution considers equal spatial allocation of vertical greenery within a neighbourhood or city, while quality compares the available systems and forms of vertical green infrastructure development between different groups. Both factors influence the available benefits of vertical greenery.

In general, overcoming inequality in access and quality of urban green spaces can be achieved by saving and providing green spaces of high quality in the public sector, using quality standards and public participation (Hoffimann et al., 2017). Moreover, mechanisms enforcing equitable and collective processes of (vertical) greening in areas with limited (vertical) greening should be established (Heynen et al., 2006). Understanding and identifying equality in vertical greenery in both cities helped determine promising features to overcome this issue. Literature on accessibility of vertical greenery is limited, but more information was obtained during the research.

3. Method

3.1 Research design

To analyse the governance of vertical greenery, a qualitative research design was used. This design had explorative and comparative features. Qualitative research allows for in-depth examinations of specific issues because the reason for particular answers can be obtained. Furthermore, the respondents can think along with the research, and the focus can be adjusted during the research. These factors are convenient for a situation in which expectations are unclear. Explorative research features, such as a broad scope and open questions, were used to obtain a comprehensive understanding of governance of vertical greenery. The comparative features, studying the cases of Amsterdam and Singapore, provided insights into similarities in the problems and the solutions provided. Comparing these cases may allow other cities in the world to learn from Amsterdam's and Singapore's governance approaches. The reasons these cities were chosen are explained later in this chapter.

For the data collection, a combination of methods was used. First, desk research was executed. Literature studies and document analysis were performed in the early stages of the research to obtain an overview of the situation and gain knowledge to prepare for the interviews. Data was collected from secondary sources such as reports, publications, previous research, newspaper articles, and websites.

Second, semi-structured interviews were conducted to gain information from stakeholders and experts. How these actors were selected is explained in the next section. Semi-structured interviews are flexible and allow the interviewer to deviate from the predetermined course while still having a pre-developed interview guide covering the most important topic elements. This approach enables information comparisons across respondents. The interview guide was structured based on the theoretical framework (uncertainty, complexity, and inequality) and was constantly adjusted with newly gained information. The interviews occurred at the interviewee's preferred location in the Netherlands and Singapore and lasted approximately one hour. Permission to record the interview on an audiotape and use the data was requested. Afterward, the interview was summarized and sent to the participant for changes, additions, and approval.

Third, in both cases the physical application of vertical greenery was observed to understand the results of the specific governance arrangements and other influential factors. The observed sites were chosen based on information from the interviews or information gained in the document analyses. Additionally, sites for observation were recommended or found by exploring neighbourhoods in both cities.

3.2 Object and stakeholder selection

Vertical greenery has many forms and names (e.g., vertical greenery infrastructure, green walls, green facades) but is described as 'all systems which enable greening a vertical surface with a selection of plant species, including all the solutions with the purpose of growing plants on, up or within the wall of

a building' (Manso & Castro-Gomes, 2015, p. 864). When appropriate, a distinction was made based on categorization by Manso and Castro-Gomes (2015) between green facades and livings wall systems (LWS). Green facades are climbing or hanging plants on a vertical structure while living wall systems cover the vertical surface with different plants to create a uniform growth and allow for more plant species. This study only considers vertical greenery adjacent to or visible from the public sphere that provides benefits to the whole city.

In addition to defining the object, demarcating the selected stakeholders is necessary. Stakeholders were selected based on their interest in vertical greenery or influence on vertical greenery. Interest can be determined if the stakeholder will gain any (in)direct benefits from VGI development. Actors representing others, such as governments or non-governmental organizations (NGOs), do not necessarily benefit themselves; they represent the interest of others. These represented groups can be inside or outside the city territory, but vague concepts like future generations are not included in this research. However, stakeholders experiencing negative benefits were included given the important role they can play in the processes. Stakeholders with influence have a significant say in establishing vertical greenery and vertical greenery policy.

The selected actors were categorized using the triad network model explained by Thongplew, van Koppen, and Spaargaren (2016) and based on Mol (1995). The model describes three types of networks: economic, policy, and social. Economic networks consist of economic or industrial actors, which are governed by economic rules and resources and have a structural influence on economic processes. Here, interdependencies between firms and market power and resources play an important role. The policy network focuses on the interactions between governmental agencies and industrial organizations. The rules of the game, political-administrative dependencies, and organizational capacity determine this network. The social network consists of the interactions between industrial actors and civil society with a special focus on NGOs and social movements influencing vertical greenery development directly or via state and market actors. For a comprehensive overview of the involved stakeholders, including actors from all networks is essential.

The selection of stakeholders is based on two methods. First, stakeholders were mapped using interest in vertical greenery and influence on decision making for vertical greenery and were categorized by the tree network models, based on information gained from document and online source analysis. This overview was used to select stakeholders for interviews but was open to change as more became knowledge available. Therefore, the second method of stakeholder selection was snowball sampling (Hage, Leroy, & Petersen, 2010). The approached actors were asked to identify key stakeholders. Figure 3 presents the first version of the stakeholder maps for Singapore and Amsterdam.

Identifying actors with interest and influence on vertical greenery development within the three networks helped develop a comprehensive overview of all stakeholders involved in the development of vertical greenery while structuring and identifying the key players. The distinction between the different

networks is useful when comparing the stakeholders that govern with theories and literature from the conceptual framework. An overview of the respondents is provided in the list of interviews.

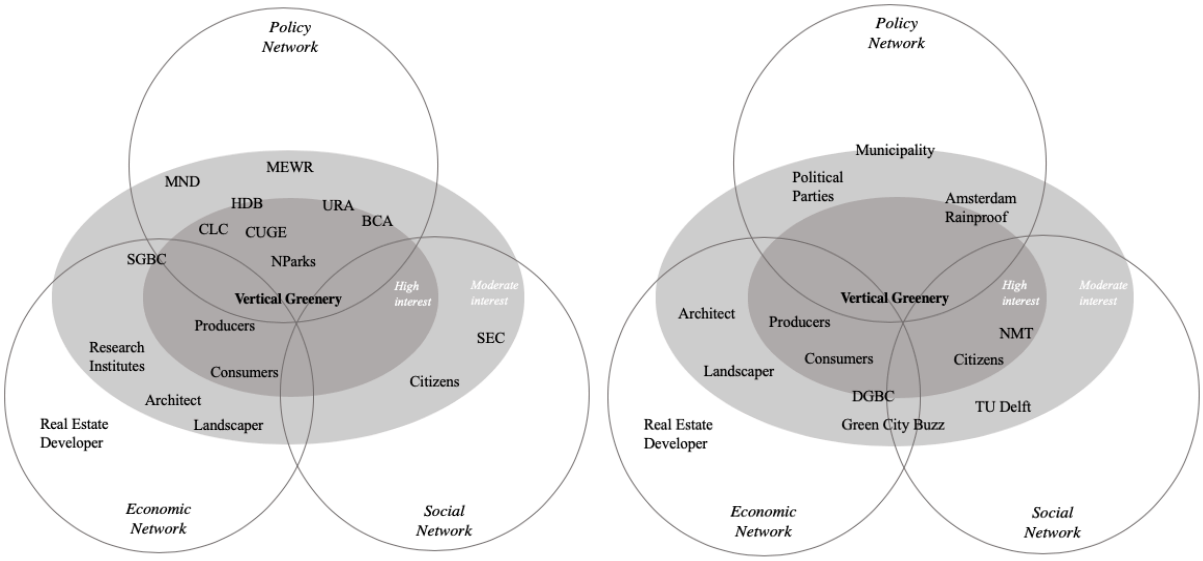


Figure 3: Stakeholder map of vertical greenery in Singapore (left) and Amsterdam (right). Based on Thongplew, van Koppen, and Spaargaren (2016).

3.3 Singapore and Amsterdam

This research was conducted using two case studies. Both cases are cities and were analysed on their environmental governance of vertical greenery. One of these cases, Singapore, is a worldwide example of widely applied vertical green infrastructures. The other city, Amsterdam, hosts a few examples of vertical green infrastructures.

Both cities have many different features, which makes comparison difficult. Environmentally, both cities have a totally different geographical context and different climates. These differences influence the usage of plants and definitely contribute to the differences in establishment of vertical greenery. Although the political systems are both based on democratic values, they consist of difference practices and institutional settings. Additionally, Singapore is a city-state, so the difference between local and national government is small, while Amsterdam is part of the Netherlands, creating a larger gap between the local and the national. In economic terms, the countries are both some of the richest of the world because of trade and favourable tax conditions. The gross domestic product (GDP) per capita in Singapore was slightly higher than in the Netherlands but differs when only Amsterdam is included (The World Bank, 2017). However, the social and cultural differences between the cities are significant. Singapore's largest population groups consist of Chinese, Malay, and Indian, all of whom have their own cultures and practice their own religions. These cultures mixed with western influences create a unique melting pot. Amsterdam hosts 180 nationalities, but almost half of the population is Dutch. Therefore, the dominating western-European culture is mixed with a variety of others.

Despite the many differences, comparing these situations using unique context, dynamics, and actors will prevent incorrect one-size-fits-all solutions while still allowing for generalizability. This practice results in an overview of a variety of features beneficial for vertical greenery governance from which multiple cities around the world can benefit.

3.4 Research progress

For the practical realization of the research, desk research was performed first. This research provided knowledge of vertical greenery, the instruments used, and the specific actors involved. It was sometimes necessary to complete extra desk research after an interview to review policies or documents to which the interviewee referred.

For the interviews, stakeholders were contacted a month to two weeks prior to the proposed date. In Singapore, many potential interviewees where unavailable or never replied to emails and calls. Snowball sampling with a request for contact with the specific actor was useful. This way more stakeholders willing to participate were found. In Amsterdam, approaching stakeholders was easier, and these individuals were more willing to participate. The semi-structured interviews lasted between 50 minutes and 90 minutes. Respondents in Singapore had more uniform answers and information saturation appeared faster. After adjusting the questions and directing them to different actors, I was able to gain more and new information. For respondents in both cities, ambiguous information was sometimes provided and is noted in the results.

After the interviews, the summarized recordings were sent to the respondents for approval and possible adjustments. In the Netherlands, this process was quick, and respondents mostly just accepted the summaries; in Singapore, the process required more time for reminders and adjustments. For the adjustment, information was sometimes changed to more politically correct statements. Given the possible consequences attached to speaking out freely in Singapore, obtaining honest or critical answers was challenging. Therefore, some answers might be socially desirable. However, by staying critical, giving the option for anonymization and choosing words carefully, I was able to partially overcome this problem. In addition, in Singapore, finding respondents from the social network was difficult. According to Wong (2012), this problem might be caused by the limited initiatives from civil society.

3.5 Analysis

To analyse the results, the interview summaries were coded into different categories. Based on the conceptual framework, the categories were divided into three themes: (1) uncertainty and knowledge of vertical greenery, (2) challenges and solutions during the process of vertical greenery development, and (3) inequality in the provision of vertical greenery. Within these themes, content was divided into recurring themes. By focusing on the content of all interviews, the research questions could be answered.

4. Empirical results from Singapore

This chapter presents an overview of the interview results from Singapore. An overview of the vertical greenery governance is briefly discussed, followed by the results on the themes of uncertainty, complexity, and inequality.

4.1 Singapore: governing the city in a garden

This section introduces Singapore and its vertical greenery governing. Section 4.1.1 summarizes some key features of the island-state, which influence the possibilities of and governance for vertical greenery. In Section 4.1.2, the government's approach to vertical greenery is placed in a historical perspective, to provide a better understanding how the practice originated. Section 4.1.3 discusses the policy network actors influence on vertical greenery and their specific policy instruments. In Section 4.1.4, the stakeholders and tools in the economic and social network are introduced. This foundation will help clarify the results in the rest of the chapter.

4.1.1 Understanding Singapore

The environment of Singapore is as a small, densely built island with a tropical climate. Given the climate, the island is home to a variety of plant species, despite the high density of buildings. The existence of tropical flora has been essential for the development of vertical greenery in Singapore. There are many native species, such as epiphytes as seen in Figure 4, that extract nutrients from air and water, needing little soil (Cheng, interview). These species are increasing and expanding the possibilities for integrating greenery into the built environment.

Figure 4: A small example of a vertical greenery system using epiphytes located in gardens by the Bay. Source: own work.

Singapore has a unique governance approach. Given the small land area and lack of natural resources, it is surprising that the state is now thriving. When gaining independence, Singapore was a 'fledging nation troubled by high unemployment, urban slums, poor infrastructure, lack of sanitation, and an unskilled labour force' (Civil Service College, Singapore & Centre for Liveable Cities, Singapore, 2014, p. 3). After gaining independence, Singapore's pioneers began a governance system and development approach to overcome many of these problems. Over the years, the Centre for Liveable Cities (CLC) has distilled the planning principles and the urban governance approach, as summarized in the Livability Framework. This

framework is summarized in Figure 5. The upper part of the triangle, in blue, provides an overview of the preferred outcomes, while the lower parts of the triangle, in purple, display the tools used. This framework indicates that, since the independence, the government is largely involved in the development of the country and acts as a leader of progression.

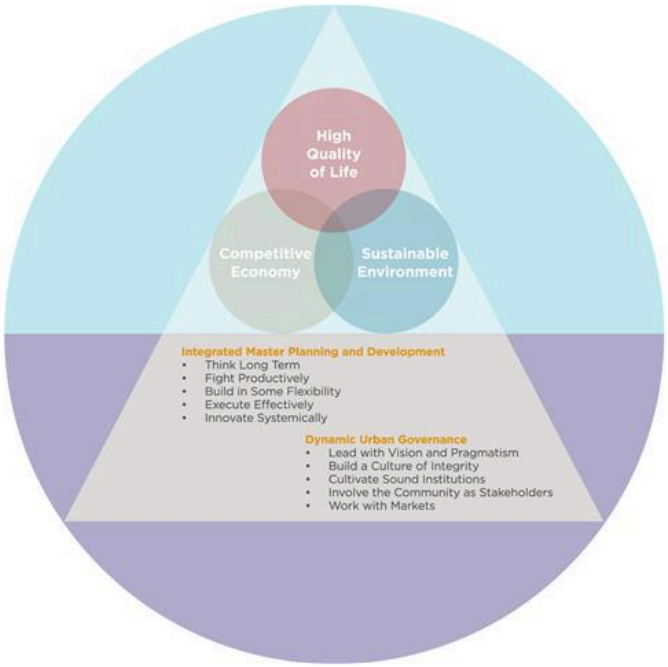


Figure 5: The CLC livability framework. Ten implicit principles are grounded in two key pillars of the CLC livability framework—Integrated Master Planning and Development; and Dynamic Urban Governance. Source: https://www.clc.gov.sg/research-publications/frame

4.1.2 From garden city to city in nature

Singapore's relationship with greenery is rooted in history. The first person to make greenery an institutionalized part of the country's identity was Lee Kuan Yew. Therefore, Yew is often referred to as Singapore's Chief Gardener (WOHA, interview). In 1967, Yew introduced the Garden City plan to transform Singapore in a green city with a clean environment and ensure a pleasant quality of life for the people. According to WOHA, he believed green spaces are the following:

> great for building community, have a calming effect on people and reintroduce biodiversity to the city, on top of great environmental benefits. Well maintained greenery also leaves a good and lasting impression, which boosts investor confidence and lifts the economy. (WOHA, interview)

As this statement illustrates, green spaces are not only a way to improve the environment but also a method of fostering economic development. To begin this plan, he started a tree planting campaign.

Since its beginning, the Garden City plan has been one of Singapore's development pillars. The Garden City Action Committee was established to guide the policies for making the island green and to

coordinate between the different government agencies (NParks, interview). Later helped by the Parks and Recreation Department, the Garden City Action Committee's focus was to create parks and open spaces and establish greenery around roads to connect these areas. Part of this focus was to add greenery to overhead bridges, flyovers, and some remaining walls using scrubs, creepers, and palms.

From garden city to city in a garden

In 1996, the National Parks Board (Nparks) continued to develop, maintain, and upgrade parks and greenery along the roadsides. However, the greenery was still too disjointed from everyday life. Beatly, author of more than 15 books on green cities, explains the reasoning behind Singapore's next step:

> Cities too often fall into the unfortunate dichotomy between urban buildings and nature. Nature is often understood to be found primarily in a park, a forest or a botanical garden—perhaps not far away, but over there somewhere. It requires a trip. (Civil Service College, Singapore & Centre for Liveable Cities, Singapore, 2014, p. 3)

Therefore, in 1998, the Garden City vision was revised to a City in a Garden vision. This change would ensure that greenery would be embedded in citizens' everyday lives, making it present around the places citizens live and work (Steed, 2015).

During the early 2000s, greenery became increasingly embedded in planning and design practices. The architecture company WOHA was one of the first to demonstrate the possibilities of vertical greenery in building design. In 2007, the Newton Suites, a condominium in central Singapore, was officially delivered and included a 100-meter-high green wall with a vegetation area that exceeded 130% of the surface of the original land plot (WOHA, interview). Since the building was developed by a commercial party with a normal budget, the feasibility of integrating greenery into the built environment was clearly demonstrated.

The Sustainable Singapore Blueprint

In 2002, the government launched the Singapore Green Plan 2012, as a result of the Johannesburg Summit on Sustainable Development, to prepare for new challenges on local and global scales (MEWR, 2006). This plan was a continuation of the first Singapore Green Plan in 1992. Plans to improve the countries sustainability efforts had, and still have, wide support: 'Singapore is a small but populated island, constrained by many factors. Being economically self-sufficient, and thus sustainable, is an important thing to strive for' (SGBC, interview).

The attention to sustainability and emerging domestic and global challenges led to the 2009 Sustainable Singapore Blueprint (SSB), created by the Inter-Ministerial Committee on Sustainable Development. This document outlines the targets and initiatives for better resource efficiency and improvement of the city's urban environment for the next 10 to 20 years ('Inter-Ministerial Committee

on Sustainable Development', n.d.). One of the targets set in the document, based on the example at the Newton Suites, was the achievement of 200 ha of skyrise greenery in 2030; this goal is still set in the renewed SSB (MEWR, MND, & CLC, 2015). Currently, there is much potential for Singapore to become a City in Nature (CLC, interview). However, how this vision should be interpreted is still unknown.

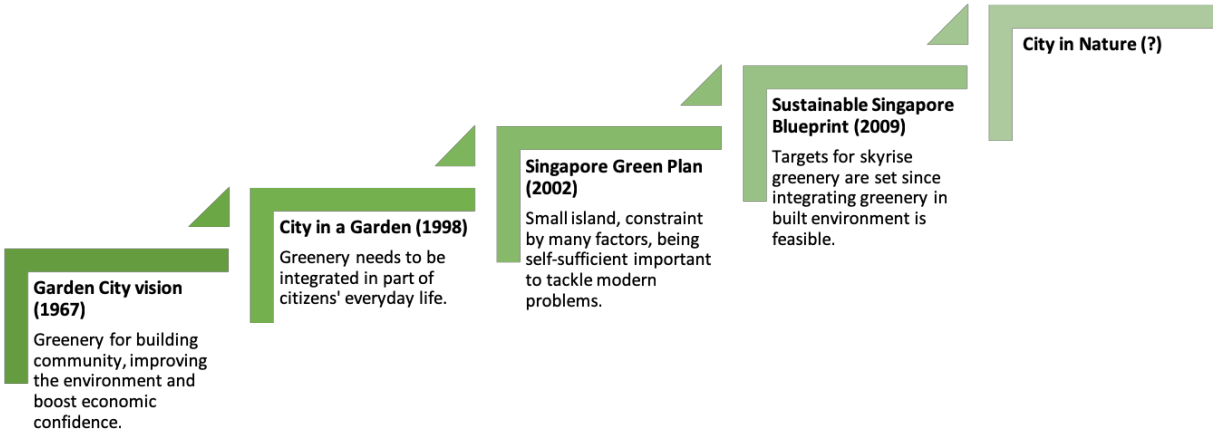


Figure 6: An historical overview of significant decisions by the government of Singapore relating to skyrise greenery. Source: this research.

The integration of vertical greenery (as part of skyrise greenery) into policy, summarized in Figure 6, can be traced to the core of the country's development and is a logical next step in the pursuit of the City in a Garden vision. Best practices, the islands restraints, and a dominant discourse of environmental problems in the global sphere are contributing factors for the institutionalization of skyrise greenery into policy.

4.1.3 Governing vertical greenery

Since the adoption of skyrise greenery targets into policy, the Ministry of National Development (MND) is responsible for ensuring the targets will be met by 2030. Therefore, the MND assigned multiple statutory bodies to the task of working on skyrise greenery. Vertical greenery policy is embedded in skyrise greenery policy, which includes green roofs and sky terraces.

This section introduces Singapore's policies and programs; an overview is provided in Figure 7. The governmental bodies and their policy instruments are discussed separately. First, the policy instruments of the Urban Redevelopment Authority (URA) are presented. Second, the instruments of the Building and Construction Agency (BCA) and, third, the instruments of the National Parks Board (NParks) are reviewed. Last, the policy instruments of the Housing and Development Board (HDB) are provided.

The Urban Redevelopment Authority

The URA is the urban planning body of Singapore and has launched different vertical greenery policies as part of policies on skyrise greenery. The authority set a Landscape Replacement Area (LRA) Policy within the Development Control Guidelines that obliges new buildings in strategic areas to replace 100% of their plot areas with different forms of landscapes in their designs (URA, 2019). Of this requirement, at least 40% must be permanent deep soiled greenery, called softscape areas. The remaining 60% of the original plot can be designed as communal facilities, such as playgrounds or waterbodies and are called hardscape areas. The greenery provided in softscape areas should be lush, meaning it has a green plot ratio standard (GnPR) of 4.0. To achieve this standard, the total surface of the leaves, as calculated by the leaf area index, should be four times the total site area. Outside the strategic areas, new buildings need to replace 30% to 40% of the landscape with a GnPR of 3.0 or higher. Vertical greenery can account for 10% of the landscape replacement requirements, either as softscape or hardscape areas. The URA exercises flexibility when evaluating individual cases (URA, 2019).

In addition, the URA stimulates more intense greenery under the LUSH program through an exemption or bonus to the gross floor area (GFA). The GFA is the total floor area allowed to develop according to the master plan (Steed, 2015). When providing outdoor refreshment areas, communal gardens or sky gardens a bonus to the GFA is given. Moreover, some forms of greenery are exempted from the GFA (URA, 2017).

Building and Construction Authority

The BCA is a governmental agency that ensures safety, quality, productivity, sustainability, and user-friendliness in Singapore's built environment. Policy on vertical greenery is embedded in the BCA Green Mark Scheme, a certification tool that 'provides a meaningful differentiation of buildings in the real estate market' (BCA, n.d.). A point system calculates a building's level of sustainability and gives three distinctive ratings. For greenery, points are given for Urban Heat Island (UHI) mitigation, creation of new ecology, sustainable storm water management, advanced green efforts (GnPR > 5.0), and advanced tropical façade performances, such as low heat gain facades, greenery on east or west facades, and thermal bridging (BCA, 2016).

National Parks Board

The National Parks Board created a special department focusing on skyrise greenery, now consisting of five people. The department uses three main policy tools to foster greenery development: incentives, awareness and recognition creation, and research.

The Skyrise Greenery Incentive Scheme (SGIS) began in 2009, covering up to half the costs for installation of vertical greenery systems (National Parks Board, 2009). At that time, the scheme was only available for low and mid-rise buildings in central areas with low levels of street greenery. Now,

under the SGIS 2.0, it covers up to 50% of both vertical and rooftop greenery across Singapore, specifically focusing on existing residential and non-residential buildings.

Creating awareness and recognition is accomplished through a different medium than the incentives. In addition to communication via the website, publications, seminars, and conferences, NParks rewards the most outstanding skyrise greenery designs with an award. Furthermore, the Landscape Excellence Assessment Framework (LEAF) functions as certification that recognizes excellence and professionalism in high-quality urban landscapes, with a special interest in provision and management of greenery (NParks, personal communication, March 12, 2019).

With the Centre for Urban Greenery and Ecology (CUGE) and other partners, the NParks research department contributed substantially to the development of knowledge of and guidelines on skyrise greenery. They published books such as *Vertical Greenery for the Tropics* (Tan, Chiang, Tan, & National Parks Board (Singapore), 2009) and *Greening the Vertical Garden City* (Steed, 2015).

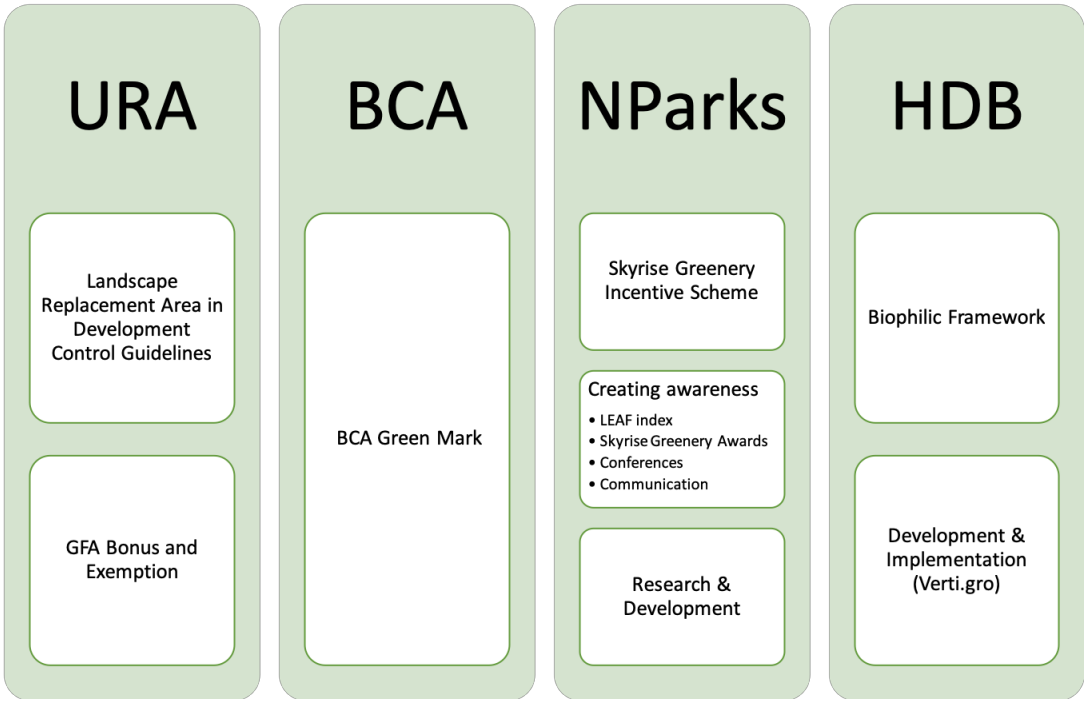


Figure 7: An overview of the Singaporean government agencies working on vertical greenery and their tools. Source: this research.

Housing and Development Board

The Housing and Development Board is the agency focused on housing the people of Singapore. This agency develops dwellings that residents can own for a maximum of 99 years under a special lease construction and owns 80% of all the residential buildings. Two of the board's projects relate to vertical greenery. The Biophilic Town Framework was created "to guide the enhancement of existing natural assets and development of residential landscapes for a greater sense of place, better health and well-being and enhanced quality of life for our residents" (Tan, 2018, p. 5). This project does not specifically

focus on vertical greenery but sets out a vision for biophilic design, including the use of vertical greenery.

Second, the HDB develops and implements innovative greenery solutions (Y, interview). The Verti.Gro system, developed and patented by HDB, is an easy, low-tech solution that allows the installation of vertical greenery in the form of creepers on many buildings. By now, HDB has implemented this system in a variety of its towns.

Thus, support for vertical greenery is expressed by a wide variety of governmental policies and programs, using an integral approach involving multiple governmental bodies and organizations. Singapore's politics and administration actors evidently see a solution in vertical greenery as part of skyrise greenery given the governance efforts around it.

4.1.4 Other stakeholders governing vertical greenery

Other actors also aim to influence the development of vertical greenery. This section briefly discusses the most prominent stakeholders in the economic and social network, as seen in figure 9. The actors and tools in the economic network, and then the social network, are explained below.

Stakeholders in the economic network

The economic network of vertical greenery is shaped by a variety of actors. According to the Singapore Green Building Council (SGBC; interview), after the government, developers and clients are the most important actors for the realization of vertical greenery since they have the most economic incentives and a firm influence on a development process. Singapore hosts many of the world's most green developers, such as City Development Limited and CapitaLand, which are actively trying to incorporate greenery into their development (SGBC, interview). However, these companies are outlier since the majority of the developers are not motivated to use vertical greenery.

Figure 8: Parkroyal on Pickering, one of the most well-known buildings including vertical greenery designed by WOHA. Source: own work.

For architects, this difference in interest is similar. Some companies invest in vertical greenery and some do not. WOHA is Singapore's pioneer architecture company regarding the use of greenery (WOHA, interview). This company

spends considerable resources on research and development to realize buildings with vertical greenery, such as the Oasia Hotel Downtown, Singapore School of the Arts (SOTA), and the Parkroyal on Pickering (Figure 8). However, this architecture company is an outlier rather than the standard.

Vertical greenery professionals have the most interest in the development of vertical greenery. Companies such as Elmich, Prince's, GWS, and Earthscapes provide different vertical greenery systems. While some only provide the systems, others also deliver products for other types of greenery or maintenance services.

The Singapore Green Building Council was established by the BCA but now functions as an independent industry council fostering public-private partnerships across the building and construction value chain (SGBC, interview). The council's certification scheme helps the industry make more environmentally friendly decisions.

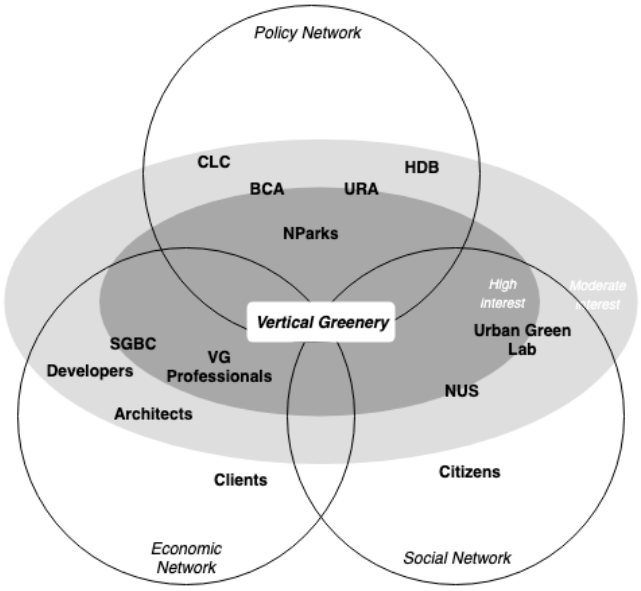


Figure 9: An overview of the Singapore's stakeholders in vertical greenery divided into policy, economic, and social networks.

Stakeholders in the social network

The social network of Singapore's stakeholders in vertical greenery does not contain many actors. A research department at the National University of Singapore (NUS), working together with NParks on research on vertical greenery and its effects, has the most interest in vertical greenery in this network. Urban Green Lab, an educational initiative created by one of the researchers at NUS, also actively promotes vertical greenery. Citizens are rarely involved in vertical greenery development.

4.1.5 Conclusion

This section identified vertical greenery in Singapore as the next step of a vision aimed to increase citizens' living standard and foster economic development. The island's climate creates a variety of options for integrating greenery in buildings. Led by vision and pragmatism, the government used an integral approach incorporating skyrise greenery in the policy and practices of multiple agencies. The top down approach is carried out by sound institutions in close cooperation with market actors.

4.2 Uncertainty: governing a knowledge gap

Following the conceptual framework, this section discusses the theme of uncertainty regarding vertical greenery. Section 4.2.1 explores aspects of scientific uncertainty around vertical greenery in Singapore. Section 4.2.2 provides an overview of the governance within the theme of uncertainty, and Section 4.2.3. offers insights into the lessons learned from the governance approach and the new direction that is taken.

4.2.1 Issues of uncertainty

Knowledge within the theme of uncertainty can be divided into two parts: knowledge of the effect of vertical greenery and knowledge of the technical features of vertical greenery. These two topics are discussed consecutively.

Knowledge of the effects of vertical greenery

Understanding and proving the effects of vertical greenery is important for its existence. The original garden city plan by Lee Kuan Yew was built on the premise that it would contribute to both the environment and economic development. The general arguments for making the city green were known, but specific information on the benefits of vertical greenery was yet to be studied. Moreover, most of the research was not completed in Singapore, which meant that results of the research and effects of greenery in Singapore could be different. Proving insights into more detailed effects was necessary to legitimize the policies, convince possible clients, and later improve the policies influencing these effects (Tan et al., 2009). In general, the insights contributed to the integrity of the policy, which is important according to the livability framework. Thus, the uncertainty concerning the effects of vertical greenery was based in a lack of scientific knowledge.

Knowledge of technical features of vertical greenery

Since vertical greenery was a relatively new area, lack of knowledge on the technical features of vertical greenery existed. In Singapore, many policies are based on best practices by market or industry actors, which means that knowledge of vertical greenery did not have to be gained from the ground up. When the skyrise greenery policies were introduced, different projects had already proven the possibilities of vertical greenery. In addition to WOHA, in Singapore, Patrick Blanc gained international recognition for his living wall systems (GWS, interview). The gap in knowledge was not specifically in developing a system that would work but more in developing different systems that would work in different situations and could be applied to different designs.

To overcome the knowledge gap, traditional boundaries had to be crossed. Vertical greenery consists of growing living organisms onto man-made structures, which results in difficult circumstances for the plants. Developing a system that holds vertical greenery is not the greatest challenge (GWS, interview), but this form of greenery is artificial and more difficult to design, install, and maintain (Steed, 2015). Therefore, one needs a spectrum of knowledge: ‘It is a combination of design, plant

physiology and facilities management while the educational system only delivers you as a horticulturist or architect' (Tan, interview). The combination of different disciplines had not been done before. Therefore, there was a lack of scientific knowledge of technical features for successful vertical greenery systems. Furthermore, no specific scientific or practical discipline had produced information to fill the gap in knowledge, causing some uncertainty.

4.2.2 Governing issues of uncertainty

The knowledge gaps regarding the effects and technical features of vertical greenery, combined with the inability of an existing scientific discipline to deal with these gaps was addressed in different ways. In general, research and development were stimulated by various policy instruments from the policy and economic network. First, the policy network's policy instruments are discussed: the building of institutions, the provision of information, and incentives. Second, the economic network's policy instruments are reviewed: trading mechanisms and voluntary instruments. An overview of these instruments is provided in Figure 10.

Building institutions

To begin the skyrise greenery program, NParks established a special department to focus on skyrise greenery and oversee the development of vertical greenery, guiding the involved actors if they needed help. Together with the other governmental bodies, this department was the central organ governing skyrise greenery. In addition to incentivizing, network management, and the provision of information, these bodies conducted research together with the NParks research department, CUGE, and the National University of Singapore (NUS). NUS had been working on rooftop and vertical greenery for some years (Tan, interview).

Information provision

The generated scientific knowledge from the research initiated by NParks was actively shared. A book that explained the effects of vertical greenery systems, basic technologies, system typologies, and considerations of design and maintenance was published (NParks, interview). At organized events and conferences, information was also provided on both the technicalities and effects of these systems. These measures were designed 'to promote vertical greenery within the city, through advancing the understanding of this new nature-architecture hybrid' (Tan et al., 2009). In other words, using books and conferences, NParks was trying to inform and convince actors to develop vertical greenery.

Incentives

The government tried to engage companies in vertical greenery development by means of incentives. The Skyrise Greenery Incentive Scheme, as well as the Skyrise Greenery Awards and the BCA Green Mark, gave actors encouragement to integrate vertical greenery into their buildings. As seen in the

livability framework, the Singaporean government wishes to involve the economic network in vertical greenery integration to further stimulate development. The incentives make vertical greenery systems more attractive for customers. By creating demand, the government provided an opportunity for vertical greenery professionals who would eventually invest in research and development to fill the knowledge gap.

Voluntary instruments

The incentives to become involved in skyrise greenery also originate from within the economic network. Some companies, driven by biophilic, sustainability, or aesthetic considerations were since the early days involved in the development of knowledge of vertical greenery systems or interested as clients. The architecture company WOHA was one of the first to invest in research and development on its own, to identify the plant types, and to integrate them into the building. Critical features the company developed were the selection of the right plant species, accessibility for maintenance, and locating plants in areas with sufficient day light. Also, they created mock-ups to test the plants' growth rate and uniformity of coverage (WOHA, interview). Moreover, Patrick Blanc also successfully delivered vertical greenery systems based on years of experience. These actors voluntarily created a foundation for vertical greenery demand by developing these systems. However, they did not seem to focus on researching the effects of vertical greenery.

Trading mechanism

The voluntary market instruments, combined with the government incentives and regulations, created demand for vertical greenery, which had to be filled by supply. The supply was to be provided by existing and new vertical greenery professionals, sometimes already involved in the greenery industry. Many Singapore-based landscaping companies, such as Elmich Prince's, developed their own products. Also, the development of the Verti.gro system for HDB and NParks involved small players in the market (Y, interview). Although the development of the vertical greenery system was mainly left to the market, for skyrise greenery professionals it still was important to be involved in the network. Newcomers, like GWS, did not receive much help in the development of knowledge: 'Most of the knowledge on the system we gained ourselves by reviewing the available knowledge' (GWS, interview). Despite the involvement in vertical greenery systems development and research, the market did not seem to participate in research on the effects of vertical greenery.

4.2.3 Lessons learned: a new method of research and development

The approach in which the policy network focused on the research on the effects and the economic network on the development of the vertical greenery systems led to some undesired consequences. Research focused on proving general effects of vertical greenery. The effects on the transmission of heat especially needed specific clarification for Singapore's climate features. To compare the effects of the

different systems, NParks let leading companies in vertical greenery systems install their systems in Hortpark. The green walls would be the basis for studies on surface temperature, ambient temperature, energy use, shading impact, and acoustics (Tan et al., 2009). The NUS also helped the development of measurement tools, such as the GnPR for the BCA Green Mark. All aesthetic, environmental, and economic benefits are included in a book by Tan et al. (2009). Only vertical greenery's benefits on biodiversity were not researched extensively by NUS (Tan, interview).

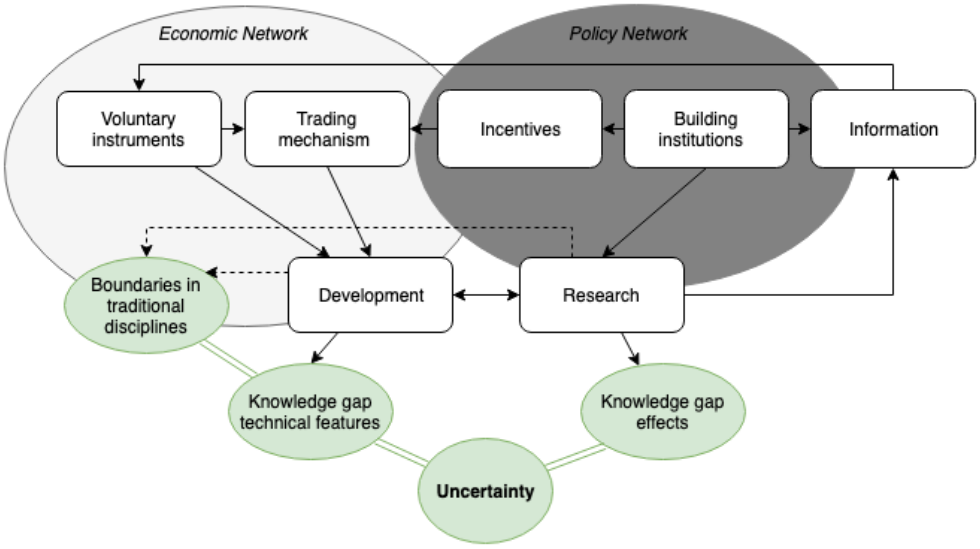


Figure 10: An overview of the governance instruments aiming to influence research and development to overcome issues of uncertainty. The dotted arrows represent the new approach. Source: this research.

The market's development of vertical greenery systems was not executed as planned. In the early days, there was significant separation between the different stakeholders and their parts in the process: 'The ones selling the green wall only focused on achieving their targets. They did not look if the walls were implemented in a correct way. All parts of the chain were only focusing on their own job, without looking at the impact for the rest of the chain' (GWS, interview). As a result, vertical greenery was installed in awkward places where it did not grow, and expensive maintenance was not effective. Many walls started to age, and some did not do so nicely; others failed from the beginning.

At this point, the scientific community worked hard to prove the beneficial effects of vertical greenery. However, they were blamed for the failures of some vertical greenery systems: 'For the beginning things were going concurrently: science and the people practicing it where fishing out green walls. When things starting to fail and the public perception changed, it was the scientific community who took the hit' (Tan, interview). When a documentary argued that there were no real temperature effects of vertical greenery, there was a backlash from the industry and the government started to call universities for clarification. However, as Tan explains, a multitude of information is not given to the broader audience: 'The physics of the systems are very sounds and the effects are clear, but people just know too little' (Tan, interview).

An important part of the scientific uncertainty regarding technical features was thus underexposed in the governance approach. By placing the research and development of vertical greenery system in the hands of vertical greenery professionals, the government overestimated the ability of these professionals to cross the boundaries of traditional knowledge disciplines: 'NParks took care of half the costs and did not really focus on the science behind it' (Tan, interview). Owners did not experience many of the greenery's benefits and only saw rising maintenance and related costs, which negatively affected the public perception of vertical greenery. The governments approach to overcome the gap in knowledge with help from the market thus eventually led to new uncertainties.

A new approach

The lesson during the first years of skyrise greenery development led to a new approach from both the policy and economic network. For example, NParks started to communicate more knowledge about the correct implementation of vertical greenery, such as a handbook for skyrise greenery development (National Parks Board, 2017). Consulting NParks for advice on installation is free of charge. Moreover, the organization established guidelines for planning the vertical garden city together with the URA (Steed, 2015). To inform the network and develop the knowledge together, NParks is actively sharing the available information through sharing sessions and email blasts (NParks, interview).

Institutes, like NUS, are helping with correct implementation by actively creating and sharing transdisciplinary knowledge to reduce the number of failing projects. They made a design massing which identifies the best places to incorporate greenery into a design:

> What we are trying to do is to understand the climate, the design and how the plant species will react to these two things. From here we can see if adjustments need to be made; maybe the design need to change, lighting has to be added or different plants have to be selected. (Tan, interview)

Helping to bridge knowledge between different disciplines will benefit the mutual learning between these disciplines and will give all actors a better understanding of greenery, as Steed (2015) recommended.

The new direction of research is more focused on the development of vertical greenery system than on the effects of vertical greenery. The National University of Singapore is also advocating for a new approach in the development of vertical greenery systems (Tan, interview). A new position of Landscape Technical Officer, as Figure 11 depicts, should oversee the whole process and prevent more failures. Bridging gaps in transdisciplinary knowledge. The market is also contributing to overcoming this gap. Traditionally, skyrise greenery contractors would only sell their products. However, GWS is using advice from NUS and taking an approach that overcomes separation between different disciplines:

‘Our approach is more holistic; we design the wall, sell the product, select and pre-grow the plants, install it and take care of the maintenance, the latter is only available in Singapore’ (GWS, interview).

4.2.4 Conclusion

Overall, within the theme of uncertainty, most governing is completed by the policy network. The initiative began at the top, where a variety of governmental actors imposed regulations, incentives, and policies to make sure the vertical greenery targets would be reached. The governmental bodies focused on researching the effect of vertical greenery by working together with knowledge institutes. Moreover, by using different policy tools, they created demand for vertical greenery. The market, inspired by voluntary ideals or encouraged by the government, was left to develop various vertical greenery systems. Initially, development of systems seemed successful since the tropical climate made it relatively easy to install greenery and keep it growing. However, the industry did not account for some challenges, causing systems to fail and negatively impact societal support for vertical greenery. To overcome this backlash, the government and knowledge institutes became involved in the development of the systems to increase vertical greenery projects’ success rate. This new approach in which gaps in transdisciplinary knowledge were addressed and knowledge was shared among actors was essential to maintain societal support.

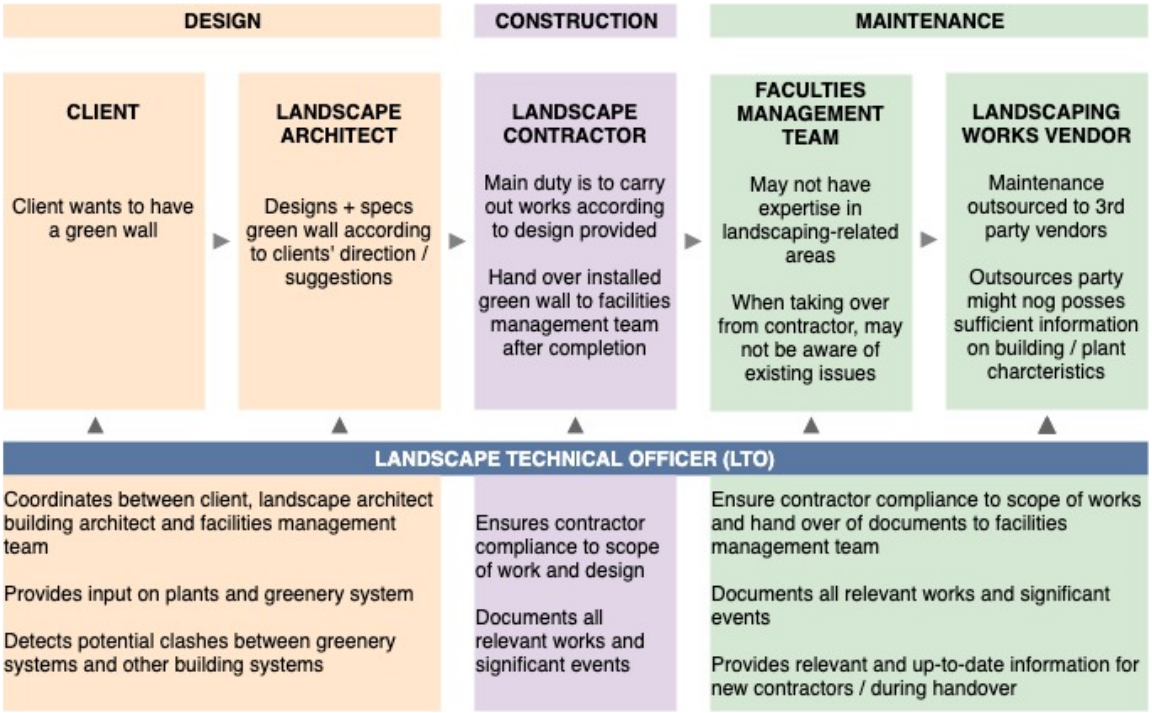


Figure 11: The proposed role of the Landscape Technical Officer. Source: NUS SDE

4.3 Complexity: the challenge of aligning stakeholders

The second theme, complexity, is discussed in this section. Section 4.3.1 addresses the complex challenges present in Singapore's vertical greenery development, and Section 4.3.2 reviews the governance arrangement made to overcome these challenges.

4.3.1 Issues of complexity

The complex problems of vertical greenery in Singapore seem to originate from one issue: convincing all stakeholders to choose vertical greenery. A development project will usually involve development authorities, a developer with a project team, a client, architects, landscape architects, structural engineers, mechanical and electrical engineers, a quantity surveyor, building contractors, landscape contractors, and the building managers (Steed, 2015). The actors involved in the decision-making process need have similar visions of the development and vertical greenery. These similar visions also must be stable over time: large development projects can sometimes last more than 10 years from start to finish. All stakeholders must also agree on the management level (WOHA, interview).

For older HDB towns, there is an extra difficulty since citizens are also involved in the decision making process. Vertical greenery can be applied during renovation programs. The focus of these programs is decided by the town councils, which are chosen by a voted member of parliament from the specific electoral district (Y, personal communication). In the process, citizens can give feedback via the residents' committees. Some citizens, worried about pests or dripping water, might disagree with the development authority, town council, or even other residents on vertical greenery implementation.

Thus, convincing everyone on the development or renovation project to agree can be challenging. Two key reasons actors may oppose vertical greenery are rooted in complexity. First, there is a mismatch between payers and receivers, and second, vertical greenery development necessitates long-term commitment. Addressing these barriers will help to overcome the complexity between stakeholders. These themes are discussed below.

Mismatch between payers and receivers.

The first complex issue that prevents stakeholders from agreeing is the disconnect between the costs and the benefits of vertical greenery. Not only are vertical greenery systems more expensive than conventional facades or green roofs since all elements are vertical, but the positive externalities are also often not directly experienced by the one paying for the system (GWS, interview). Vertical greenery effects often appear on city, neighbourhood, or micro-climate levels, often beyond the investors' borders. As Steed (2015) explains, greenery and its externalities do not know boundaries set by humans, resulting in many actors thinking vertical greenery is not only expensive but also has too few personal benefits. Therefore, within vertical greenery, there is a mismatch between the payers and receivers.

Maintenance

The second issue that prevents some stakeholders from being in favour of vertical greenery is the long-term care the systems need. Developers or end-users expect a finished building instead of continuous maintenance (Cheng, interview). Therefore, especially in the beginning of skyrise greenery development, end-users frequently complained about maintenance (CLC, interview). Some companies, or even government bodies, try to do the minimum skyrise greenery application and maintenance or avoid it: 'This is interesting since other government organizations are trying hard to promote these techniques, so not everybody is singing the same song' (GWS, interview).

A significant portion of the resistance is the costs of maintenance. As GWS explained, since all vertical greenery aspects are vertical, maintenance is not only necessary, but also more expensive than that of conventional greenery. Although labour is relatively cheap in Singapore, people still notice the extra costs. When a budget cut occurs, vertical greenery is often the first item to be removed, given it continues costs (GWS, interview). For example, at Vivo City, green walls were removed because of maintenance issues and rising costs, often related to a failure in design (Y, interview).

Thus, complexity in vertical greenery development in Singapore is mainly found in aligning all the stakeholders and convincing them to choose vertical greenery. The two greatest obstructions here are the mismatch between payers and receivers and the long-term maintenance.

4.3.2 Governing issues of complexity

Policy, economic, and social networks address the issues of complexity through several approaches. This section discusses the most visible approaches: regulation, information communication, direct and indirect incentives, good design practices, and the involvement of citizens. An overview of the challenges and governance approaches is presented in Figure 12.

Regulation

The most direct way to align all stakeholders is the regulation of vertical greenery in developments. As explained, this alignment is achieved through the Landscape Replacement Scheme. All actors work together on the integration of greenery since they must. Contributing to success of this policy is the government's holistic approach. The fact that skyrise greenery is integrated into the policies of all governmental bodies under the MND prevents difficulties within the government and spreads a uniform message: 'Perhaps what is key is for government agencies to have a good relationship with one other so that when it comes to policy formulation, it would be carried out in a more holistic manner' (NParks, interview).

However, direct regulation might face objections from companies or citizens who disagree or experience regulation as a lack of decision-making authority. Therefore, regulations must fit within the state's governance approach and its cultural and institutional arrangements. In Singapore, regulation as a tool for progression is accepted by companies and citizens:

> Here in Singapore, we had a very strong leadership. A lot of things moved very fast. If the government decided that Singapore wants to be a green country in the next 10 years: we become a green country. When the government decided we want to be a super green country, we become a super green country. Although this is slightly changing now, and more people are involved in policy making. (GWS, interview)

Thus, top-down instruments are more common and accepted in Singapore. Therefore, a government as a driver for change is accepted and does not face much resistance.

However, regulation might not always yield the best results. The quality of the design and greenery can be subordinate to the fact that the greenery is obligatory: 'Regulation might result in cookie-cutter designs where people are motivated to just fulfil the minimum. Incentives, I feel, allow for more creative and innovative building designs to be developed' (NParks, interview). Regulation of vertical greenery is thus an effective way to combat the complexity between different stakeholders within the process of development but might result in a democratic deficit and projects with minimum fulfilment.

Incentives

Costs and benefits of vertical greenery are influenced by the policy network, such as NParks' Skyrise Greenery Incentive Scheme (SGIS), the BCA Green Mark, and the LUSH program. The SGIS aims to reduce the installation of vertical greenery on existing buildings, so the scheme does not affect the new buildings. For existing building stock, the other incentives help but 'this is still difficult because you have to convince the owner to put a green wall on their building' (GWS, interview). GWS is not the only ones that acknowledge a human factor still exists: 'We have the incentive scheme to help with the initial instalment, it is just whether you want to make the effort or not' (NParks, interview).

The BCA Green Mark program does not directly influence the costs of vertical greenery but does increase the benefits of developing a building including vertical greenery. Buildings that have a Green Mark certification have a higher value than ones without the certification, and thus these buildings can charge more rent. This distinction is especially important for the branding of larger companies: 'Multinationals from other countries will only lease green mark platinum buildings. If the building is not platinum, they will usually not consider it. Therefore, there is a huge economic incentive to green buildings according to the green mark' (SGBC, interview). Also, HDB wants to have new buildings to have at least Gold+ or Platinum standards. For renovation, HDB noted that the certification does not play a significant role since the citizens do not deem it important (Y, interview).

Another policy incentivizing developers and architect to include skyrise greenery are the GFA exemption and bonus policies under the LUSH program. This program increases the benefits of vertical greenery since developers and architects can incorporate greenery while maintaining the maximum

saleable floor area (Steed, 2015). In addition to regulation, having policies that incentivize market actors is essential for success:

> You must have enlightened developers who see this [integrating greenery in buildings] as something that is a valuable proposition. It is their contribution to this city and the vision we have for this city. And this is something that is linked back to the URA. They do not only use the policy to encourage the developer, they also used other tools such as GFA exemption to incentivize them. The loop has to be closed in that sense. (CLC, interview)

Compromising with the market or industry is, thus, important to alleviate regulation.

To influence the issue of maintenance, the most frequent complaint against vertical greenery, there is not much done in terms of incentivizing. The government does not control costs after implementation: 'For the installation, we have the incentive scheme which reduces the initial costs. But the costs after that are for the user' (NParks, interview). Under the LEAF scheme, there are points given for the ease of maintenance, which should stimulate green walls that require little maintenance. In addition, NParks handles the maintenance of all the governmental buildings with skyrise greenery.

Thus, direct and indirect incentives reduce costs and increase the benefits of vertical greenery, as well as addresses the mismatch between the payer and the receiver. However, for Singapore, these incentives do not influence the complex challenges in the long term. Furthermore, application of vertical greenery still depends on the human factor, which means that when non-market actors are involved, the incentives might not play a role.

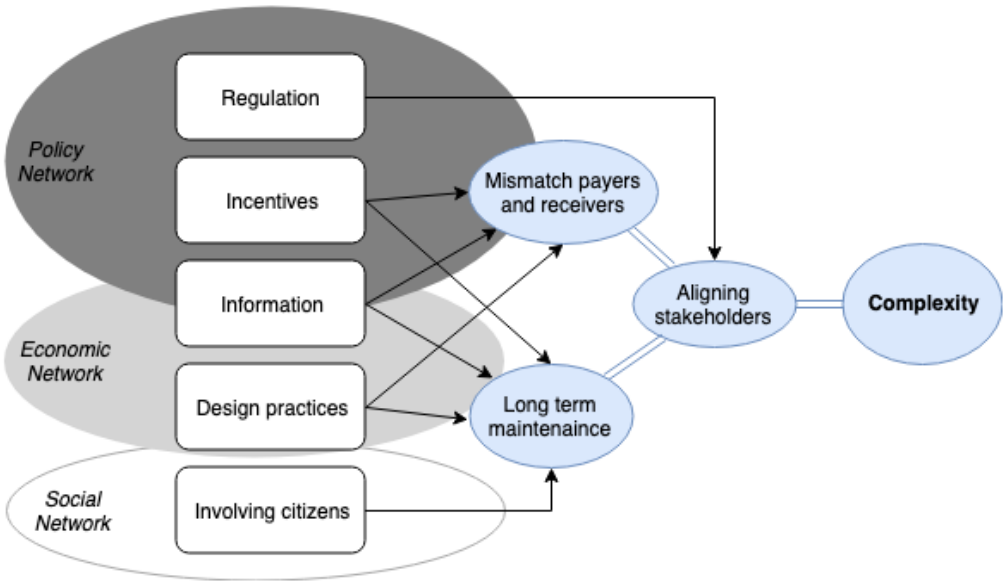


Figure 12: An overview of the governance instruments contributing to overcoming issues of complexity. Source: this research.

Information

Information is also used to overcome the complexity between different actors and to allow them to agree on the use of vertical greenery. The government is not only trying to introduce vegetation and its benefits to the people by means of the previously mentioned publications, events, and aid, it is also contributing to talks in HDB towns. When citizens are involved in renovation decisions, the government organizes meetings to inform citizens of vertical greenery and disprove their negative ideas of the systems (Y, interview).

Other actors also try to influence the costs by providing information. Some market actors emphasize the benefits for the individual investors to convince them to integrate greenery into their developments. For example, actors might explain that greenery can increase property value without using the green mark, such as at a building on Cecil street (Tan, interview). There was no interest to rent office space in a building just outside the CBD, but after development of a green wall, even large multinationals were interested. Moreover, greenery can also enhance branding for sustainability, which became a spearpoint for different hotels after moving into a building with skyrise greenery (Cheng, interview). Compared to green roofs, vertical greenery is an excellent marketing tool since it is so visible (GWS, interview). Communicating the specific benefits for the involved stakeholders can enhance support for vertical greenery and reduce its complexity between actors.

Last, to address long-term issues, expectations must be well managed. Cheng explains that WOHA has a reputation for designing living, breathing buildings. The company's clients are aware that 'buildings are not "set-and-forget", they are living evolving systems that need maintenance and upgrade' (Cheng, interview). Besides WOHA, GWS is also trying to manage what clients can expect: 'Especially for places where there are multiple seasons, it is important that the customer expects and accepts that the wall might be not appealing in the winter' (GWS, interview).

Therefore, spreading information is crucial to overcoming the challenges in both the mismatch between the payers and receivers and long-term maintenance.

Good design practices

Another approach to overcome problems in complexity is to use good design practices. The practices are not only used by the market, but also by the government:

> If the government is trying to promote a policy it is a lot easier for us to walk the top and lead the way by championing it and doing it in our own project first, to show the private sector it can be done, it is viable and economically doable. [...] In the end setting a good example strengthens the synergy between the public and private sector. (CLC, interview)

Good design practices is a tool that is trying to change the perception of other actors on vertical greenery systems by showing the systems; feasibility and can, therefore, contribute in overcoming complexity.

The architects and developers can help overcome the complexity through good design practices. For example, WOHA tries to bring the benefits to the client by using greenery in a functional way. Greenery in combination with principles from tropical design, such as open spaces, can enhance the air flow through the building and serve as natural air conditioning (WOHA et al., 2011). Thus, for some developments, hallways and other spaces in the building do not need air conditioning. In countries with tropical climates, elimination of air conditioning can save a huge amount of energy and costs.

Moreover, the way a wall is designed can address issues of maintenance. Considering key features in the design can reduce maintenance and ease resistance among stakeholders. Vertical greenery must be accessible; it cannot be obstructed by flaws in the design or refusal when private property has to be crossed (SGBC, interview). In some cases, vertical greenery companies forgot to incorporate access into the design, such as CleanTech One, displayed in Figure 13 (Tan, interview).

Furthermore, choosing the correct systems and vegetation can reduce maintenance requirements. In the past, NParks learned that maintenance is more convenient when climbers are not directly grown on the surface of walls (NParks, interview). WOHA found innovative ways to incorporate maintenance into its designs, such as placing creepers in planter boxes on a different skin for the Oasia Hotel Downtown (CLC, interview). In addition, GWS tries to reduce costs by convincing people to choose a more natural solution with less maintenance, 'but this [does] not always work. When people spend their money, they want something that looks good with an interesting design" (GWS, interview). Moreover, vertical greenery company GWS is trying to develop a new system with NUS to monitor maintenance and cut costs; only on demand maintenance will be executed then. Thus, NUS is evaluating existing green walls to determine how facades can best be maintained and how accessibility for maintenance will affect the design (Tan, interview).

An interesting new trend is completely overcoming the problem of maintenance: artificial green walls. 'This overcomes the problem of maintenance and reduce the costs but still gives you the biophilic feeling [sic]. Although many of the environmental benefits have disappeared, customers use this mainly for insolation, sound absorption and to carry out their green image' (SGBC, interview). This new trend is fascinating because it almost completely eliminates most of the benefits.

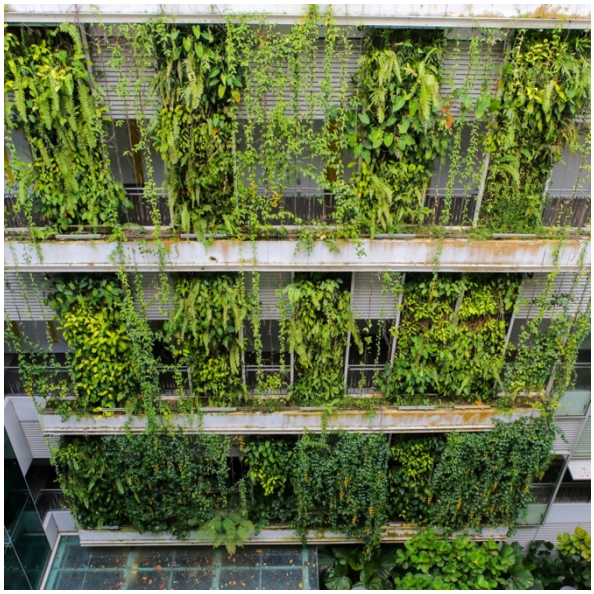


Figure 13: Incorrect application of vertical greenery. Tan (interview) explains that there are two failures here: the system is not accessible to maintenance and the hybrid between an LWS and support system will never be successful since they overgrow each other. Source: http://www.fas.nus.edu.sg/srn/archives/photos-bank/gr

Setting a good example and using good design practices can thus also contribute to overcoming issues of complexity. Artificial vertical greenery solutions help combat the challenge of maintenance, but this solution loses many of the benefits of vertical greenery.

Involving citizens

A promising new direction is the involvement of citizens as lay people of vertical greenery. However, to encourage citizens involvement, the following changes might need to be made: 'That is why we should move to more edible gardens, where developers can partner citizens on the maintenance of these community gardens.' (CLC, interview). For example, at Khoo Teck Paut Hospital, citizens help maintain the skyrise greenery, which reduces maintenance costs and helps convince the client to choose vertical greenery.

4.3.3 Conclusion

Issues of complexity within vertical greenery development in Singapore occur in the interaction between different stakeholders. Having all actors agree on vertical greenery implementation is especially difficult. This difficulty is caused by the mismatch between the payers and receivers and the long-term commitment of maintenance. As Figure 12 illustrated, to overcome this problem, policy, economic, and social networks use different approaches, such as regulations, incentives, communication, good design practices, and the involvement of citizens, to cope with the challenges of complexity.

4.4 Inequality: governing accessibility and quality

This section evaluates the (in)equality of vertical greenery and Singapore's governance arrangements. Section 4.4.1 discusses the issues of inequality regarding vertical greenery, while Section 4.4.2 addresses the governance approaches that aim to overcome inequality in vertical greenery.

4.4.1 Issues of inequality

Following the conceptual framework, this section distinguishes between two issues of inequality: in accessibility (i.e., unequal distribution of vertical greenery) and in the quality of the available vertical greenery systems.

Accessibility to vertical greenery

In Singapore, the equal distribution of greenery is relatively high. The city in a garden vision resulted in many public green spaces, accessible to everyone. Vertical greenery in Singapore is also accessible to citizens, despite their lack of involvement in its development. Given the economic incentives to use vertical greenery as a marketing tool, this greenery is often placed in areas that can be seen from public spaces, making is available to everyone.

No specific numbers on the distribution of vertical greenery in the different areas are available. However, personal observation indicated that vertical greenery is more visible in the central areas of Singapore, called strategic areas by the URA. Moreover, vertical greenery is often found on public buildings, such as malls (e.g., Westgate, Summerset, Oases Terraces); semi-public buildings from knowledge institutions (e.g., SOTA, SMU, NUS, NTU, Nanyang Polytech); buildings from private market actors, such as banks and hotels (e.g. Ocean Financial Centre, Bank of China, Park Royal Hotel, Hotel Oasia Downtown, Ascot Orchard, Rendezvous Hotel); and private condominiums (e.g. Kallang Riverside, Newton Suites, Residences at Emerald Hill, Urban Resort). For HDBs, vertical greenery is implemented in many places. However, different forms of skyrise greenery, such as rooftop greenery and sky terraces, are more common. For example, HDB flats, such as SkyVille@Duxton, Waterway terraces, and Pinancles at Duxton, have multiple sky terraces on intermediate floors and publicly accessible sky parks on the top floor. Spatial segregation in Singapore is relatively low, and HDBs and condominiums are mixed (X, interview).

Figure 14: Vertical greenery at Oases Terraces, a multi-use, publicly accessible building. Source: own work.

Vertical greenery is seldom installed by citizens because of the lack of private property and the high costs of instalment. However, vertical

greenery systems are occasionally installed on citizens' balconies (GWS, interview). Thus, there are many places where vertical greenery is available to everyone, but it is still more often implemented in central areas on public non-residential buildings and private condominiums than on HDB flats.

Quality of vertical greenery

Differences in the quality of vertical greenery systems influence the experienced benefits. For the absorption of heat, the more expensive systems have larger benefits than the cheaper creepers: 'The pocket, planter and cassette system create a cool layer in between the system and the building, also supported by the automatic irrigation. For the support systems, there is no such layer but only shade since the roots are in the ground or a planter box' (NParks, interview). Therefore, greenery accessible to underprivileged people might be of lower quality, causing fewer benefits.

4.4.2 Governing issues of inequality

Governing equality is achieved through a variety of actors in the policy, economic, and social networks. The four most visible forms of governance are discussed in this section. First, regulation and guidelines as a tool to combat inequality in vertical greenery is introduced. Second, information as a tool is presented. Third, educational projects are explored. Last, self-governing approaches on vertical greenery are discussed. The issues of inequalities and the governance approaches are summarized in Figure 15.

Regulation, guidelines, and incentives

The equal availability of greenery is influenced by policies from URA and HDB. The URA provides an option to fulfil part of the LRA, as discussed, with green communal spaces instead of only greenery (URA, 2019). Moreover, under the LUSH program, development projects are granted a GFA exemption for communal space on the ground floor, first floor, and sky terraces (URA, 2017). Despite the regulations and incentives to open skyrise greenery for all, it rarely influences the availability of vertical greenery since it is not something that can be turned into a communal space. However, given the necessity of a certainty leaf density, these policies do influence greenery quality.

In addition, HDB directly and indirectly influences vertical greenery. The HDB Biophilic Town Framework does not have specific guidelines on vertical greenery but aims to create nature-centred neighbourhoods, which could consist of vertical greenery systems (HBD, 2018). Incorporating greenery is not obligatory since the framework serves as guidelines rather than regulations (Y, interview). Another department at HDB developed the Verti.gro system, a low-tech support system that uses creepers. These systems can be installed in a new HDB or during the renovation of an existing HDB. For the latter, the town council must incorporate this system into the building plan. Greenery is often not the town council's priority but will receive attention when citizens complain (Y, interview). Directly installing vertical greenery systems in HDB buildings is done although it is often on multi-story carparks, making the thermal benefits for citizens limited.

The government's policy approaches influence inequality in greenery but seldom specifically vertical greenery. When focused on vertical greenery, the systems are often cheaper with fewer environmental benefits.

Information

Different actors encourage citizens to become involved in gardening and greenery. For instance, NParks organizes the Singapore Garden Festival, which contains balcony greenery competitions and educates citizens on the selection of plants (NParks, interview). Additionally, a special department at NParks enables citizens to become involved in greenery through the 'community in bloom' program. This program focuses on the development of community gardens on multi-story carparks.

Other actors are also trying to boost community involvement in greenery. The Urban Green Lab tries to educate people on the benefits of greenery through short videos (Tan, interview). Moreover, the lab gives guest lectures at primary schools to teach children the importance of greenery. These initiatives are rare in Singapore, although there are currently more people participating in them, especially in the food growing industry.

Therefore, enabling citizen involvement in gardening and greenery is accomplished by different actors through communication but is also not specific to vertical greenery.

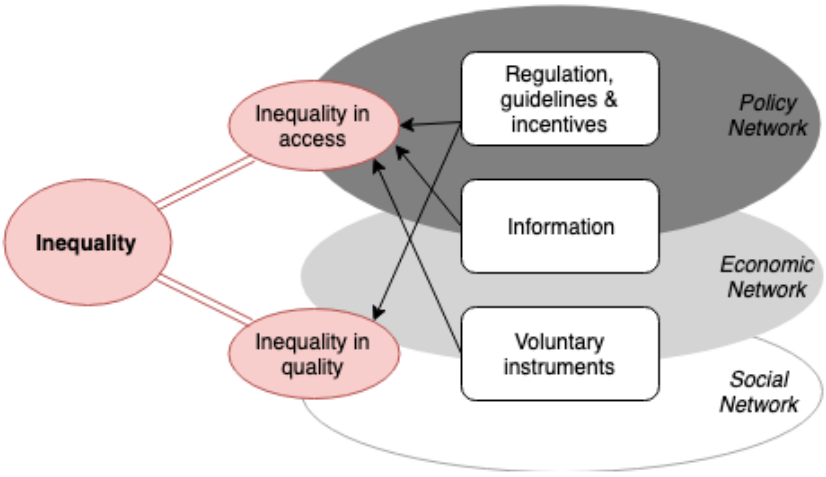


Figure 15: An overview of the governance instruments contributing to overcoming issues of inequality. Source: this research.

Voluntary instruments

Voluntary instruments, which the approaches in the previous section try to enable, are seen but do not specifically focus on vertical greenery. Some citizens garden on their balconies or in corridors, while other choose to volunteer at one of Singapore's larger gardens, such as at the Flower Dome. Officially, growing plants in HDB corridors is not allowed but many people still do it (X, interview).

Companies like GWS sell vertical greenery systems to private citizens although these systems can be expensive, and significant service must be performed: 'For residential projects, we charge 600 to 700 Singapore Dollar per square meter, for commercial project we charge lower. Although in theory

everybody is able to own a green wall, it is still a luxury item' (GWS, interview). Citizens can also just buy a vertical greenery system, securing access and quality, but this option is not affordable for most.

Although bottom-up initiatives encourage vertical greenery, these initiatives are not common. Since the government is usually actively involved in planning, citizens became more passive in shaping their city (X, interview). Citizens would rather conform to the existing rules than question or change them. Moreover, bottom-up initiatives often become businesses. Protesting is not allowed in Singapore and since NGOs are often linked to activism, this label is unappealing (X, interview). Furthermore, many activities are licensed in Singapore. To gain permission for these activities, having the available resources and a positive relationship with the government is necessary, and this is easier to achieve for a business (X, interview).

4.4.3 Conclusion

Singapore makes greenery available for all, but vertical greenery still is more available in specific places. Vertical greenery installed in social housing is often of low quality and placed on carparks, reducing the benefits for citizens living in social housing. The government approaches aiming to make greenery more available for all citizens are focused on other forms of skyrise greenery, such as sky parks. The efforts made to involve citizens in gardening make greenery more accessible, but cultural habits indicate citizens may not want to become involved. Some citizens voluntarily control their access to greenery or try to influence other citizens' access to greenery. The existing bottom-up initiatives are limited and often turn into businesses given Singapore's institutional arrangements.

5. Empirical results from Amsterdam

This chapter provides an overview of the most interesting findings regarding Amsterdam's greenery. Following the conceptual framework, the chapter discusses themes of uncertainty, complexity, and inequality. However, an introduction to vertical greenery governance is presented first.

5.1 Amsterdam: a city of participation

To better understanding the results from Amsterdam, basic features of Amsterdam and its vertical greenery development are discussed. In section 5.1.1, environmental features are summarized. Section 5.1.2 distinguishes between two types of vertical greenery applications, and the governance of these systems is introduced.

5.1.1 Understanding Amsterdam

Amsterdam is the capital of the Netherlands and has a long and rich history. The city is built on a peat bog with a layer of sand 20 metres deep. This location means the ground is not solid for building development, but it does create favourable conditions to grow greenery. Compared to other European cities mostly built on sand, Amsterdam has many trees (Gemeente Amsterdam, interview).

The climate in the Netherlands has considerable influence on the possibilities for greenery. Southwest winds cause the temperature difference between summer and winter to be minimal and results in a mild maritime climate (Rowen & Heslinga, 2019). Winters have short days and summers long, making the number of sunlight hours variable. Rain is evenly distributed throughout the year. The wind makes the weather unpredictable. Greenery in the Netherlands must be able to cope with these circumstances.

5.1.2 Vertical greenery governance and related forms of application

The governance of vertical greenery in Amsterdam cannot be summarized in a policy from a single actor. Instead, governance of vertical greenery in Amsterdam can be divided in two types of applications: professional and do-it-yourself (DIY). These applications are both governed by a variety of actors from the policy, economic, and social networks. Some actors are active in both kinds of applications.

The professional application of vertical greenery

Professional application of vertical greenery refers to vertical greenery installations designed and installed by professional companies, which sell the installations to customers. These parties often use professional systems, such as LWS. An overview of Amsterdam's professional stakeholders is presented in Figure 16.

The policy network

Within the policy network, there are three important actors actively influencing vertical greenery via policy tools: the municipality, Rainproof Amsterdam, and political parties. The municipality tries to influence vertical greenery use by incentivizing, using subsidies. New vertical greenery placed on existing buildings visible from public spaces and covering a minimum area of 30 m2 qualify for a maximum subsidy of 50% of the installation costs (Gemeente Amsterdam, 2019). The reimbursed amount depends on the system: ground-based support systems will receive €30 per m2 while LWS and non-ground-based systems will receive €50 per m2, for a maximum of €10,000. In addition to incentivizing, the municipality prescribes vertical greenery in the 'lot passport' indicating the development standards (Gemeente Amsterdam, 2013).

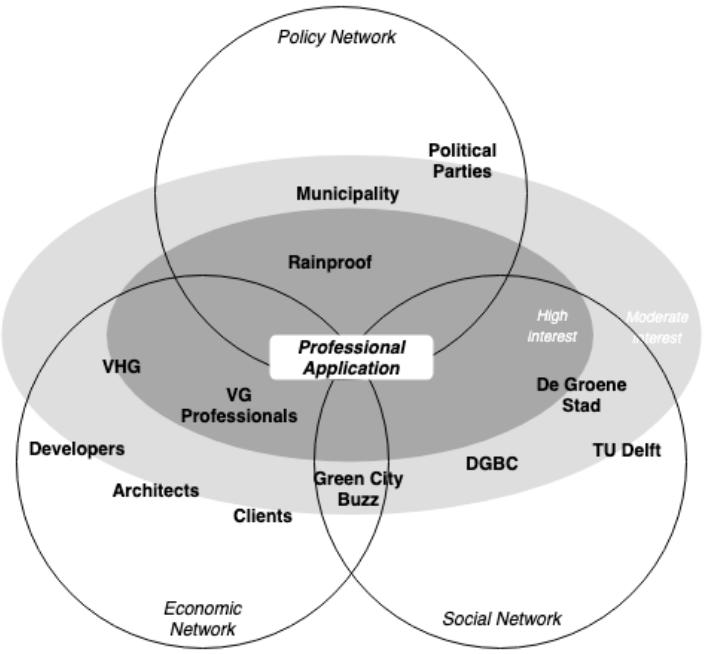


Figure 16: An overview of Amsterdam's stakeholders in the professional application of vertical greenery divided into policy, economic, and social networks. Source: this research.

Rainproof Amsterdam is an initiative of the municipality and Waternet, a water company dedicated to the whole water cycle but acting as an independent organization. The organization aims to prepare for future downpours by actively discussing the problem and promoting the tools that help to improve water management (Rainproof Amsterdam, interview). Vertical greenery is one of these tools. Rainproof links the different organizations and creates a network of actors willing to communicate the message. Thus, Rainproof's tools to influence the development of vertical greenery systems are communication of information and network management. Of course, vertical greenery is only one tool so is not the company's only interest.

Political parties are the third policy actor influencing vertical greenery. In 2016, the Party for the Animals (PvdD) proposed a pilot called *een groen sloterdijk* with vertical greenery on the columns of a railway flyover (PvdD, interview). The pilot was unanimously adopted by the municipal council, but in the operationalization by the municipality and the railway network company, it was cancelled.

The economic network

The economic network consists of all actors influencing vertical greenery from an economic point of view. The most obvious are the vertical greenery professionals, such as Sempergreen, Green Fortune or De Verticale Tuinman, which sell their own systems. Other companies selling vertical greenery are

horticulturalists that adopted this new form of greenery in addition to their classic practices, such as Van Ginkel or Copijn. These companies mostly control the development of vertical greenery by providing the systems, installation, and maintenance. Figure 17 provides an example of one of their systems.

De Branchevereniging Hoveniers en Groenvoorzieners (VHG) is the trade association of horticulturalists and greenery provisioners and represents vertical greenery professionals. Through lobbying, networking, and information provision, VHG garners attention for the integration of greenery in the built environment (VHG, interview).

The actors creating the demand, the architects, developers, and clients, can choose a vertical greenery solution. Architects Venhoeven CS were one of the first to use vertical greenery systems on a large scale in their design of the Sportplaza Mercator. Developers and clients might have interest in developing buildings with vertical greenery, but interest and motivation for vertical greenery vary per actor.

The social network

Different actors influence vertical greenery. Green City Buzz is a foundation aiming to enable large scale urban greenery (Green City Buzz, interview). Although this foundation is focused on greenery's many positive environmental effects, it tries to convince entrepreneurs and building owners to add greenery, including vertical greenery, to their properties by focusing on the added economic value.

The Dutch Green Building Council (DGBC) is a public networking organization that provides sustainability measurement tools. One of these tools is the Building Research Establishment Environmental Assessment Method (BREAAM), which measures a building's sustainability performance. Furthermore, the measurement tools attempt to make the built environment future proof through stimulation, communication, connection, inspiration, and education (DGBC, n.d.). Vertical greenery is thus a small part of the DGBC's focus.

Other actors are focused more on knowledge. De Groene Stad (The Green City) tries to inform and stimulate public and private actors to incorporate greenery into the urban environment. Moreover, at the Technical University (TU) in Delft research has been conducted on vertical greenery (Ottelé, interview).

Figure 17: An example of professional application of vertical greenery at the Hyatt Regency in Amsterdam by Sempergreen. Source: Sempergreen.

The Do-It-Yourself application of vertical greenery

Do-it-yourself application refers to installations designed, installed, and maintained by citizens or local initiatives and not by professionals, often as part of a façade garden. An overview of the stakeholders involved is presented in Figure 18.

The policy network

The policy network plays an important role in the realization of DIY application. According to the municipality, many policies in the city are built upon a culture of participation, enabling citizens to shape their neighbourhoods (Gemeente Amsterdam, interview). Different policies enable citizens to participation making the city green, but not all are entirely focused on vertical greenery. In addition, DIY application qualifies for the subsidy on green facades, and the government provides subsidies for bottom-up greening projects (NMT, interview). Most important, the government is installing the base of a façade garden on the citizens' request. Façade gardens can, but do not necessarily, include vertical greenery, often using support systems or climbers that directly attach to the surface. An example of vertical greenery as part of a façade garden is provided in Figure 19.

Rainproof Amsterdam's information communication and network management also targets citizens. Rainproof is usually not in direct contact with citizens but instead make contact through other organizations, such as neighbourhood centres, garden centres, or a gardening association called Tuinbranche NL (Rainproof Amsterdam, interview). Sometimes, markets or information evenings are held to directly influence citizens.

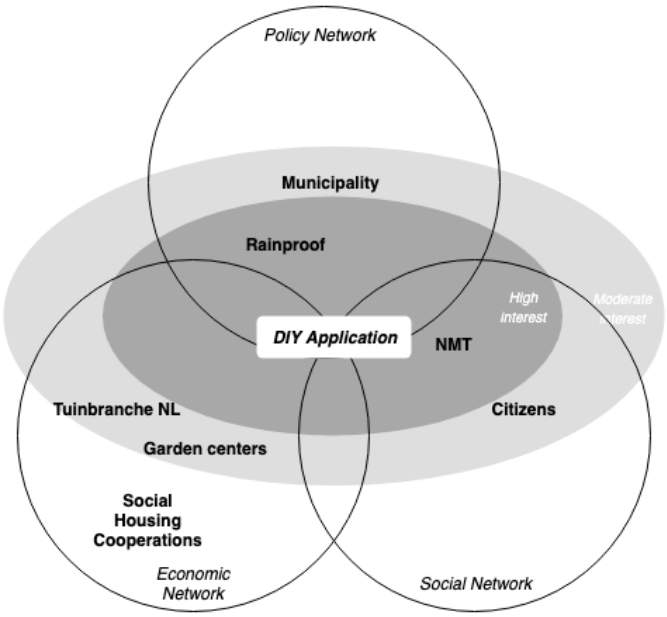


Figure 18: An overview of Amsterdam's stakeholders in the DIY application of vertical greenery divided into policy, economic, and social networks.

The economic network

The economic network is shaped by different stakeholders in DIY vertical greenery. One of the most important actors are the garden centres or hardware stores where people can buy the tools for DIY application. These companies provide not only plants but also support systems and other instruments for successful greenery installation. The Tuinbranche NL, the association for the whole gardening chain, lobbies for and promotes gardening, educates and inspires citizens, and conducts research on trends and consumers (Tuinbranche Nederland, April 30, 2019).

In addition to the tool providers, the housing corporations are important economic actors. These corporations own slightly more than 40% of Amsterdam's housing stock (Amsterdamse Federatie van Woningcorporaties, 2018). Therefore, they have a huge influence on vertical greenery use for a building and the possibilities for DIY application.

The social network

The social network is shaped by social actors such as Natuur&Milieuteam Zuid (NMT) and citizens. Natuur&Milieuteam Zuid is a social organization, financed by the municipality, that assists in, provides advice on, and promotes the use of greenery in the southern neighbourhoods of Amsterdam (NMT, interview). Moreover, NMT connects different actors and involves citizens in the greening of urban areas. Once every year, NMT presents an award for the best vertical greenery in Amsterdam.

Citizens are also crucial to DIY vertical greenery. All actors trying to influence the DIY application are still dependent on the enthusiasm and willingness of residents to engage in the projects themselves. More than 30% of the housing stock in Amsterdam is privately owned, meaning the possibilities for citizen DIY vertical greenery are large (Amsterdamse Federatie van Woningcorporaties, 2018).

5.1.3 Conclusion

Amsterdam is a relatively green city as a result of the specific climatic and environment conditions that allow for many trees. For the success of vertical greenery, these systems must be capable of dealing with the changeable climate. The municipality does not have extensive policies on vertical greenery, but the participation culture in Amsterdam enables citizens to develop greenery themselves. The method of governance led to a division between two types of vertical greenery application: professional and DIY. Both types are governed by a variety of actors.

Figure 19: An example of DIY application of vertical greenery seen in neighborhood De Pijp in Amsterdam. Source: https://hiveminer.com/Tags/amsterdam%2Cgeveltuin/Recent

5.2 Uncertainty: dealing with ambiguity and a lack of knowledge

This section focuses on the first theme explained in the conceptual framework: uncertainty. Section 5.2.1 discusses the specific issues of uncertainty in Amsterdam by combining both the professional and DIY applications. In Section 5.2.2, the governance of scientific uncertainty in Amsterdam is illustrated.

5.2.1 Problems of uncertainty

Within the theme of uncertainty around vertical greenery in Amsterdam it is, just as in the results of Singapore, possible to distinguish between the knowledge on the effects of vertical greenery and the knowledge on the technical features. These features are discussed consecutively.

Knowledge of the effects of vertical greenery

The interest in vertical greenery was came in multiple waves by different actors. In the 1980s, this type of greenery garnered much attention (Ottelé, interview). Most knowledge came from Germany, especially about systems using creepers. During this period, the positive effects of greenery where known, but scientist never quantified them. In 2007, a huge increase in the research on vertical greenery began, and TU Delft started to quantify the effects of vertical greenery (Ottelé, interview). In the beginning, the focus was on particular matter and thermal transmission, but later, the research also focused on lifecycles analysis. Research is currently more specialized. An important part of this specialization is plant morphology: 'We want to provide better insights in which plants to choose to achieve a certain effect' (Ottelé, interview). Other stakeholders, such as Rainproof Amsterdam, Green City Buzz, Sempergreen, and VenhoevenCS, also acknowledge vertical greenery's benefits but often quantifying these benefits difficult. Therefore, despite the solid scientific evidence of the effects of vertical greenery, the effects are mostly communicated in general terms instead of quantifiable factors.

Knowledge of technical features of vertical greenery

As research started at TU Delft, industry and greenery professionals began to develop buildings with vertical greenery. One of the first buildings covered in vertical greenery, the Sportplaza Mercator, was finished using Patrick Blanc's pocket system. (VenhoevenCS, interview). A greening professional, Copijn, installed the system. Other vertical greenery professionals developed their own systems: Sempergreen started to develop a special vertical greenery system for harsh climates (Sempergreen, interview). Ottelé explains that much of the knowledge about the vertical greenery systems is rooted in Dutch greenhouse agriculture, which uses similar systems. Some knowledge of technical features could be derived from this sector, although there are some major differences (Ottelé, interview).

However, not all projects went as planned. After installation at the Mercator Sportplaza, the greenery seemed to be thriving, but after a few years, many plants died due to incorrect installation (e.g., irrigation pipes where to narrow) and a failure to consider the different microclimates on the building (VenhoevenCS, interview). Blanc's system appeared to be less successful in the Netherlands given the

little space that roots have in the pocket system, making the plants not resilient to Dutch changing weather (VenhoevenCS, interview). The pocket system was incapable of holding water, so irrigation was costly. Although basic knowledge existed, developers were still missing considerable knowledge to successful implement these systems.

The system failures created backlash on the public's perception of the system, but much was learned from evaluating the project of the Sportplaza Mercator, especially knowledge of maintenance and irrigation (VenhoevenCS, interview). However, the architecture company decided to no longer use this type of vertical greenery system. Now, the company is interested in systems with climbers. The failing projects formed an obstruction for the vertical greenery market: 'If an architect sees a death wall and does not get his product sold, he will doubt when using it again' (Sempergreen, interview). Developers, like Hurks, also learned from the Sportplaza Mercator. They deliberately chose a support system with climbers in one of their developments based on the LWS experience at the Sportplaza (Hurks, interview).

However, knowledge is not always available to the stakeholders, or there is disagreement about this knowledge. For instance, some vertical greenery professionals have incorrect knowledge and deliver failed projects (Sempergreen, interview). Other actors involved in the development, such as the municipality, have little knowledge of the consequences of a façade garden's depth. Façade gardens the municipality is currently installing are too shallow, causing many DIY applications not to achieve their desired results (NMT, interview). Moreover, many of the municipality's greenery is maintained by social projects, by people who do not have the sufficient knowledge (Gemeente Amsterdam, interview). This situation does not benefit the development of this form of greenery. The fact that stakeholders that are perceived as experts sometimes do not have the necessary knowledge is also not contributing to the development of vertical greenery.

Furthermore, knowledge of vertical greenery is lacking for non-experts and ambiguity exist. First, initiators are sometimes unable to distinguish specialized vertical greenery companies with knowledge and experience from the ones that do not have knowledge and experience. For the pilot project *een groen sloterdijk,* the municipality approached a greenery professional without proven experience with vertical systems (PvdD, interview). The poor system which the company selected was followed by failed projects, which worsened perception of the systems and might result in a negative feedback loop. Second, important stakeholders still have many fears related to vertical greenery, such as the damage caused by certain creepers, despite the scientific knowledge available stating that damage to facades by creepers will only appear in certain situations (PvdD; NMT; Ottelé, interview).

Thus, issues of uncertainty in Amsterdam are found in a lack of knowledge among non-experts and ambiguity in the knowledge available. The result is failing projects, which might increase fears and uncertainty.

5.2.2 Governing issues of uncertainty

The challenges described in the previous section are governed by the different stakeholders. Overcoming uncertainty around vertical greenery in Amsterdam can be accomplished through research and development. As Figure 20 illustrates, these two approaches are controlled by voluntary instruments, trading mechanisms and information communication.

Voluntary instruments

Citizens, building owners, and companies choose to develop vertical greenery systems. These voluntary instruments help develop these systems and build knowledge of technical features. Voluntary instruments can choose DIY application or a predeveloped system from a vertical greenery professional (professional application). If a voluntary instrument is outsourced, demand for the vertical greenery professionals and systems is created, initiating a trading mechanism.

Trading mechanism

In Amsterdam, the demand for vertical greenery is mainly controlled by actors voluntarily choosing vertical greenery. However, in rare cases, greenery can be obligatory. Incentives, in the form of government subsidies, and the DGBC labelling scheme make the system more affordable and generate more interest, increasing demand.

Vertical greenery systems are supplied by vertical greenery professionals in the economic network. This trading mechanism result in competition between the actors and causes innovation in the development of vertical greenery systems. Sempergreen, for instance, developed a system with little chance of failure in many climates and gained a leading market position (Sempergreen, interview). However, according to Ottelé, the innovation of and research on new systems has come to a standstill because prices are too high; the systems implemented now are not significantly different from those of 10 years ago (Ottelé, interview). Thus, market forces initiated by voluntary instruments and incentives foster the development of vertical greenery systems, contributing to knowledge on technical features.

Information

Information is communicated for both types of applications by many stakeholders across all networks aiming to spread knowledge and initiate actors to develop vertical greenery as a voluntary instrument. From the policy network, Rainproof is the only actor trying to inform citizens and companies about the benefits of vertical greenery, mainly in the context of water management (Rainproof Amsterdam, interview). The organization targets both professional and DIY application.

In the economic network, there is a clear distinction between the two types of applications. VHG is primarily communication on the professional application of vertical greenery. The association's newly published guide 'the living building', inspires and informs architects, developers, and planners on the social, economic, and environmental effects of greenery in, on, and around buildings (VHG, interview).

Considering the DIY application, Tuinbranche NL not only informs citizens about the effects of (vertical) greenery but also explains how to install DIY vertical greenery (Tuinbranche NL, interview).

Within the social network, many actors communicate information on vertical greenery. De Groene Stad targets the professional application, as it states on its website (De Groene Stad, n.d.). In addition, NMT aids citizens in the DIY application by communicating available knowledge on vertical greenery systems and helping citizens with their designs (NMT, interview). Furthermore, researchers communicate their findings on vertical greenery effects and technical features (Ottelé, interview).

5.2.3 Conclusion

Issues of uncertainty in vertical greenery originate in a lack of knowledge among experts and non-experts and ambiguity in the available knowledge. The latter seem to be formed by fears resulting from failed projects and incorrect information. These issues are addressed by different actors attempting to influence research and development on vertical greenery. Voluntary instruments, trading mechanisms, and information communication are used to initiate and foster research and development. Here, the social and economic actors are more prominent than actors in the policy network.

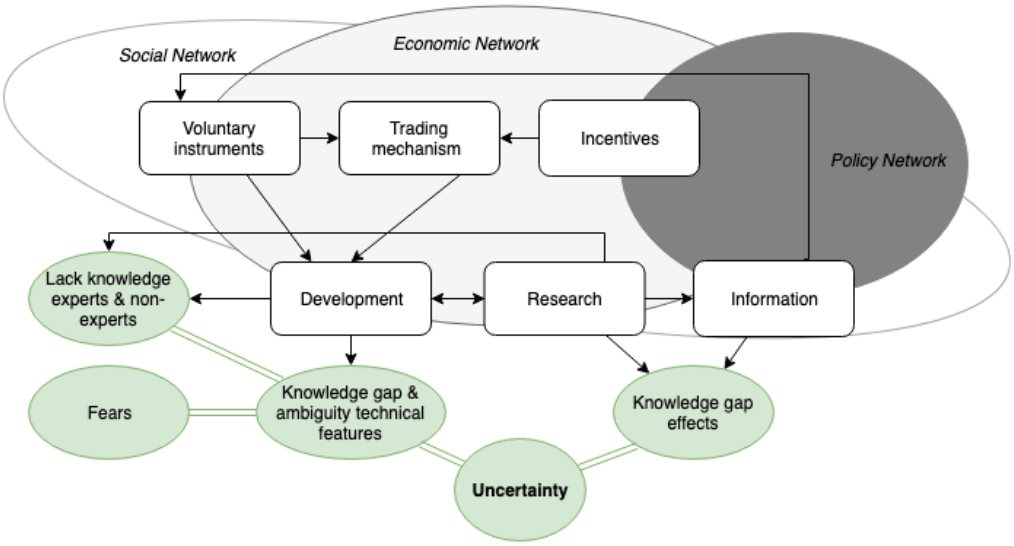


Figure 20: An overview of the governance instruments aiming to influence research and development to overcome issues of uncertainty. Source: this research.

5.3 Complexity: overcoming cost, maintenance, and legal issues

This section begins by elaborating the issues of complexity in vertical greenery. Section 5.3.2 then discusses the governance of these complexity issues.

5.3.1 Issues of complexity

Like Singapore, complexity challenges in Amsterdam appear to be related to the social interaction between the involved actors and their agendas. Aligning the stakeholders to choose vertical greenery has multiple challenges. The most important challenges, the mismatch between payers and receivers, the long-term maintenance, and existing legal barriers, are discussed in this section. An overview of the challenges in provided in Figure 22.

Mismatch payers and receivers

Similar to Singapore, in Amsterdam, there is a mismatch between the payers and the receivers. First, the price of vertical greenery systems is high (Sempergreen; Hurks; Ottelé, interview). This high price makes professional vertical greenery too expensive for most citizens, although the problem is partly solved by the DIY application and climbers (Tuinbranche NL, interview). For businesses, the professional application is still affordable, but some argue that the frugal Dutch culture hinders a willingness to pay for vertical greenery (VenhoevenCS, interview).

Second, the personal benefits of vertical greenery do not always outweigh the costs. Ottelé argues that the high price of the systems is obstructing a breakthrough, and many people are wondering why and for who they should develop these systems (Ottelé, interview). He explains that greenery has a small effect on many social, economic and environmental aspects, and other techniques can sometimes address one problem more effectively. Moreover, the payer is often not the one benefitting most. For green walls on the outside of a building, the benefits are less visible for the owners and residents, but these walls create a positive atmosphere for the neighbourhood, which results in advertisement (Sempergreen, interview). Vertical greenery systems are thus perceived as expensive, and whether the costs outweigh by benefits is unclear.

Long-term maintenance

The fact that vertical greenery needs long-term maintenance often increases complexity. Some systems require more maintenance than others. According to Sempergreen (interview), most people misjudge long-term maintenance needs, especially when choosing pot or pocket systems. In these systems, the irrigation washes away the soil, removing the nutrients. The dying plants often need replacement, which do not fit the maintenance budget. In the end, the maintenance contract will be offered to professionals with a lower price. However, these professionals cannot fix the problems.

Features to execute or ease maintenance are forgotten in the design or deliberately excluded to save expenses. For the Sportplaza, the developer decided not to include a tool to capture rainwater for

irrigation of the walls to save an additional 10,000 euros on the whole project (VenhoevenCS, interview). However, after installation, water consumption was extremely high and increased the end users' costs.

Some stakeholders do account for these factors, however. Developers, such as Hurks, explain that the maintenance costs are for the investor or client, and therefore, these costs must be carefully calculated. If the costs are too high, investors will be less willing to purchase the building, which might necessitate a reduction in the price (Hurks, interview). The investor includes the maintenance expenses for vertical greenery in service costs charged to the residents. Higher costs can reduce the demand for the building unless people are willing to pay for the project, like Bosco Verticale.

Much of the maintenance for the DIY application depends heavily on the citizens and residents, which can cause difficulties in the long-term continuity of the vertical greenery. In larger projects, citizens who voluntarily maintain greenery can be unpredictable:

> In the spring everybody is enthusiastic, but from June onwards many people stop showing up. It is very important to create a social shell around it, but this is difficult in cities. It is not impossible, but it is difficult and results in less quality. (Green City Buzz, interview)
>
> .

Façade gardens may be even more difficult since residents have to maintain these gardens themselves and might lose interest or move. In addition, people constantly need to gain knowledge of the maintenance, which is not efficient (NMT, interview).

Legal aspects

Legal aspects make the development and maintenance of vertical greenery more complicated. First, to develop of vertical greenery different properties may need to be crossed, especially for DIY greenery. Many estates in Amsterdam are on the boundaries of the property line between private property and the municipalities property (Green City Buzz, interview). For ground based vertical greenery, such as many DIY projects, using public area adjacent to the building is necessary, despite these areas not being officially one's own property. Moreover, not all stakeholders wanting to install vertical greenery own all, or even part of, the property. These stakeholders could be renting an apartment or own an apartment on the second floor. For the installation of vertical greenery, obtaining approval from all property owners is important. Large (social) housing cooperations often do not allow people to grow or attach anything to the buildings' walls, causing a significant obstruction to vertical greenery development (NMT, interview).

Second, permission of other stakeholders, such as the companies owning sub-surface infrastructures, may also be necessary. A Green City Buzz project was completed with some risk since the municipality did not distributed a permit given 21 cable companies could still object (Green City Buzz, interview). Similarly, a property identified as a monument cannot have any aesthetic features

changed without approval from the municipality (Gemeente Amsterdam, 2015). Therefore, the installation of vertical greenery is prohibited for monuments. These parties' involvement in the development of (ground bound) vertical greenery makes the process complex.

Third, agreements on protection of vegetation can mean vertical greenery is chosen les often. A political party pursuing greenery in the city is focused on trees because of their legal protection (PvdD, interview). According to the party, trees provide more securely available greenery in the long-term since one cannot remove a tree without a permit. Vertical greenery, however, is not offered the same protection. According to NMT (interview), legal protection of vertical greenery is possible under the list of monumental trees and shrubs, but this protection can occur only after a certain number of years.

5.3.2 Governing issues of complexity

Complex challenges present in the development of vertical greenery are influenced in a variety of ways by all networks. This section discusses regulations, incentives, information communication, design practices, and lobbying as methods to govern problems of complexity. These tools are discussed consecutively, and an overview is provided in Figure 21.

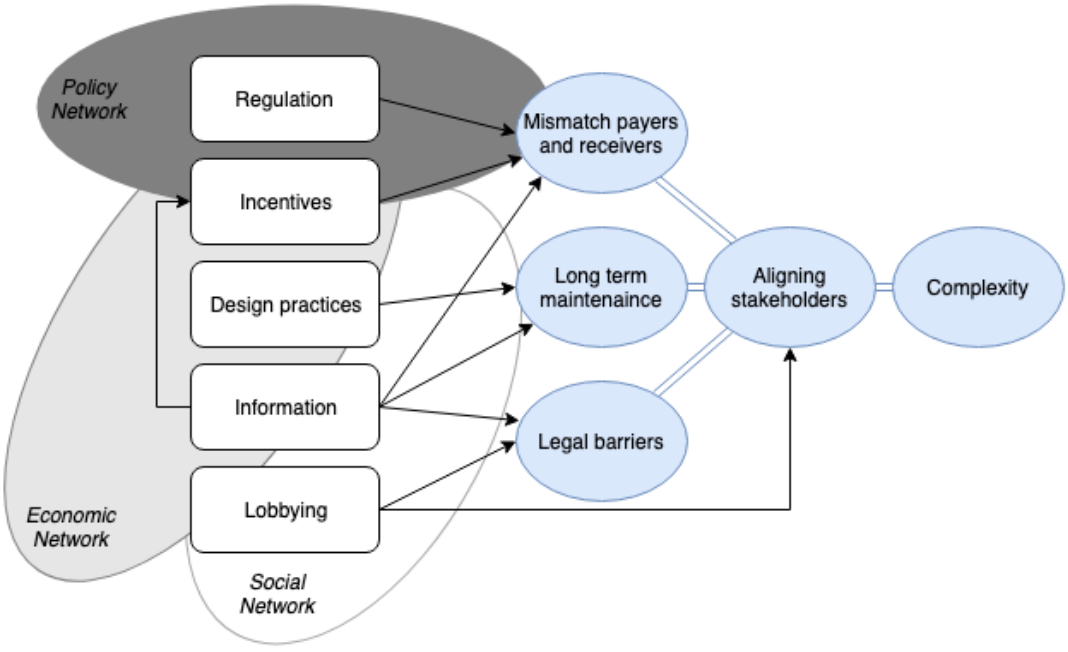


Figure 21: An overview of the governance instruments that help overcome issues of complexity. Source: this research.

Regulation

As explained, in rare cases, the municipality prescribes vertical greenery for a specific building project. This occurred for a building named the Spakler, displayed in Figure 22, developed by Hurks (Hurks, interview). Although no officials could confirm this information, the green wall was supposedly prescribed to cover the parking garage, which is visible from many of the neighbouring apartments.

Since the Spakler developers had less interest in making this part of the building green than did the residents of the surrounding apartments, Spakler serves as an excellent example of how to govern the mismatch between payer and receiver.

Incentives

Other policy tools intended to govern the mismatch between vertical greenery payer and receiver are the subsidy incentives, labelling, and 'sustainable' tenders. The municipality's subsidies, for vertical greenery specifically or add greenery to a neighbourhood, directly influence the cost and can change the payer's consideration of costs and benefits (NMT, interview). Moreover, the municipality's help with the installation of the base for façade gardens also increases the incentives for people to install these gardens.

Labels, like BREAAM by the DGBC and LEEDS, can also adjust this consideration by increasing the benefits of vertical greenery development. Clients, developers, and architects are interested in putting these labels on their buildings to increase the buildings' value (Sempergeen, interview). However, these labels are expensive and sometimes lag behind in knowledge on new systems (VenhoevenCS; Ottelé, interview).

In addition, tenders by the municipality can create more incentive to develop vertical greenery. Sustainability is a 'hot topic'; many municipalities want to be part of this trend. In some cases, municipalities will prescribe certain sustainability measures and features, such as energy efficiency or social sustainability. In other cases, municipalities state in the tender that the building must be sustainable, respond to climate change, or contribute to the municipality's sustainable development goals (Hurks, interview). These tender requirements causes developers to compete and fosters innovation. Although vertical greenery is only a small part of sustainability measures, these incentives help overcome the mismatch between payers and receivers.

Information

The communication of information is used to govern all three challenges to stakeholder alignment. Communication on the effects of vertical greenery is performed by actors in the policy, economic, and social networks. For example, Rainproof Amsterdam communicates through campaigns, network management, and events, (Rainproof Amsterdam, interview). Other communication includes the book on the living building by VHG (VHG, interview) and publications from Ottelé (Ottelé, 2011). Other

actors use specific benefits to 'sell' vertical greenery: Green City Buzz tries to use the economic effects of vertical greenery to interest businesses (Green City Buzz, interview) but state that validation of the effects is still difficult and needs to be researched further. By emphasizing the benefits, vertical greenery costumers' considerations of costs and benefits can change.

Information communication is also used to make better use of other policy tools. For instance, NMT (NMT, interview) helps citizens with their applications for subsidy for (vertical) greenery. These subsidies were not always known to citizens, or if known, eligibility requirements were unclear. The organization actively communicates this information to citizens, advising them how they can change their applications or design to qualify for a subsidy.

Last, information is communicated on technical features, mostly for the DIY application. This information can help people overcome maintenance problems and legal challenges. Tuinbranche NL informs citizens how to develop and maintain vertical structures via handbooks on its website (Tuinbranche NL, interview). Furthermore, NMT informs citizens how to design their greenery in an easily maintainable way. One piece of advice is to dig the façade garden a bit deeper after the government installs because the extra space for the roots will make the plants more resilient (NMT, interview). Although NMT has also communicated this advice to the municipality, no action by the municipality has been taken to prevent this. Moreover, NMT explains to citizens how they can install vertical greenery when the housing corporation objects. By installing a support system that does not touch the wall, the greenery will stay on the ground of the municipality that allows it. Thus, the housing cooperation cannot remove the system. This information helps to improve maintenance and surpass legal challenges.

Good design and maintenance practices

Actors that professionally install vertical greenery systems are also is trying to overcome complexity in vertical greenery. For example, Sempergreen tries to create as many successful projects as possible. The company helps architects incorporate the walls in their designs in practical and economic ways (Sempergreen, interview) and visit at least six times a year for check-ups. Moreover, Sempergreen's well-developed system includes a service that monitors its green walls over the whole world. Based on the monitors, extra maintenance is directed. Customers can complete the maintenance themselves if they have training. According to Sempergreen, everyone in the industry should deliver successful projects because failure disturbs the market.

Other actors developed different ways to overcome the problem of maintenance. Green City Buzz, for instance, connects with locals with experience maintaining greenery and involves them in its projects (Green City Buzz, interview). These people have the chance to briefly provide maintenance on the vertical greenery a few times every week, instead of once every two months. Having locals with experience take care of the greenery consistently will improve the greenery's quality and can prevent expensive renovation of systems, which increases costs.

Lobbying

Lobbying is used by the economic and policy networks to align stakeholder and change legal barriers. For instance, VHG approaches architects, developers, and facility managers to convince them to incorporate greenery in and on their buildings (VHG, interview). The organization's goal is to have all actors incorporate greenery at the start of a project instead of at the end. This shift would save considerable time and money and increase the possibilities for greenery integration. Moreover, VHG is involved in many 'green deals', mostly occurring at regional levels, and projects with a variety of municipalities. On the national level, VHG is involved in the *Deltaplan Ruimtelijke Adaptatie,* policy to adapt the public space to cope with climate change: 'Until now, big chances in the practices required a chance in the legislation or building regulations. But the current government is holding back, they prefer deregulation' (VHG, interview).

Other parties are also involved in lobbying. Tuinbranche NL (interview) promotes its vision of a healthier, greener environment at different organizations but states that the government perceives it as too much of an economic entity. Therefore, the organization does not receive much financial support. Additionally, Green City Buzz works to convince the association of municipalities to change the legislation for the sub-surface cable companies who have the possibility for objection for ground based vertical greenery (Green City Buzz, interview). Lobbying is, therefore, used by the economic and social networks to directly align stakeholders and to reduce legal obstructions.

5.3.3 Conclusion

Issues of complexity in development and maintenance of vertical greenery exist in Amsterdam. As in Singapore, the complexity of aligning all stakeholders to the common goal is the main challenge. The mismatch between payers and receivers, the long-term maintenance, and legalities are the greatest barriers both for the DIY and professional greenery applications. These barriers are addressed by actors from all networks. Regulation is introduced in rare cases. Most influence is gained through incentives, information, and good design and maintenance practices. Actors within the social and economic networks try to influence the stakeholders directly or change the legal barriers via lobbying.

5.4 Inequality: self-governing access

This section evaluates the governance of vertical greenery in Amsterdam on issues of inequality. Section 5.4.1 discusses the issues of inequality in accessibility and quality of vertical greenery. In Section 5.4.2, the tools and actors governing these issues of inequality are introduced.

5.4.1 Issues of inequality

To better understand the governance of vertical greenery, a clear understanding of the problems is essential. Thus, this section introduces two main inequality issues: accessibility to vertical greenery and quality of vertical greenery. These issues are discussed consecutively.

Inequality in accessibility

Vertical greenery in Amsterdam is relatively accessible for most people, but there is still room for improvement. There is a lack of specific research, but personal observation indicates that the DIY application makes vertical greenery available for many people, and most DIY vertical greenery is located in residential areas. In areas with more residents than passers-by, there is a sense of ownership of the street and greenery provision. This sense of ownerships encourages DIY application (Gemeente Amsterdam, interview). As explained, governance in Amsterdam is built on a culture of participation: in areas with many residents, residents are expected take care of the greenery themselves. This culture can be seen at GWL terrain, de Pijp, de Weesper en de Plantagebuurt. In areas with many passers-by and a fewer residents, other actors use professional application of vertical greenery, for instance, at the Hyatt Residency and the Hotel Kimpton de Witt. However, these professional applications are fewer than the DIY applications.

More residents does not guarantee more vertical greenery. Greenery also depends on other neighbourhood features. For instance, in Buitenveldert, a residential area, there are significantly fewer requests for façade gardens than in other areas in southern-Amsterdam. According to NMT (interview), this lack is the result of the extensive public green spaces available, caused by modernist planning. More greenery in the neighbourhood can thus mean a lesser interest in vertical greenery. Furthermore, in socially weak neighbourhoods, citizens with relatively low educations and incomes are often not interested in greening their streets (Gemeente Amsterdam, interview). These individuals appear to have other priorities. Moreover, neighbourhoods with high social cohesion are often more able to protect and influence greenery (PvdD, interview). For example, NMT began as a citizen's initiative in the southern neighbourhoods of Amsterdam in the 1990s. Now, the association is professionalized and assisted by the municipality. In other neighbourhoods, citizens initiatives were never financially supported by the municipality and no longer exist (NMT, interview).

Accessibility, especially in the DIY application, also depends on the resources that residents must find themselves. According to NMT (interview), it is not difficult to realize vertical greenery: in addition to a place to grow, one needs some knowledge of plants and little capital to acquire the plants.

Of course, these are not resources that every resident possesses. Moreover, residents need an interest in greenery, which is not always present. In many cases, DIY application of vertical greenery is first performed by those with an existing interest in greenery and the environment (Gemeente Amsterdam, interview). According to research by the Tuinbranche, the only group that it significantly interested in gardening and greenery are people over the age of 45 (Tuinbranche NL, interview). However, a new trend indicates that younger individuals also spend more on plants than they did before.

Thus, the DIY application of vertical greenery appears more in residential areas where there is a sense of ownership. However, this factor is not present in every residential area; vertical greenery also depends on the availability of conventional greenery, social economic status, social cohesion, and personal resources. In areas with few residents, other actors sometimes install vertical greenery, but this practice is still rare.

Inequality in quality of vertical greenery

Differences are also apparent in the quality of greenery. Higher quality systems are often more available for those who can afford them. As explained, the LWS and pot systems have higher environmental benefits and are thus also more available in Amsterdam for actors that can afford a professional application. However, Ottelé (interview) states that in the Netherlands the differences in benefits between the systems are minor. According to Sempergreen (interview), the actors that can afford more expensive systems are often businesses since they see the expense as an investment. Although companies consider how they can reduce the price of their systems, they do not search for cheaper systems: 'The product that we deliver has, in our opinion, the best quality available for this price. A cheaper system will cause a reduction of the quality, which is something that we do not want' (Sempergreen, interview). Therefore, quality is more important in professional application, even at a higher price.

Systems more readily available for people are often of lower quality: 'Residents usually have two left hands when it comes to gardening: the knowledge is lacking although their enthusiasm causes that they can see the difference between their plant and weeds at a certain point' (Gemeente Amsterdam, interview). Furthermore, Green City Buzz states that enabling citizens to install greenery themselves sometimes result in sloppy greenery with incorrect maintenance: 'Every city has targets which are mainly quantitative, but these are rarely measured or achieved. Qualitatively, there are little ambitions and often only touched upon in political games' (Green City Buzz, interview).

The inequality in vertical greenery quality is thus caused by better systems being more expensive. Conversely, the systems with fewer environmental benefits are often cheaper and more available. Moreover, the municipality appears more concerned about quantity than quality.

5.4.2 Governing issues of inequality

Issues of unequal access to and quality of vertical greenery is governed by a variety of actors using incentives, information, voluntary instruments, and design and maintenance practices. These tools are discussed on this section and illustrated in Figure 23.

Incentives

First, municipality's incentives for vertical greenery increase the number of people who can afford this option. Although financial incentives can halve the installation costs, vertical greenery can still be expensive. The municipality assisting in the development of DIY greenery by installing the base for a façade garden is a more effective incentive (NMT, interview). This practice directly addresses the problem of resources and helps make the systems more available to the greater public, increasing accessibility.

Information

Parties from all networks provide information on greenery to boost the residents' resources and stimulate DIY application of vertical greenery. Within the policy network, Rainproof Amsterdam provides information on vertical greenery's positive effects and possible methods of installation (Rainproof Amsterdam, interview). From the economic network, Tuinbranche Nederland assists by providing a checklist for the installation of vertical greenery (Tuinbranche Nederland, interview). Within the social network, NMT not only helps residents to design their facades, the organization also assists residents with their applications for subsidies and other related requests (NMT, interview). Moreover, NMT advises individuals on the selection of plants based on the association's own research.

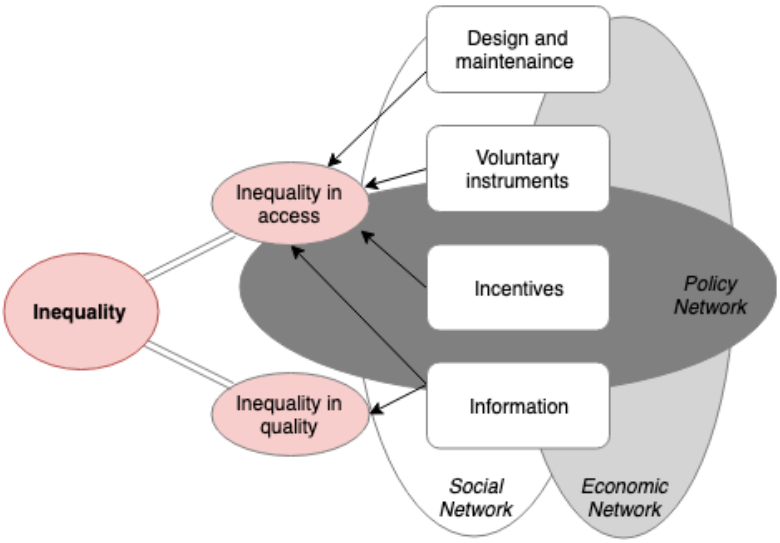


Figure 23:An overview of the governance instruments contributing to overcoming issues of inequality. Source: this research

Voluntary instruments

Voluntary development of vertical greenery helps accessibility. The possibility for DIY application makes vertical greenery available to more people, given greenery is rarely integrated into a building. Despite architects and developers often draw greenery in the design, it is seldom realized in the development process (Hurks, interview): 'In the end, for these kinds of projects it very much depends on the residents. We are the developer and building: if it is sold, we are not responsible for the maintenance' (Hurks, interview).

As stated, quality of vertical greenery seems to be subordinate to the quantity for DIY application, although this situation might change. With Stadswerken, NMT is working to improve the quality of DIY greenery (NMT, interview). The installation of deeper façade gardens would help with this goal. Furthermore, when these residents have access to the right knowledge, they can also improve the quality of the greenery.

In some cases, professional application can make vertical greenery more available to residents while ensuring greenery quality. For example, the Harmoniehof, a housing cooperation ensures that the creepers directly on the façade are well maintained on most of their properties (NMT, interview). Residents pay a small fee for this service. Figure 24 illustrates the vertical greenery at Harmoniehof in 1935, a decade after the building was finished.

Figure 24: Vertical greenery at the Harmoniehof in 1935. Source: https://www.arcam.nl/harmoniehof

Design and maintenance practices

Design and maintenance practices also influence the availability and quality of vertical greenery. In general, the lower the price of a system, the more people can afford it. As stated, companies such as Sempergreen aim to reduce the price of their current systems (Sempergreen, interview). However, since the current systems delivers the best quality, these companies do not wish to bring cheaper, lower quality systems to the market. For example, developer Hurks chose a support system with creepers to keep prices low, guarantee quality, and prevent failed facades, such as at the Sportplaza Mercator (Hurks, interview). These systems could be incorporated into both in high and low budget projects, depending on the developers' priorities. Of course, the chance of greenery incorporation is higher with a larger budget, but other actors also argue that low-tech solutions will make greenery more available for more groups (VenhoevenCS, interview; Ottelé, interview). These systems are more robust and create great opportunities for low-rise buildings.

5.4.3 Conclusion

The focus on active participation of citizens means the accessibility (and quality) of vertical greenery is primarily in the citizens; control. These citizens, and their resources, decide whether they want to develop greenery and whether they can maintain a certain quality of greenery. Therefore, socially strong neighbourhoods with low conventional greenery and more residents than passers-by have much vertical greenery. For professional application, availability of vertical greenery systems often clashes with affordability since cheaper system are generally of lower quality. The more complicated systems are thus more often used by actors, such as companies, that see the greenery as an investment.

6. Evaluation of empirical results

Using the results presented in the previous chapter, this chapter compares the two case and explains them using the conceptual framework. In Section 6.1, the similarities and difference between the issues and governance of uncertainty are discussed. Section 6.2 compares the issues and governance of complexity. In Section 6.3, both cities' approaches are evaluated on their inclusivity and, finally, all three themes are combined, and their connections are reviewed in Sections 6.4 and 6.5.

6.1 Uncertainty: political versus technical problems

In both Singapore and the Netherlands, a lack of knowledge of the effects and of the technicalities of vertical greenery obstructs vertical greenery's development. In Amsterdam, there are also issues of ambiguous knowledge of the technicalities. Based on the four types of uncertainty problems presented by Koppejan and Klijn (2004), issues of uncertainty are rooted in political problems in Amsterdam and in technical problems in Singapore.

The difference between these problems is the way these issues of uncertainty are governed and solved. Research and development are used in both cities to overcome issues of uncertainty. However, in Singapore, the government's top-down approach creates a network of government institutions and market stakeholders that actively provide each other with feedback and thus develop vertical greenery together. Although the government has a significant voice in this feedback, this practice is a form of joint production of meaning, as explained in the conceptual framework. Since knowledge development in Amsterdam was scattered, rather than collectively, diverging frames of reference causes issues of ambiguity.

In Singapore, governance arrangements aimed to complete centralized visions using public-private partnerships, which also contributes to the lack of diverging frames. By involving and incentivizing the market and assisting vertical greenery professionals, the government uses public-private partnerships to influence the market with its skyrise greenery targets. This strategy is similar to the process of internalization, described by Vermeulen (2002) in the conceptual framework, and surpasses issues of uncertainty in social and political support.

Singapore's government supported vertical greenery industry led to a lack of competition and innovation in the vertical greenery systems, not always establishing high quality systems. However, in Singapore's tropical climate, vertical greenery possibilities are higher and even poor-quality systems are more likely to survive. The long-term survival of failed system in the tropical climate delays the first major backlash as a result of ill implemented systems. Therefore, the whole vertical greenery industry was more mature when the first backlash occurred. The maturity of the industry, combined with the support of the government, made Singapore's vertical greenery industry able to survive the backlash. In Amsterdam, however, the difficult climate caused ill-implemented systems to quickly fail. Although it fostered competition and innovation for successful systems, the immediate backlash diminished the

popularity of vertical greenery as a whole. Many vertical greenery professionals in Amsterdam did not survive the backlash.

Regarding the cities' technical and political problems, while Singapore's governance networks working to overcome their technical problems, Amsterdam's networks have done little to resolve their political problems. In Singapore, the knowledge gap between disciplines is addressed by the economic and policy networks, especially in providing transdisciplinary knowledge of vertical greenery systems. Moreover, government research institutes work with universities to research greenery's effects. Recently, the universities have begun contributing to the development of vertical greenery systems. In Amsterdam, the lack of knowledge about vertical greenery system is addressed by the economic network and the uncertainties regarding the effects of vertical greenery are addressed by scientific knowledge from researchers. However, beside the provision of information and minor lobbying, there is no real attempt to gain political or social support for vertical greenery. Thus, the governance arrangements in Amsterdam do not adequately addressing the problem.

For governance features, the results indicate that tools directly contributing to overcoming issues of uncertainty are influenced by other policy instruments. In Singapore, research, development, and joint production of meaning are influenced by building institutions, incentives, voluntary instruments, trading mechanisms, and provision of information. These tools are primarily achieved by the policy and economic networks in top-down or public-private governance arrangements. In Amsterdam, research and development are pushed by incentives, voluntary instruments, trading mechanism, and the provision of information, all through different networks. Here, issues of uncertainty are influenced more by interactive and self-governance arrangements.

However, interactive and self-governance arrangements might not be able to successfully overcome issues of inequality. In particular, non-experts' acceptance of knowledge is an underexposed topic, as Maglicco (2018) also found. Given vertical greenery is a partial solution to many problems, overcoming its uncertainty cannot be successfully managed by the social and economic network. Therefore, the involvement of the government, actively advocating for research, development, and establishment of a network will contribute more to overcoming uncertainty in the development of vertical greenery.

Issues of uncertainty still pose a barrier for the development of vertical greenery. In Singapore, uncertainty seems to be a technical problem since the city has a solid basis of scientific knowledge and enough political support as a result of internalization. The government's top-down approach directly and indirectly helps encourage research, development, and the creation of a network. Now, research and development are focused on improving the application of vertical greenery by bridging disciplines. In Amsterdam, issues of uncertainty in vertical greenery are rooted in politics. Although a foundation of scientific knowledge exists, societal interest and political support for vertical greenery is lacking. Many actors, especially non-experts, do not have knowledge of vertical greenery. Issues of uncertainty in Amsterdam are addressed by interactive or self-governance, making the social and economic networks

important. However, these networks involvement does not rectify the lack of political and societal support.

6.2 Complexity: centralized versus participatory governance

Issues of complexity between the different actors in the development of vertical greenery are present in both Amsterdam and Singapore. The leading barrier to the development of vertical greenery is stakeholder agreement. In both cities, the mismatch between the payers and receivers and the long-term maintenance cause some actors to not be in favour of vertical greenery. In Amsterdam, a third factor forms a barrier: legalities.

The governance arrangements used to overcome these issues are different in Singapore and Amsterdam. First, the cities have different initiating actors. In Singapore, the government, inspired by different factors, took the lead in establishing vertical greenery. The vision of a city in a garden, combined with new sustainability interests and the proven feasibility of vertical greenery use in private projects, made the government to believe in the form of greenery. The government translated vertical greenery implementation into a top-down vision, integrated in many policies, to develop the country. As Singapore's liveability framework indicates, to execute these visions, the government involved different market actors in a network and used their feedback for improvement. According to O'Toole and Montjoy's (2017) theory, explained in the conceptual framework, the governance of vertical greenery in Singapore is a hybrid between centralized governance and public-private governance. These results support Han (2017), who states that this 'authoritarian environmentalism' is in line with the legacy of a development state and thus rooted in history.

In Amsterdam, the initiating actors are scattered. Vertical greenery is developed by the economic network and the social network, with some assistance from the government in the policy network. On one hand, vertical greenery professionals, together with scientists and greenery enthusiast, are responsible for the current development of the systems. On the other hand, the participatory culture in Amsterdam led social organizations with citizens to work on the local level for many years to promote and establish (vertical) greenery. Therefore, the governance of vertical greenery in Amsterdam, according to O'Toole and Montjoy's (1984) theory, is between interactive governance and self-governance. Here, the government is building on a participation culture, which was also found by Driessen et al. (2012).

The contrast in initiating actors between the cities also led to a difference in vertical greenery application. In Singapore, the most common vertical greenery development method is professionals installing greenery as part of a development or building renovation. Since Amsterdam's governance is shaped by its social and economic network, these networks encourage the application of vertical greenery by citizens, or DIY application. This application requires fewer stakeholders and, therefore, directly addresses the problem of aligning multiple stakeholders. The lack of citizen involvement,

private property, and empowerment prevents DIY application in Singapore. Therefore, the governance approach has an influence on the physical shape of vertical greenery development.

However, DIY application has downsides. The bottom-up approach makes it more complicated to govern all vertical greenery in the city, for instance, in terms of quality. Moreover, in newly developed areas, opportunities are missed since greenery is not incorporated into the city planning. Furthermore, the vertical greenery development is dependent on citizens' (and companies') willingness to participate, which means that a lack of resources or a change in priority prevents further development of greenery and jeopardizes existing greenery's longevity.

The issues of complexity are managed similarly in the two cities but by different actors. In Singapore, the government has imposed clear regulations, created incentives, and provides plenty of information; in Amsterdam, regulation is incidental, incentives are formed by the policy and economic networks, and information is provided by non-governmental actors. Moreover, since the government is not the initiating actor, stakeholders in Amsterdam lobby for better regulations. In both cities, however, good practices are used to show stakeholders the possibilities and feasibility of vertical greenery. In Singapore, these good practices are also performed by the government. Additionally, vertical greenery systems are innovated to reduce maintenance issues and increase individual benefits of the systems. Singapore leads in innovation.

The conceptual framework can be used to determine the success of the government policy instruments. O'Toole and Montjoy (1984) explained that the absence of the government as initiating actor is apparent in a situation with little government coordination efforts, as in Amsterdam. Moreover, vertical greenery development in Amsterdam seems to be mainly governed by voluntary instruments and only has two of Glasbergen's (1992) six policy instruments: spatial regulation and subsidies. Therefore, governing from the policy network cannot be identified as one of the models that Glasbergen distinguishes (legal control model, economic control model, communication model, and spatial control model). On the contrary, Singapore's governmental approach closely resembles the models. Therefore, Singapore uses a Norm-Taxation Stimulation approach in combination with the provision of information. For this approach, different instrument models are combined to overcome their limitations and is, according to Glasbergen (1992), promising in effectively addressing environmental issues.

Despite the similar barriers for vertical greenery development in both cases, each city deals with these barriers in different ways. In Singapore, the hybrid centralized and public-private governance with extensive governmental policy instruments contributed to overcoming issues of complexity through obligatory vertical greenery development and assistance in many necessary features. This approach resulted in large-scale, professional vertical greenery application. In contrast, Amsterdam has a combination of interactive and self-governance on vertical greenery, initiated by the economic and social networks. Despite the lack of strong governmental policy tools, the two networks in Amsterdam established a niche of vertical greenery application. As a result of the participatory culture, this niche includes both professional application and DIY application of vertical greenery. For the DIY application,

issues of complexity are reduced, increasing usage. Thus, both top-down and bottom-up governance arrangements can deal with issues of complexity in development of vertical greenery.

6.3 Inequality: accessible but low-quality vertical greenery

This research also evaluated how inclusivity is handled regarding the development of vertical greenery. Given their different governance and application, Singapore and Amsterdam both have unique ways of dealing with unequal availability of vertical greenery. In both cases, much of the vertical greenery is available in the public sphere.

In Singapore, the incorporation of greenery in city planning is impressive. The city in a garden idea has truly been realized and the amount of green space available for everyone on this small island is exceptional. In terms of vertical greenery, the regulations and the incentives to provide publicly accessible green spaces helps make greenery integrated in buildings accessible to all. The fact that the state's housing cooperation tries to incorporate vertical greenery also benefits its overall establishment. Thus, top-down planning can lead to equal accessibility of greenery.

Nonetheless, Singapore's system has some points of improvement. First, the systems installed in the public housing stock are generally of lower quality than the professional systems used in other projects. Furthermore, the systems are usually installed on parking garages, reducing the benefits for the actual residential areas. Second, the overall state-controlled planning left citizens less powerful regarding the provision of greenery in their surroundings. Citizens can occasionally vote for vertical greenery or become involved in community gardening, but these opportunities appear to be token gestures, created for the sake of participation, rather than designed to empower citizens to develop vertical greenery on their own. As stated in the introduction, Han (2017) argues that this lack of participation in decision making is an important aspect of inequality. However, citizens may not want to participate since many prefer to stay inside and might be satisfied with the current amount of greenery.

In Amsterdam, participation and DIY greenery installation are present. Here, the lack of government support makes citizens and companies responsible for securing the accessibility and quality of greenery. This method and the freedom to determine a preferred way of developing vertical greenery has fostered its development and made it more available to citizens. However, in neighbourhoods with limited ownership, fewer resources, or a minor interest in the development of vertical greenery, vertical greenery is generally not present. Moreover, this approach did not benefit the quality of the vertical greenery installed because development depends on the citizens' knowledge, which is often less than that of vertical greenery experts.

In terms of quality, the cities are similar. Because the systems using creepers are more affordable and easier to install for non-experts, these systems are often applied in situations with fewer resources. However, system using creepers may provide fewer environmental benefits, creating inequality. The quality of vertical greenery is not extensively governed. In Singapore, quality of greenery is incorporated into a set of regulations on leaf density. In Amsterdam, parties in the social, economic, and policy

networks try to improve the quality of systems and application through innovation and information, but poor feedback loops sometimes create challenges for quality improvement.

Top-down and bottom-up governance approaches address equal accessibility in vertical greenery in different ways. However, both attempt to make vertical greenery accessible for everyone. In general, these strategies work, but there is still room for improvement. Often the quality of these vertical greenery system is lower when fewer resources are available. Additionally, governance of vertical greenery system quality is not extensive.

6.4 Connecting uncertainty, complexity, and inequality

Although the themes of uncertainty, complexity, and inequality related to vertical greenery were separately discussed in this research, in reality, they are connected. This section explores the relationship between these issues and the governance arrangements that influence them and discusses how these relationships contribute to or obstruct the development of vertical greenery.

First, issues of uncertainty have a central role in vertical greenery development and thus need to be overcome. While scientific knowledge is necessary to accentuate the unseen effects of vertical greenery and justify its existence, knowledge also has to ensure that the visible elements, the vertical greenery itself, is successful. Many interviewees mentioned the importance of good practices based on knowledge and experience for the continuation and trust in vertical greenery. Moreover, to overcome legal barriers, the right knowledge and political support are vital. The policy instruments governing issues of complexity and inequality thus highly depend on available knowledge and societal support. Therefore, overcoming issues of uncertainty is imperative for stimulating vertical greenery developed.

Second, governing arrangements focused on improving issues of complexity or inequality can also influence each other. For instance, the involvement of citizens as stakeholders in overcoming issues of inequality affects issues of complexity. In Singapore, involving citizens increases the complexity in decision-making processes since citizens can obstruct the whole process. In Amsterdam, governing one theme can affect the other theme: DIY application makes vertical greenery available to many people, but it makes certain parts of vertical greenery development, such as quality improvement, more complex. Thus, including citizens to foster equality may or may not have a negative effect on issues of complexity.

Similarly, using more centralized governance approaches to combat issues of complexity can affect the issues of inequality. Given the lack of power among citizens, these approaches could, theoretically, result in unequal access to vertical greenery. In Singapore, however, unequal access does not occur: the centralized governance results in wide availability of vertical greenery. Nevertheless, the way issues of complexity are handled make the citizens passive and not empowered to shape their neighbourhood or city.

Fourth, having more stakeholders involved in governing issues of complexity or inequality can indirectly influence uncertainty. As explained, stakeholders each have their own knowledge and experience using vertical greenery, which can be positive, negative, or neutral. Having more actors

involved means that there are more visions on vertical greenery. Although sharing visions in the form of a joint production of meaning can help overcome uncertainty, when poorly managed, the practice can result in more confusion, increasing uncertainty issues. Thus, directly or indirectly governing issues of complexity or inequality can, in some situations, unintentionally lead to more uncertainty.

The themes of uncertainty, complexity, and inequality are interconnected. Governing issues inside one theme can increase or obstruct the other barriers. Addressing issues of uncertainty appears to be the cornerstone in the whole governance process. Approaches dealing with issues of complexity and inequality rely on knowledge and societal and political support. Therefore, for successful stimulation of vertical greenery, uncertainty must be correctly addressed. To successfully govern vertical greenery on the mentioned themes, awareness of their interconnected characteristics is crucial.

6.5 Governance arrangements contributing to the development of vertical greenery

Different forms of governance can help overcome the issues of uncertainty, complexity, and inequality in the development of vertical greenery. Regarding issues of uncertainty, interactive and self-governance can foster research and development through competition and innovation. However, the social and economic networks are not able to deal with the lack of political and societal support. Therefore, to deal with issues of uncertainty, the government should be involved. Top-down or centralized governance can, while using public-private agreements, help to reduce issues of uncertainty via knowledge gathering, network management, and joint production of meaning. Moreover, by enforcing vertical greenery through regulations, issues of social support are bypassed. However, strong government involvement can disturb market forces, meaning that poorly developed systems have more opportunity to survive, which is undesirable.

To cope with complexity issues, different governance arrangements have been developed, with varying results. Centralized or public-private governance in the form of regulations and incentives directly address the issues of stakeholder alignment, costs, and maintenance. The result may be professionally applied vertical greenery, where large scale projects are an integrated part of building practices. When little political support exists, self- or interactive governance can help people cope with problems of cost and maintenance by downscaling. In this situation, vertical greenery is developed by companies and citizens, resulting in professionally applied vertical greenery, on one side, and DIY vertical greenery, on the other side. However, this bottom-up approach depends greatly on the willingness and resources of non-state actors. One problem in situations in which vertical greenery is governed mainly by the social and economic networks is possible legal barriers, given the lack of political support. By means of lobbying and provision of information, this problem might be solved, but strong political and social support is more effective.

Issues of inequality in vertical greenery accessibility and quality can be addressed by both top-down and bottom-up types of governance. Self-governance allows companies and citizens to decide on vertical greenery development, increasing their autonomy. However, often marginalized groups might

not be capable of self-governing their vertical greenery if they lack resources or interest. Therefore, despite self-governing making vertical greenery available to more citizens, this governance type can still cause new issues of inequality. Additionally, this type of governance does not contribute to the quality of vertical greenery since citizens have to create vertical greenery by themselves, and maintaining a standard is difficult. Centralized and public-private governance are also able to guarantee decent quality vertical greenery for many through regulation and planning. The danger is that citizens become passive, lacking power.

Despite discussing these issues separately, the themes of uncertainty, complexity, and inequality are interconnected, which is important to consider when addressing them. However, overcoming issues of uncertainty is most important because the tools governing complexity and inequality are built on knowledge and trust.

7. Discussion

7.1 Evaluating methodology

The practical realization of the methodology deviated from the plan. First, the selection of the stakeholders was sometimes difficult. Snowball sampling provided access to a network of actors working on vertical greenery but may not have incorporated actors involved in vertical greenery outside the network. Although this limitation was addressed by approaching other stakeholders after mapping them, some stakeholders were not willing to participate or could have been overlooked. In Singapore, approaching stakeholders without being introduced was especially difficult. Thus, talking with developers to understand their experiences with vertical greenery and their vision of vertical greenery policies would have been helpful. Despite multiple attempts, no contact could be made with a developer. Luckily, some of the desired information was shared by other interviewees.

Second, the process of summarizing the interviews and sending them for confirmation appeared inefficient and did not always contribute to finding critical information. The email correspondence to obtain information was problematic because some respondents were too preoccupied to read and respond to my emails. As a result, considerable time was spent on sending reminders. Furthermore, the adjustments respondents made to the summaries resulted in more politically correct and less critical answers, despite the statements they made. Simply transcribing the interviews would have solved these issues. However, the interviewees in Singapore were glad they could review their interviews to ensure they did not state anything that would discredit them. Therefore, given the respondent time to review their statements did contribute finding more respondents.

Third, the broad method of interview analysis was useful for this research, but a different method would have allowed for more specific results. By demarcating and summarizing the content of the interviews, a common language on vertical greenery was created. However, if these interviews had been transcribed and analysed using qualitative research software, they would have given insights into the different ways the stakeholders framed vertical greenery and would have made it possible to obtain information from the way they discussed it. However, given the translation to a common discourse, the summary method simplified comparing the results and answering the research questions.

Fourth, regarding generalization and representation, the following factors must be considered. Given their willingness to talk to me, most respondents had a positive perception of or experience with vertical greenery, possibly making them biased. Moreover, observation indicated that Singaporeans tend to be more positive in their stories, emphasizing what works instead of what does not work. The Dutch, on the contrary, often explained what did not work and what could be improved instead of what worked. However, by asking critical questions and reviewing successful and failed projects, gaining useful information was still possible.

Regarding generalization, this research should be seen as an identification of ways to deal with vertical greenery development issues and not as a way for all other urban areas to manage it. As

explained, distinctive cultural and environmental features have considerable influence on problems and what the best solutions to these problems. Singapore and Amsterdam demonstrated that there are different approaches to cope with many of vertical greenery issues, and these approaches also have different physical results. Of course, both cities have some of the same issues and effective solutions. Therefore, although cities worldwide can learn from the results, this research should not be viewed as guidelines for successful vertical greenery governance, but rather as inspiration for governance of vertical greenery.

7.2 Reviewing the conceptual framework

The conceptual framework used in this research was helpful to determine how to promote vertical greenery in a holistic but structured way. Using the themes of uncertainty, complexity, and inequality, the research focused on specific issues and found approaches to overcome these issues. Moreover, the framework mapped out the most important actors and tools in vertical greenery governance and demonstrated that many social, historical, environmental, economic, and political factors influence the development of vertical greenery.

Scientific literature on similar situations, as presented in the conceptual framework, was supported by this study's results. Hoffiman et al.'s (2017) claim that inequality in greenery can be addressed by government provisions using standards and public participation was illustrated by the different approaches the cities used to address issues of inequality. Other scientific research provided in the conceptual framework was one sided. For instance, in Han's (2016) research, the negative aspects of top-down governance overshadowed the positive results of the governance arrangements.

Moreover, some theoretical concepts where less useful than expected. The rounds model by Teisman (2000) provided an overview of the decisions made in Singapore and was a convenient tool for gaining insights into the history of vertical greenery development. However, for this research, this model seemed too detailed and specific. Some decisions were hard to relate to one actor and actors that involved were constantly changing. The phase or stream model, which are more abstract, would have been more useful.

Other theoretical concepts would also have provided interesting perspectives. For instance, Geels' (2011) multi-level perspective on the transition theory, as pictured in Figure 25, had many similarities with the researched cases. In both situations, vertical greenery development started as a niche initiative. In Singapore, this niche was successfully adopted by in the regime after new developments in the landscape. In Amsterdam, further development of this niched did not take place. This theory would have also been useful to determine features or strategies that support vertical greenery development and structure the results. However, focusing on the three major themes of uncertainty, complexity, and inequality specifically led to approaches that contribute to overcoming the issues within these themes. Moreover, the transition theory would have made generalizations more difficult when comparing the

cases since the situations or landscapes are different. Therefore, the broad scope used in this research and the focus on the three themes ultimately led to more useful results.

7.3 Other findings and directions

This study needs to be perceived as a foundation for the practical realization of vertical greenery and the scientific evaluation of it. The insights can help governments, market actors, and civil society in their pursuit of bringing nature into cities and prepare them for the consequences of climate change. In scientific terms, this study can contribute to the relatively new domain of research on the governance of vertical greenery in urban areas. When there is more interest in measures to mitigate and adapt to the changing climate, scientific knowledge on vertical greenery might expand.

The broad scope of the research resulted in many interesting findings and relationships, but some were underexposed to keep the study focused. These findings would be of interest to future research. First, a reappearing aspect during the interview was the relationship between vertical greenery and sustainability discourse. Vertical greenery is an excellent way to communicate and express corporate social responsibility but whether it is sustainable and whether commercializing a green city is an issue is not clear. Second, different opinions exist on the relationship between greenery in the built environment and the concept of nature. Some respondents claimed that the new and fascinating trend of using plastic vertical greenery still provides a biophilic feeling. Others called the living wall systems artificial since plants are not supposed to grow that way. Moreover, there is a huge gap in the kind of vertical greenery deemed beautiful in Singapore and Amsterdam. For Singapore's new vision of a city in nature, this concept would be of interest to research. Third, (vertical) greenery contributes to the creation of value, but what this value mean for gentrification is not understand. For example, gentrification in specific areas may be partly a result of the initiatives to install greenery in the neighbourhood. The last result that could be further explored is related to the development of the DIY application. Research on the effects of DIY application of vertical greenery on citizens might make this form of application more relevant. For instance, the application could contribute citizens' health or could be educational, bringing urbanites in contact with nature.

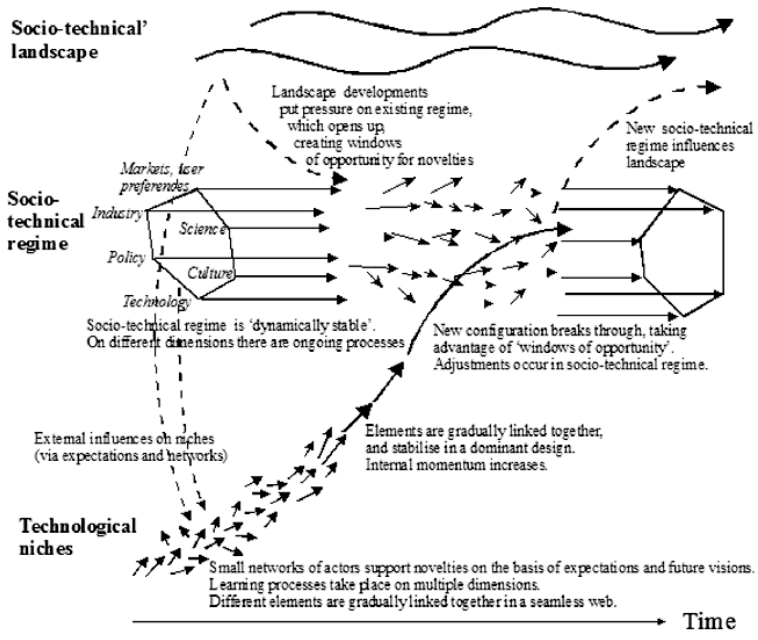


Figure 25: An overview of the multi-level transition theory. Source: Geels 2002

8. Conclusion

This research aimed to identify features that help promote vertical greenery development by overcoming current barriers. The research especially focussed on finding governance arrangements that contribute to overcoming issues of uncertainty, complexity, and inequality in the development of vertical greenery. To generate the answers, a qualitative study has been conducted comparing vertical greenery governance in Singapore and Amsterdam.

The results indicate that issues of uncertainty in vertical greenery development are still present in vertical greenery development and are mainly found in a lack of knowledge and diverging opinions by different stakeholders. Bottom-up governance arrangements hardly address these issues of ambiguity or a lack of awareness and support. Therefore, it is necessary to have an overarching actor guiding stakeholders for research and development on vertical greenery. Issues of complexity, caused by ensuring all actors crucial to the development of vertical greenery are in agreement, can be managed by distinctive ways of governance and lead to different physical applications of vertical greenery. Evaluating vertical greenery governance on issues of inequality, such as unequal distribution and quality, indicates that both top-down and bottom-up governance can help solve inequality issues, but both have limitations. Top-down governance arrangements can guarantee accessibility to vertical greenery. However, this type of governance does not empower people to shape their neighbourhoods and might cause them to become passive. While bottom-up governance arrangements increase citizens' autonomy, they do not necessarily empower marginalized citizens because accessibility to vertical greenery highly depends on resources and interest.

The results have also shown that issues of uncertainty, complexity and inequality, and the governance arrangements addressing them are interrelated. Addressing one themes can affect the others. Overcoming issues of uncertainty in vertical greenery has a central role in supporting vertical greenery development since knowledge and political support are necessary in both governing issues of complexity and of inequality. Ultimately, different governance arrangements can contribute to overcoming complexity and inequality, but both have limitations and different results. Reducing uncertainty is crucial to promoting vertical greenery development and requires active approach by an overarching actor, such as a government, to guide actors to debate, discus, and share knowledge on vertical greenery.

This thesis has called for action in practice and science to encourage an undervalued form of greenery by gaining relevant knowledge and creating a foundation for other research directions. Both Singapore and Amsterdam posed as two examples of urban areas planning to improve their living environments in their own way. Hopefully, this thesis will inspire urban areas around the globe to consider how to guide the integration of greenery in the built environment and, possibly, share their theoretical knowledge and practical experience.

9. Recommendations

To enable large scale greenery of urban areas using vertical greenery, the following recommendations are made for municipalities, civil society, companies, scientist, and other urban innovators. First, based on the conclusions, securing political momentum and societal support for vertical greenery is vital. As the research suggests, this support can be garnered by providing comprehensive information on the benefits of vertical greenery and addressing non-experts. Moreover, successful vertical greenery systems should be installed to demonstrate its feasibility. The increased awareness and attention will make vertical greenery visible and will contribute to the overall establishment of this type of greenery.

Second, after generating political momentum and societal support, network of stakeholders should be developed to integrate greenery into the built environment. Overarching actors such as a government, must build upon the societal support and link companies, governments, scientist, and citizens. Together, these actors should gain new knowledge on vertical greenery, discuss its legitimization, exchange information, and learn from each other. Bringing together a variety of experts from different disciplines and various stakeholders in the urban scape will not only foster transdisciplinary knowledge necessary for development of vertical greenery but also bridge the gap between science and practical application.

Third, especially for further development of vertical greenery in Singapore, citizens should be allowed to decide on their surroundings. In addition to DIY application of vertical greenery outnumbering professional projects, this application will also benefit the health and minds of those involved. Citizens must be provided with the opportunity to actually shape the city. In Singapore, this measure might enhance happiness, citizens involvement, and national identity, even if the result is not as well-manicured as professional installations. Moreover, reducing top-down management might result in the diverse and evolving city in nature that was envisioned.

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List of interviews

This list gives an overview of the organization and the interviewed individuals in this research. Some names and organizations are anonymized if preferred by the respondent. Transcripts of the interviews are confidentially stored at the Wageningen University & Research data base of the Environmental Policy chair group.

Interviews in Singapore

H. Cheng

Former Senior Architectural Designer and Associate at WOHA, March 9, 2019.

Cheng worked many years for the architecture company WOHA and has a lot of experience in the architecture and building sector. Given Cheng did not originate from Singapore but lived there for many years, she was able to point out many unique features of the state not observed by outsiders.

WOHA

A. Yeo - Director, March 9, 2019.

WOHA is an internationally known architecture company mainly operating in Southeast Asia, China and Australia. Their work features sustainable designs as a reaction to urbanization and climate change. In many projects they incorporated vegetation and are were the first one in Singapore to use vertical greenery on a large scale.

Singapore Green Building Council (SGBC)

J. Tan - Executive Manager Membership & Communications, March 11, 2019.

E. Lua - Manager Certification & Technology, March 11, 2019.

The SGBC is set up to foster public-private partnerships across the building and construction value chain. The council tries to fasten the transition towards more sustainable technologies and helps other actors to find solutions which conform with the BCA's standards. For vertical greenery in specifically, the council conducts lifecycle analysis on different systems making them knowledgeable on the development of vertical greenery systems in Singapore.

Centre for Liveable Cities (CLC)

E. Tan – Deputy Director for Research, March 12, 2019.

A. Tan – Manager, March 12, 2019.

The Centre for Liveable Cities was established in June 2008 by the Ministry of National Development and the Ministry of the Environment and Water Resources. The vision is to become a global knowledge centre for liveable and sustainable cities by distilling, creating and sharing knowledge on liveable and sustainable cities. Vertical greenery, as part of the city in a garden vision, is a well-known topic for this organization.

National Parks Board (NParks)

J. L. Lok – Senior Manager Skyrise Greenery, March 12, 2019.

NParks or National Parks of Board is a government organization assigned with the task to manage and enhance greenery in Singapore and is a statutory board under the Ministry of National Development (MND). A special department within this organization, consisting of five people, is taking care of skyrise greenery. This also includes vertical greenery.

GWS Living Art

Z. Toh – Owner and director, March 14, 2019.

GWS Living Art is a company specialized in urban green technology and integrates greenery in the built environment. The company emerged as a start-up from Chop Ching Hin Pte, a nursery company with many years of experience throughout South East-Asia. GWS delivers both green walls and green roofs.

T. Tan PhD

PhD Building Science at NUS & owner of the Urban Green Lab, March 21, 2019.

Tan is, as a scientist, specialized on rooftop and vertical greenery. The building science department has contributed significantly to the knowledge on vertical greenery in Singapore. Additionally, Tan started his own platform, the Urban Green Lab, to educate people on the benefits of greenery in a simple way.

Y (Anonymized)

Public Housing Specialist, March 21, 2019.

Y has many years of experience working on greenery and vertical greenery with the public housing organization of Singapore.

X (Anonymized)

Environmentalist & Community Manager, April 1, 2019

X is a local sustainability and environment enthusiast and is involved in different projects by the government, companies and civil society to make Singapore more sustainable. Due to the many years of experience, X has considerable knowledge on the governments approach and the (non)existence of bottom-up initiatives.

Interviews in the Netherlands

Rainproof Amsterdam

S. Busing - Community manager, April 16, 2019.

Rainproof Amsterdam is a networking organization that aims to increase the sponge effect of the city by adjustments in the public and private sphere. One of the tools promoted is vertical greenery.

Green City Buzz

T. van der Knoop - Founder and director, April 24, 2019.

The non-profit organization Green City Buzz aims to make urban areas attractive, future-proof and economic places by large scale qualitative greening. In different projects, the organization made use of vertical greenery installations.

Sempergreen

W. van Wikselaar – International sales & technical support, April 24, 2019.

Sempergreen has been producing vertical greenery systems for more than 16 years and is currently worldwide market leader. They produce pre-grown cassette systems which can survive in the most extreme weather conditions.

Hurks

S. de Ruijter – Projectdirector Hurks bouw & vastgoedontwikkeling, April 26, 2019.

Hurks is a real-estate developer and builder and has been involved in the development of de Spakler, a building in Amsterdam covered with vertical greenery.

VenhoevenCS

T. Venhoeven – Founder, principal architect and urban planner, April 30, 2019.

VenhoevenCS is an urban planning and architecture company aiming to improve the environment. The Sportplaza Mercator, one of the first buildings in Amsterdam covered in greenery was built after their design.

Tuinbranche Nederland

B. Horstra – Deputy director, April 30, 2019.

Horsta is deputy director of the branch organization for garden retailers and their suppliers. They conduct research on garden consumers and share information with these consumers on vertical greenery.

Gemeente Amsterdam

L. Sour - Public space policy advisor, department Ruimte & Duurzaamheid, May 2, 2019.

The department Ruimte & Duurzaamheid (Planning & Sustainability) consist of about 20 to 30 employees working full time on the planning and provision of greenery in Amsterdam in the public sphere and built environment.

Dr. Ir. M. Ottelé

Assistant professor at Faculty of Civil Engineering and Geosciences, TU Delft. May 7, 2019.

Ottelé has been researching vertical greenery extensively since his PhD dissertation *'The Green building Envelop: Vertical Greenery'* published in 2011. Mostly, he addressed topics of particular matter, thermal aspects and lifecycle analysis.

Branchevereniging Hoveniers en Groenvoorzieners (VHG)

M. Geuze - Policy advisor, May 8, 2019.

VHG is the association for greenery professionals. Since last year they have been communicating more on greenery in, on and around buildings.

Partij voor de Dieren (PvdD)

A. Bakker – City councillor, May 9, 2019.

Partij voor de Dieren (Party for the Animals) is a political party in Amsterdam having seats in the local council. In 2015, they initiated a resolution to start a pilot to use vertical greenery on flyovers in the Sloterdijk Area. Despite the resolution got accepted unanimously, no vertical greenery was installed.

Natuur & Milleu Team de Pijp (NMT)

L. Voshaar – Senior Advisor, May 9, 2019.

NMT is an organization that aims to achieve a green, sustainable environment in the southern parts of Amsterdam. This organization spends many efforts on information provision and promoting façade gardens and vertical greenery.