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A framework to explain the role of boundary objects in sustainability transitions

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ABSTRACT

Our modern society is characterized by increasing diversity and complexity, leading to overwhelming challenges like climate change or environmental degradation. These problems are posing impracticable ethical dilemmas and conflicts of interest among an expanding range of institutional logics. While this cognitive, ideological, scientific, and political diversity can represent a major barrier for the collaborative work that sustainability transitions require, it is also a necessary resource for innovation and adaptation. It is then natural to wonder how diversity and collaboration among institutional logics can be accommodated and balanced. In this article, we develop a framework to explain the role of *boundary objects in sustainability transitions* (BOIST framework), which describes how ambiguous artefacts (boundary objects) can be deliberately employed by actors to drive transitions through bridging conflicting logics without constraining their diversity. The applicability of the framework is demonstrated with an in-depth case study of the Copenhagen municipality's transition to more sustainable stormwater management.

1. Introduction

Our modern society is characterized by a relentless growth of diversity, complexity and uncertainty (Beck et al., 2003; Milly et al., 2008) that leads to interdependent, unstructured, and pervasive problems—what in social policy is called wicked problems (Rittel and Webber, 1973; Weber and Khademian, 2008). These problems are overwhelming societal challenges like climate change, environmental degradation and loss of biodiversity, bioengineering, artificial intelligence, or mass surveillance. They typically create ethical dilemmas and conflicts among actors with different worldviews (sets of values, beliefs, interests and goals). These major societal challenges, and the large socio-institutional transformation that they can lead to, are the object of study of the interdisciplinary field often called sustainability transitions (Loorbach et al., 2017; Markard et al., 2012). This field aims at finding ways to understand, promote, accelerate, and orient socio-technical regimes towards more sustainable social configurations.

Overarching social problems have traditionally been addressed in a rigid top-down style, by a strong government that imposes a solution based on a defined set of values, beliefs or goals in order to generate unity, collaboration and eliminate uncertainty (Hobbes, 1960). In the best of cases, the enforced worldview builds on scientific evidence to determine a (supposedly) optimal solution,

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constrain diversity, enforce collaboration and settle the debate once and for all (Sarewitz, 2004; Stirling, 2010). While in the past, this approach was successful to confront simple and undisputed societal challenges (e.g. Pahl-Wostl et al., 2011), it becomes increasingly clear that our current social reality, with complex and non-linear behaviours, refutes the existence of these simple, universal and objective solutions for wicked problems (Funtowicz and Ravetz, 1993; Prigogine and Stengers, 1984)—and therefore also refutes the utility of the rigid top-down approach. This suggests instead that diversity is essential for understanding, innovation, flexibility and adaptation to complex and uncertain problems (Biggs et al., 2012; Page, 2010; Stirling, 2010), with governance being distributed among a growing number of actors with contrasting worldviews (Kooiman, 2003; Sørensen and Torfing, 2016). But from this arises the dilemma of how to build up the wide social collaboration required to create sustainable solutions to complex social challenges (Leck and Simon, 2012), without imposing unity or restricting the expanding cognitive, ideological, scientific and political diversity (Keulartz, 2009).

While this tension is central in sustainability transitions, it has rarely been explicitly addressed (cf. Stirling, 2011) and has not yet received attention in existing frameworks of transition governance. For example, in the framework built by Smith et al. (2005) (sustainability) transitions are dependent on two main factors: the existence of selection pressures (and their effective articulation), and the adaptation capacity available. In turn, this adaptation capacity has two sub-dimensions: the presence (and diversity, we claim) of resources—like knowledge, funding, or legitimacy—and the capacity for coordination among regime members for the effective exploitation of these resources. However, Smith et al. do not elaborate on how to build coordination among a local community actors that exhibit different worldviews, without restricting their diversity. Keulartz (2009, p. 266) claims that the answer to this question can be found in the concept of *boundary work*—a term with origins in science and technology studies (Gieryn, 1983)—that refers to “the constructive effort to support communication and coordination across the fences that separate communities”. We argue, more concretely, that a particular tool of boundary work, namely *boundary objects* (Star, 2010; Star and Griesemer, 1989), has the ability to simultaneously support coordination and diversity. Furthermore, we claim that boundary objects may be the answer to two additional questions that arise from Smith et al.’s framework: What does *articulation of selection pressures* mean in practice? How are available resources concentrated to make the transition possible?

Boundary objects are artefacts (things, concepts, discourses, processes, etc.) that have the ability to simultaneously project disparate interpretations—they have interpretive flexibility—while constituting a solid nexus for communication and collaboration among disparate worldviews (Star, 2010; Star and Griesemer, 1989). The concept, originally from the field of science studies, has had a prolific life in a wide range of disciplines during the last 30 years (Trompette and Vinck, 2009), and also has occasionally been borrowed in the field of sustainability transitions as an accessory element (Augenstein and Palzkill, 2016; Klerkx et al., 2010; Pel, 2016; van der Jagt et al., 2019; Wittmayer et al., 2017). However, during the last few years, some studies have begun to explore its potential for expanding the theoretical base of the field. For example, Stirling (2011) refers to boundary objects as a tool to simultaneously encourage “pluralistic tolerance” and foster the collaboration among diverse views that sustainability transitions require, while more recently Koehrsen (2017) has investigated how boundary concepts can help to enable cooperation among worldviews without consensus. More examples include the empirical work of Hauber and Ruppert-Winkel (2012) and Harlow et al. (2018), who describe how boundary objects are able to align conflicting interest and guide a transition in the energy and transport sector.

Building on these studies, in this article we develop a framework to explain the role of *boundary objects in sustainability transitions* (the *BOIST* framework), which focuses on three proposed capabilities of boundary objects: (1) to build cooperation among conflicting worldviews without constraining diversity, (2) to articulate selection pressures, and (3) to concentrate resources in order to make transition possible. This analysis is done simultaneously at two levels: the *system level* and the *actor level*. The system level describes how boundary objects affect the transformation of the socio-technical system, while the actor level describes how certain actors [*boundary spanners* (Klerkx et al., 2010; Richter et al., 2006; Smink et al., 2015; Williams, 2002)] embedded in those systems deliberately employ boundary objects to drive change [conduct *boundary work* (Gieryn, 1983; Guston, 2001; Richter et al., 2006; Williams, 2002; Zietsma and Lawrence, 2010)]. Attention to boundary work resonates with the growing interest in an agency perspective in sustainability transitions (Avelino and Wittmayer, 2016; Barnes et al., 2018; Farla et al., 2012; Fischer and Newig, 2016; Wittmayer et al., 2017), contrasting with the more common analysis of transitions that focus on systemic changes (e.g. de Haan and Rotmans, 2011; Geels, 2004, 2002). This agency approach is useful to analyse the governance of transitions (e.g. Frantzeskaki et al., 2012; Turnheim et al., 2015), and more specifically transition management (Brown et al., 2013; Loorbach and Rotmans, 2010; Rotmans and Loorbach, 2009) or strategic niche management (Raven et al., 2016; Schot and Geels, 2008). Following this vein, our framework provides an agency approach to boundary objects from which they can be seen as tools for transition management.

This article is structured as follows. First, we expand on the two building blocks of our framework: institutional logics and boundary objects. Next, the theoretical development of the framework is presented, which is structured following the life cycle of a boundary object (Star, 2010; Steger et al., 2018) in a particular community of practice in a particular place, offering a simultaneous system and agency perspective. Then, we apply the framework to analyse the case study of stormwater management in Copenhagen (Denmark), where the concept of climate change adaptation (CCA, the boundary object) was used to (1) articulate a selection pressure, (2) build cooperation across conflicting worldviews and (3) concentrate the necessary resources to drive the transition towards more sustainable modes of stormwater management.

2. Conceptual development of the framework

2.1. Theoretical building blocks

From the outside, socio-technical regimes may seem heterogeneous with incoherent sets of social structures. However, there is usually a finite number of interacting worldviews, with their characteristic systems of values, beliefs, interests and goals that support and constrain thinking and action in a particular direction. These worldviews, which the boundary object literature calls *social worlds* (Star and Griesemer, 1989), have recently been introduced in sustainable transitions as institutional logics (Brodnik et al., 2017; Fuenfschilling and Truffer, 2014; Smink et al., 2015)—a concept with roots in institutional theory (Friedland and Alford, 1991; Thornton et al., 2012; Thornton and Ocasio, 2008). These institutional logics (hereafter referred to simply as logics) may cooperate or compete with each other, resulting in incoherencies across the regime (Besharov and Smith, 2014; Goodrick and Reay, 2011; Smink et al., 2015). In general terms, a transition in a socio-technical system can be conceptualized as a transformation of the relative influence of its constituent logics (Brodnik and Brown, 2017).

Some logics are inherent and essential to the functioning of a socio-technical system—as we will see later for the hydraulic logic in the modern stormwater management regime. Other logics, however, emerge in the regime as niche innovations (Brodnik et al., 2017; Smink et al., 2015) reflecting deeper changes in underlying societal structures (changes at the landscape level)—for example, the market logic spread over many socio-technical systems when neoliberal politics became popular in western countries during the 1980s. If disparate logics are strongly represented and offer contradictory prescriptions (for instance, health services may be regarded as a human right or as a profit-making business; mass surveillance may be seen as an issue of public protection or of citizen control), extensive and intractable conflicts can arise, threatening the durability of the socio-technical regime (Besharov and Smith, 2014).

In our transitions framework, we conceptualize boundary objects as elements that enable the articulation of selection pressures and the interaction, communication, alignment of interest and cooperation among logics without a need for consensus (Bartel and Garud, 2008; Bressers and Lulofs, 2010; Cash et al., 2006; Cash and Moser, 2000; Koehrsen, 2017; Star and Griesemer, 1989) (see Fig. 1). A clear explanation of the idea of boundary objects can be offered based insights from semiotics. In this field, a *sign* (e.g. a word) is composed of two elements: a *signifier* (what we can perceive with our senses, e.g. a word’s sound or written form) and a *signified* (its meaning) (Saussure, 1959). A boundary object is a signifier (not necessarily a word, for example it could be a physical artefact or a process) characterized by its large interpretive flexibility (Star and Griesemer, 1989). It has the capacity to adopt concrete signifieds inside different logics—called *translations* in science and technology studies (Callon, 1984)—while remaining ambiguous enough to support collaboration across logics without forcing actors to abandon their initial standpoints (Carlile, 2004; Star and Griesemer, 1989). Indeed, the word *boundary* refers to the shared space between institutional logics, and the word *object* does not refer to a physical entity, but to the shared aim of action (Star and Griesemer, 1989). Some examples of boundary objects include computer models (Larson et al., 2015), the IPCC report (Cash and Moser, 2000), ecosystem services (Abson et al., 2014), innovation

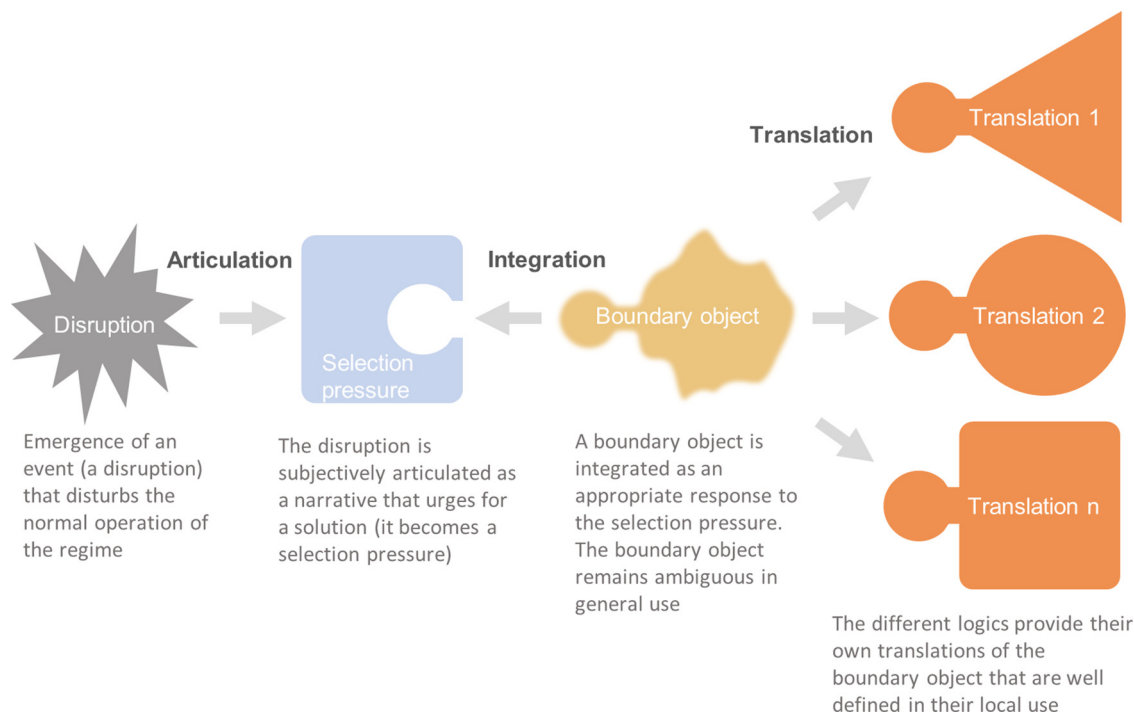


Fig. 1. A boundary object serves to simultaneously articulate a selection pressure, provide an undisputed solution and support multiple translations influenced by different institutional logics.

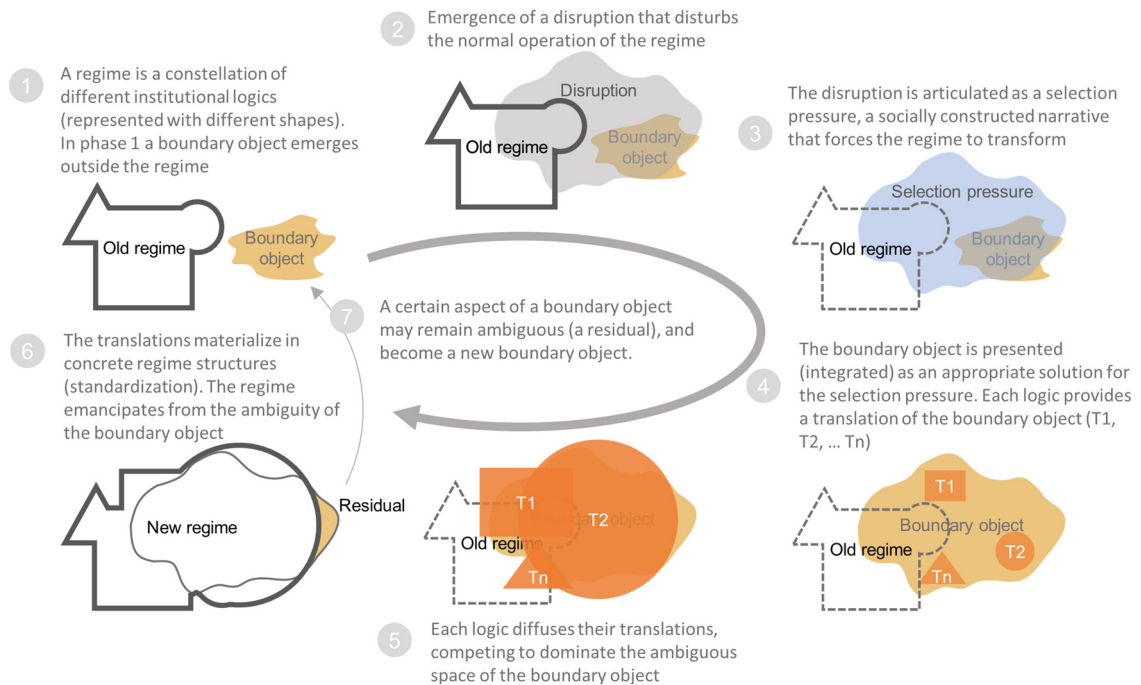


Fig. 2. The BOIST framework describes seven phases in the lifecycle of a boundary object during a transition.

narratives (Bartel and Garud, 2008), frameworks like the Integrated Water Resource Management (Molle, 2008), many other ill-defined ideas like resilience (Brand and Jax, 2007), or even the concept of sustainability transitions itself (Loorbach et al., 2017).

2.2. Introducing the seven phases of boundary objects

In this section, we present a description of the seven phases of the transition framework, which are introduced according to the circular life of a boundary object, inspired by the work of Star (2010) and Steger et al. (2018). Fig. 2 provides a visual representation of each of these phases, with brief explanatory text. These seven phases can be understood as both systemic developments and actor strategies.

2.2.1. Phase 1: Emergence of a boundary object

A boundary object usually emerges outside the regime and can be later introduced into the regime by advocates of an institutional logic that, early on, intuit a (representative or communicative) value on it. Sometimes, new, ill-defined boundary objects grow from previously existing boundary objects that have lost their ambiguity. This is what Star (2010) calls *residual categories*—or just *residuals*.

2.2.2. Phase 2: Emergence of a disruption

A disruption can emerge independently of the boundary object. The Oxford English Dictionary defines *disruption* as a “disturbance or problem which interrupts an event, activity, or process”, which, in this framework, corresponds with a disturbance of the normal operation of a stabilized socio-technical system. Typical examples of disruptions include rapid demographic changes, natural disasters, new legislation or revolutionary technical innovations.

2.2.3. Phase 3: Articulation of a selection pressure

While some authors in sustainability transitions have referred to what we call disruptions as *selection pressures* (e.g. Berkhout et al., 2004; Smith et al., 2005), we introduce a clear distinction between the two terms. Selection pressures are disruptions that have been *articulated*. Without this articulation, disruptions are neutral events that lack social significance—they have not received attention or meaning from the members of the regime. Regimes are social constructions (Geels, 2011) that require an *articulation* of the causes and consequences of disruptions that happen in the “real world”. Without this articulation, a disruption goes ignored and does not exist from a social perspective (Beck, 1992; Snow and Benford, 1988).

More specifically, we consider a selection pressure the shared realization that a certain disruption calls into question the capacity of the current socio-technical system to fulfil its intended function, requiring urgent efforts for adaptation—or for suppression of the disruption. A selection pressure instigates action; *something must be done*.

Transitions literature often assumes that sudden or violent disruptions are essential to open a window of opportunity and force the transformation of the regime (Geels, 2011; Smith et al., 2005; Smith and Stirling, 2010). Conversely, we argue that what is indispensable is the social construction of an effective selection pressure, which can also be developed in response to minor or gradual

disruptions—which are ubiquitous in modern societies (Berkhout et al., 2004). The articulation is often an arbitrary process, but it can also be purposeful, enabling regime actors to trigger and shape a transition.

2.2.4. Phase 4: Integration of the boundary object and emergence of multiple translations

We argue that boundary objects can function as appropriate responses to selection pressures because they can be simultaneously attractive and vague ideas—what Molle (2008) calls a *nirvana* concept. On the one hand, they may be an appealing signifier that is widely accepted, representing a suitable solution for the selection pressure from any perspective. On the other hand, they are so plastic and ambiguous that any logic can create their own signified (translation). Using a boundary object as a reference point, it is possible to achieve an incipient cooperation to approach the selection pressure prior to consensus among the different logics (Koehrsen, 2017; Star, 2010).

In the same way that selection pressures could be intentionally articulated, advocates of a certain logic can promote what we call the *integration* of a certain boundary object into a selection pressure (Fig. 1). After the link is established, advocates of the different logics start elaborating their *translations* in tune with their values and worldviews, including a concrete solution for the problem and the motivational reasons to support it (Snow and Benford, 1988). Accordingly, the dominant logic of the incumbent regime makes a translation of the new boundary object that supports the existing regime structures, while “divergent” logic(s) that aim at triggering a transition normally promote some solutions that question the status quo.

2.2.5. Phase 5: Dominance of the ambiguous space

The existence of a selection pressure is a stressful situation for governance actors who are compelled to respond quickly and adapt the regime to the new development—or, instead, they try to lock the regime in the old configuration and withstand or neutralize the selection pressure. Consequently, these decision-makers are willing to provide resources (like financial support, political support or administrative expedition) and legitimacy to those actors that represent the most accepted translation of the already integrated boundary concept. At this point, the motivated advocates of different logics strive to put forward their translations in the incipient discursive arenas, where the boundary object is still ill-defined (what we call the *ambiguous space*) to gain access to the resources and be granted the legitimacy to act.

We identify four actor strategies that may be employed to conquer the ambiguous space, which correspond with growing degrees of diffusion and fixation of a boundary object in the regime.

The first is the *ownership* of the boundary object. Actors that introduce the boundary object into the regime create an early translation that fit their own logic. Even if this translation is not fully understood or accepted by other actors, the primary logic may be publicly associated with, and credited as, the “owner” of the boundary object.

The second strategy, *storytelling*, involves the definition and dissemination of a compelling narrative (a translation) that can persuade other actors through diverse means, including networks, research, education, conferences and the media, which expands the body of supporters. Storytelling is a well-known strategy in organizational research as a tool of resource acquisition (Lounsbury and Glynn, 2001; Martens et al., 2007). The success of this diffusion is strongly dependent on how compelling the story is, as well as the skill, power and social capital of the communicator. A good story creates a series of positive feedback loops, as other actors appropriate the narrative and diffuse it with their actions and within their networks.

The third strategy, *accommodation of other logics*, involves the partial merging of translations in areas where they become compatible and mutually supportive, as long as the union does not disturb the internal coherence of their original translations (Besharov and Smith, 2014). This idea has been repeatedly studied in the field of institutional theory, and it is often referred as *aggregating interests* (Fligstein, 1997). In this process, the translation gains support and legitimacy from a wider body of actors and, at the same time, incorporates useful elements from other rationalities “in a way that resonates with the interests, values, and problems of potential allies” (Battilana et al., 2009, p. 80). Others, like Schön and Rein (1994, p. 207) in policy analysis, call this strategy *double vision*, and define it as “the ability to act from a frame [a logic] while cultivating awareness of alternative frames”. In practice, the application of this strategy can unfold in multiple ways. For instance, it can involve the exploration of synergies with other logics through networking, the engagement with the overarching political agenda to benefit from the momentum of politically goals already legitimated, or the development of interdisciplinary predictive models.

The fourth actor strategy is the *construction of obligatory passage points*—borrowed from science and technology studies (Callon, 1984). The agents of an institutional logic that get control over an ambiguous space become central nodes in a network of collaboration made together with the accommodated logics. As a sort of gatekeeper, they acquire the legitimacy and capacity to define the new regime’s structures that all actors must follow in order to engage in collaborative work.

2.2.6. Phase 6: Standardization and emancipation

After the ambiguous space is significantly reduced, consensus starts to emerge across the different institutional logics and the boundary object is materialized in the form of *standards* (Star and Griesemer, 1989)—agreed-upon definitions, classification, and rules—which makes the boundary object less vague and constrain the range of action of the members of the regime in a certain direction. Apart from standards, the dominant logic can reify a boundary object in the shape of demonstration projects (Farrelly and Brown, 2011; Vreugdenhil et al., 2010). For instance, new infrastructures or interdisciplinary prediction models not only make the boundary object an unambiguous instantiation of a certain translation, but can also support further diffusion of the translation, become a reference point for future projects and develop a sense of ownership from multiple disciplines towards the new infrastructures and/or practices being demonstrated.

The new hybrid translation that solidifies reflects to a large degree the dominant logic, while incorporating elements of other

competing logics that had been accommodated. These structures are now so embedded in the regime that they eventually become taken-for-granted and invisible (Star and Bowker, 2006; Star and Ruhleder, 1996). At this point the boundary object loses its ambiguity, and therefore, it is not a bridge, but a merged area of institutional logics. By definition, it ceases to be a boundary object and loses relevance for future transformations of the regime. In our own words, the regime *emancipates* from the boundary object's influence.

2.2.7. Phase 7: Emergence of residuals

So far, we have seen how the boundary object slowly transforms from ambiguous to concrete. However, some aspects of the boundary object resist the standardization—no logic manages to make them concrete. These remaining regions of ambiguous space are marginalized and become newborn, independent boundary objects, or what Star (2010) calls *residual categories*, which are available to trigger a new transition.

3. Empirical application of the framework

3.1. Data collection and analysis

The sustainability transition selected for empirical application of our framework is the transformation of the stormwater management regime of the municipality of Copenhagen (Denmark) from approximately the year 2007–2019. During this period, the regime experienced a significant change in its policies and practices, reflecting a new configuration of logics. This case study shows how the transition was accelerated and oriented through the instrumental use of a boundary object—*climate change adaptation* (CCA).

The case study comprised collection and analysis of secondary and primary data, construction of a chronological narrative of the case's key developments including actor perspectives and strategies and, finally, analysis of this narrative using the boundary objects in sustainability transitions framework developed in Section 2.

The secondary data included a desktop review of existing academic literature related to our case, newspaper articles, videos of conference presentations, legislation, industry reports and municipal agencies' planning documents. Especially relevant were the transcripts of four interviews conducted by Steffensen (2013) in 2012 that made it possible to contrast old and new narratives, providing evidence of the regime transition. All this information was analysed with the software NVIVO 11 (Bazeley and Jackson, 2013). The content of the data was first coded to identify individual elements (like *hydraulic logic* or *storytelling*), the codes were then grouped into the framework's descriptive categories (like *institutional logics* or *actor strategies*), and finally, classified into themes (corresponding with the framework's seven phases). Primary data included eight semi-structured interviews conducted in December 2018 and January 2019 with actors that had an active role in the stormwater sector of Copenhagen during the period 2008–2018. The participants were selected via the snowball method, which particularly addressed key gaps in the narrative constructed from the other data sources (Table 2). When all the chronological gaps were filled and the analysis reached saturation point (Guest et al., 2006) the data collection and interviewing process concluded. These new interviews were transcribed and coded in the same fashion as the secondary data. Finally, the interpretation of the case study was validated by the interviewees, who had the opportunity to read a draft of the article and provided feedback.

3.2. Defining the case and its institutional logics

To categorize the diversity of institutional logics that were present in the stormwater management regime during the period of study, we have focused on the classification of institutional logics created by Fuenfschilling and Truffer (2014) for urban water management systems in industrialized countries, which includes: the *hydraulic logic*, the *water sensitive logic* and the *market logic*. These are ideal types, meaning they are caricatures of existing logics—simplistic and generalizable static models—that serve as heuristic tools for empirical analysis (Doty and Glick, 1994). The reality is, of course, much more nuanced. Within Copenhagen's stormwater sector, actors had values and worldviews that do not perfectly fit within those three logics, but there is a general alignment.

This socio-technical transitions occurring in urban water have been previously described (Brown et al., 2009; de Haan et al., 2015), suggesting that urban water regimes are evolving from technocratic regimes focused on large-scale infrastructures and rigid institutions—which can be identified by the dominance of a hydraulic logic—towards adaptive, reflexive and resilient regimes that focus on distributed and integrated infrastructures and institutions—which can be identified by the dominance of a water sensitive logic.

The hydraulic logic has a public welfare orientation based on the protection of people and goods from damages inflicted by stormwater, which is considered a nuisance. To fulfil its mission, this logic takes an eminently mechanistic approach to control nature; stormwater must be conveyed, pumped, or stored with large, centralized and robust infrastructures that, being mainly buried underground, are invisible to citizens. The most direct representative of the hydraulic logic in the municipality of Copenhagen has traditionally been the water utility. This organization stands out for technical competence for design and management of the infrastructure and their members are mostly engineers. Their mission is simple and well-defined. In the words of a utility staff member interviewed in 2012: “Actually, our only objective is to guarantee that all the water is conveyed away” (interview #3).

The water sensitive logic is closely related to a still ill-defined stormwater paradigm that has been emerging during the last two decades (see e.g. Novotny and Brown, 2014; Pahl-Wostl et al., 2011, 2006; Pinkham, 1999). This logic has a clear orientation towards environmentalism, sustainability, adaptation, resilience, and ultimately, enhanced livability. To fulfil that goal, the logic is

Table 1
List of interviews.

| Source | Interviewee and role |
|-----------------------------------|---|
| Secondary data (Steffensen, 2013) | #1 Manager in the technical and environmental department of the municipality of Copenhagen (hereafter simply referred as the environmental department) #2 Project leader in the economic department of the municipality #3 Project leader in the water utility #4 Project leader in urban development department of the municipality |
| Primary data (2018–2019) | #5 Manager in the environmental department of the municipality #6 Researcher from Aalborg University with focus on CCA in Copenhagen #7 Manager in the environmental department of the municipality #8 Manager of the water utility #9 Leader of a neighbour's association #10 Project leader in the environmental department of the municipality #11 Researcher from Aalborg University with focus on CCA in Copenhagen #12 Manager in the environmental department of the municipality |

underpinned by a complex and systemic understanding of reality that considers a wide range of confronting and synergistic needs that must be integrated. Contrasting with the hydraulic logic, the water sensitive logic does not see stormwater as a nuisance, but rather as a resource that can deliver recreational, aesthetic, environmental or even health benefits to the city. The water sensitive logic suggests an experimental and integrative approach that adapts to nature, mixing traditional and low-technology infrastructures—both under and above the ground, both grey and green—that provide a multiplicity of services. The most salient advocates of the water sensitive logic in Copenhagen belong to a small group of champions from the *technical and environmental administration of the municipality* (hereafter simply referred as the *environmental department*). From an agency perspective, this case study describes how these actors purposefully use the idea of CCA (the boundary object) to accelerate and orient the regime transition towards a configuration that clearly reflects the water sensitive logic.

Finally, market logic has played an important role in Copenhagen's transition. In this logic, the municipality is understood as a corporation, whose objective is to maximize the benefits (socioeconomic optimality) of their shareholders (the citizens). Here, stormwater is an economic issue, primarily focusing on the costs of its management and the potential economic damages of flood. The market logic is especially popular at the political level of the municipality as it provides a widely accepted framing for decision-making.

3.3. CCA and Copenhagen's transition to the water sensitive logic

We now present the chronology of how Copenhagen's stormwater management transition unfolded, organized and interpreted through the seven phases of the boundary object's life cycle (Fig. 2). Table 3 (located at the end of section 3) presents a summary of this analysis, as well as key definitions of the concepts involved. Table 1 (also located at the end of section 3) summarizes the most relevant actions carried out to use boundary objects instrumentally in the transition.

3.3.1. Phase 1: Emergence of climate change adaptation (CCA) as a boundary object

Before the 2000s, it was a widespread belief that developed countries would be marginally affected by climate change, thanks to their low vulnerability and adaptive capacity (Moser and Ekstrom, 2010). However, the publication of the IPCC (2007) report was a critical moment that marked the emergence of climate change adaptation (CCA) as a global agenda. In 2008—when CCA was non-existent in the Copenhagen municipality's plans, and narrowly defined as an issue of flood prevention in the water utility plans—two managers of the environmental department represented the City of Copenhagen at an international climate change conference, where they became inspired by the adaptation plans of other cities like London, Rotterdam or New York. Back in Copenhagen, these two managers championed the adaptation agenda, trying to convince the local government to start working on a CCA plan, and indirectly using it as “leverage for greening the city” (interview #10). However, the idea was rejected with the argument that the municipality should focus instead on mitigating climate change. In Copenhagen's 2009 Climate Plan (CM, 2009), mitigation was indeed the main issue, but CCA was timidly introduced for the first time in the municipality plans as a small subchapter, although no concrete measures were described. The environmental department champions opted then for the strategy of building interest and legitimacy for CCA by inviting representatives from the aforementioned cities to present their work, and from there, politicians gave commitment to start working on Copenhagen's CCA plan, which was finished during the first half of 2011. At that point CCA was effectively introduced in the municipality plans, forming a boundary object.

3.3.2. Phase 2: Emergence of a cloudburst as a disruption

On 2 July 2011, the most intense cloudburst ever recorded in Copenhagen hit the city centre, with 135 mm (one quarter of the average yearly rainfall) measured in only 2 h (Beredskabsstyrelsen, 2012), causing significant damage to public and private infrastructures. Insurance companies reported that more than one third of the building owners in the municipality filed insurance claims, exceeding a total of EUR 800 million (Arnbjerg-Nielsen et al., 2015).

Table 2

The framework's main theoretical concepts and their associated case study interpretations.

| Phase | Key concept | Theoretical description | Case study interpretations |
|---|---|--|---|
| #1. Emergence of a boundary object | Regime | A more or less stable amalgam of different institutional logics that yield a semi-coherent set of rules | The stormwater management regime of Copenhagen |
| | Institutional logics (or simply <i>logics</i>) | Distinguishable rationalities, with their characteristics system of interests, values and worldviews that support and constrain action in a particular direction | Hydraulic logic, market logic, water sensitive logic (adapted from Fuenfschilling and Truffer, 2014) |
| | Dominant logic | The logic that imbues the majority of the regime's structures | Before the cloudburst, the rules of the regime were strongly influenced by the hydraulic logic |
| | Boundary object | A signifier (e.g. a word or physical artefact) with interpretive flexibility, susceptible to accept multiple signifieds (meanings or translations) | CCA emerges outside the regime. Initially, there is little agreement across logics about what it means in practice. |
| | Actors | Individuals or organizations that belong to a regime and draw on one or several institutional logics | For example, the environmental department of the municipality, the economic department, the water utility, local politicians, and neighbour associations |
| #2. Emergence of a disruption | Disruption | An event that disturbs the normal operation of the socio-technical system | The cloudburst event of 2 July 2011 |
| #3. Articulation of a selection pressure | Selection pressure | The shared realization that a disruption calls into question the capacity of the current socio-technical system to carry out its function | The City of Copenhagen is suddenly perceived as highly vulnerable to climate change (which manifests as cloudbursts) |
| #4. Integration of a boundary object and emergence of multiple translations | Integration | The boundary object is presented as the right response to the selection pressure (it is integrated) even though its meaning is still ambiguous | CCA is identified as the right response to avoid catastrophic effects of another cloudburst; however, there is not general agreement on what CCA involves |
| | Translation (T ₁ , T ₂ , T _n) | Signifieds for the boundary object, i.e. concrete meaning to the boundary object according to each institutional logic | The hydraulic logic translates CCA as a hydraulic solution. The water sensitive logic translates CCA as an opportunity to improve the city's amenity. The market logic translates CCA as an economic solution and opportunity |
| #5. Dominance of the ambiguous space | Ambiguous space | The use of a boundary object without being attached to any concrete or well-defined signified (meaning) | The earliest use of climate change adaptation did not have a concrete meaning |
| #6. Standardization and emancipation | Standards | New elements of the socio-technical system that constrain the range of action by actors. They are instantiations of one institutional logic's translation | CCA materializes in the form of new rules and infrastructures that mostly instantiate the water sensitive logic (e.g. green, visible and multifunctional infrastructures) |
| | Emancipation | Disconnection of the new regime from the transformative influence of the boundary object | New standards are taken for granted and not seen in direct connection with CCA anymore |
| #7. Emergence of residuals | Residual | Remaining regions of the ambiguous space that no logic manage to concretize, becoming new boundary objects | The link between economic growth and environmental objectives is not described by the CCA narrative; the <i>green shift</i> boundary object gives a response to this need |

3.3.3. Phase 3: Articulation of the cloudburst as a selection pressure

The day after the cloudburst, members of the Danish Meteorological Institute hurried to announce that the cloudburst could not be linked with certainty to climate change; however, they confirmed, this kind of event could be more common in the future ([DMI, 2011](#)). Despite this announcement and probably compelled by the need for a plausible explanation for what had just happened, the media, municipality staff and the government immediately accepted that the cloudburst was a confirmation and direct consequence of climate change, implying that a new cloudburst would happen again in the near future.

The cloudburst, an isolated disruptive event, was socially articulated as a newly discovered risk; in other words, a selection pressure that required an urgent response. [Brown et al. \(2011, p. 4044\)](#) call this a situation of political risk: "Politicians, state agencies and large corporations considered they had no other option than to 'take action', that external pressures led them to a position where they had to be seen to be doing something and quickly". According to a manager of the water utility (2018) "both [the mayor of the environmental department and the municipality mayor] took turns on getting on TV and promising the people 'here we are doing something'" (interview #8). Another member of the environmental department confessed in 2019 that some municipality workers referred to the cloudburst of 2011 as the "fundraising rain" (interview #12).

From being an almost irrelevant concept prior to the cloudburst, CCA became an extremely popular issue in Copenhagen. It was a recurrent topic in the media and the number of reports from a variety of institutions about climate change, floods and greening of the city exploded in 2012 ([Krawack and Madsen, 2013](#)). As a staff member of the environmental department put it in 2012 "Climate change adaptation is the talk of the town" (interview #2). It might seem self-evident that the cloudburst would become attached to CCA and transform into a selection pressure. However, in reality, this is far from inevitable; [Lyons et al. \(2018\)](#) found that the

Table 3

Summary of agents' strategic use of boundary objects to accelerate and orient sustainability transitions.

| Phase | Theoretical description of agency | Agency in the case study |
|--|--|--|
| #1. Emergence of a boundary object | <i>Introduction of a boundary object in the regime</i> and building up its legitimacy | Some actors of the environmental department championed the idea of CCA (the boundary object) in the municipality plans, supported by actors from other major cities |
| #2. Emergence of a disruption | The emergence of a disruption is rarely something that is under the influence of the regime actors | The occurrence of the cloudburst was not an event that could be controlled by actors |
| #3. Articulation of a selection pressure | <i>Creation of a narrative</i> in which the disruption becomes a selection pressure that forces decision-makers to act <i>Promotion of the boundary object</i> as a solution for the new selection pressure that is appealing and ill-defined in general use <i>Creation of multiple translations</i> of the boundary object that are well-defined inside an institutional logic Claiming "ownership" of the boundary object <i>Storytelling</i> . Diffusion and promotion of a translation Accommodation of other logics <i>Creation of obligatory passage points</i> . Create new regime's structures that all actors must follow in order to engage in collaborative work | Creation of the narrative where the cloudburst is a direct effect of climate change, which becomes an emerging threat to a vulnerable city; something must be done Promotion of CCA as a solution for the problem of vulnerability of the City of Copenhagen The hydraulic, the market and the water sensitive logics each create their translations of climate change adaptation The environmental department actively contributed to build and strong association between itself, CCA, and the water sensitive logic translation Advocates of the water sensitive logic carried out <i>communication tasks</i> to publicize their translation of CCA as a positive message of common interest, innovation, and sustainability, which motivated political power to support them with resources Advocates of the water sensitive logic fitted their translation to the interests of hydraulic and market logics The environmental department gained responsibility for coordinating the cloudburst management plan, becoming in practice an obligatory passage point |
| #6. Standardization and emancipation | <i>Creation of standards</i> , which unambiguously define the meaning of the boundary object <i>Creation demonstration projects</i> | The environmental department had responsibility for defining the characteristics of the new stormwater infrastructures Demonstration projects like the Climate Neighbourhood (Klimakvarter) became a reification of CCA |
| #7. Emergence of residuals | The emergence of residuals is an unintended effect that under certain circumstances could be exploited to create a new boundary object | The link between economic growth and environmental objectives is not described by CCA; the <i>green shift</i> boundary object gives a response to this need |

association of extreme weather events with climate beliefs heavily depends on the previously existing logics.

In the case of Copenhagen, CCA functioned well as a boundary object for several reasons. First, because it provided a sensible and useful narrative that everybody could agree with in a moment of confusion and urgency—nobody could be against CCA, it was a *nirvana* concept (Molle, 2008). Second, it was accommodated in the current international and scientific landscape, which gave it legitimacy. And third, it provided interpretive flexibility for different logics.

Advocates of the water sensitive logic quickly recognized the cloudburst and the sudden interest for CCA as a window of opportunity to drive their agenda: "We ride on a wave and suddenly it disappears if we do not make some radical changes" (interview #4 in 2012).

3.3.4. Phase 4: Integration of the boundary object (CCA) and emergence of multiple translations

Advocates of the hydraulic logic translated CCA as a matter of coping with increasing volumes of stormwater by systematically increasing the size of the buried pipes. However, already in 2008, Copenhagen's water utility showed some features of the water sensitive logic, acknowledging that the traditional hydraulic logic approach was not fully sustainable. For instance, the municipal master plan for wastewater (CM, 2008) proposed to limit the amount of stormwater entering the combined pipes, mainly to protect the sanitary service by preventing the overflow of combined volumes of stormwater and wastewater. The plan recommended that as much stormwater as possible should be managed locally by infiltration, retained on surface where it caused little damage or re-directed on surface to nearby lakes or streams.

The water sensitive logic translation of CCA was inspired by what the environmental department champions learned in the international conference in 2008. They recognized there that CCA could be seen as an opportunity to make changes in the urban space and improve the liveability. The following paragraph from the Copenhagen's CCA Plan of 2011 summarizes the approach:

The work on climate adaptation offers us a unique opportunity to develop Copenhagen to continue to be one of the world's best cities to live in. By choosing solutions that improve the city's physical environment and create attractive urban spaces in relation to residence, transport and experiences, we can use climate adaptation efforts to raise the quality of life of the people of Copenhagen (CM, 2011a, p. 57).

At that time, this positive approach was innovative, but has become more widely acknowledged in academic literature and in practice over the last decade (Aylett, 2015; Shaw et al., 2014). However, in 2011 the conversion of this CCA understanding into practical measures was still unclear. At this point, "the interpretation space for what the new concept of stormwater management,

namely climate adaptation, actually covers, is still open for negotiation” (Steffensen, 2013, p. 12).

The environmental department champions also pointed out in their 2012 interviews that in the period just after the cloudburst, it was important to manage the urgency and panic because the regime did not automatically turn away from the hydraulic logic and initially resorted to the construction of large pipes. This backlash—which has been widely documented in other case studies (see e.g. Rogers et al., 2015)—is illustrated in an appendix (CM, 2011b) to the wastewater master plan (CM, 2008). This document was released as an emergency response to the cloudburst, aiming to implement urgent adaptation measures before the next “cloudburst season” (CM, 2011b, p. 7), expected in summer 2012. This appendix is of strictly hydraulic character, proposing new pipes to directly convey stormwater to the sea, reopening and creating new wastewater overflows to the harbour, and using parks and small lakes to store stormwater until the capacity of the wastewater system recovered from the storm.

At the same time, strong political pressure resulted in the rapid creation of a cloudburst management plan (CM, 2012), which provided greater concretization to the water sensitive translation. This document mostly promoted local management of stormwater at the surface: creation of green boulevards, redesign of recreational areas and daylighting of streams. The objective was not to completely substitute the old underground system, which would be unrealistic, but instead to develop a whole new system of integrated surface solutions. These solutions should be able to handle cloudbursts and also provide multiple functions when it is not raining—like recreational and aesthetic value, enhanced biodiversity, or improved physical and psychological health of the citizens—while, at the same time, deferring the augmentation of the underground pipe network. From the perspective of the water sensitive logic this type of management was an opportunity to revitalize the city and make it greener.

However, this translation was not unproblematic. During the last century stormwater was managed underground, where it was invisible and isolated from other urban services. Bringing stormwater to the surface meant that its management would overlap with multiple societal functions that compete and collaborate in a shared urban space, making the situation much more complex and potentially conflicted. For instance, residential developers complained about the space taken by infrastructures inspired by the water sensitive logic—like raingardens and swales—and car owners were concerned that these infrastructures would reduce the space dedicated to parking or that the use of roads as floodways would create new risks and disturb the traffic during the storms. Another group that viewed the surface solutions with distrust was the municipal department in charge of water quality of the city’s water bodies. They considered that the road’s runoff under light rainfall was too polluted to be diverted to the lakes and streams and they advocated for the use of the traditional underground system that conveyed stormwater to wastewater treatment plants.

While the water utility became gradually receptive to the introduction of surface management of stormwater—they saw it as an inevitable measure to maintain the hydraulic efficiency of the sewers—the approach’s complexity motivated them to occasionally turn back to old, well-known and simpler solutions: “if things are too complicated on the ground, the natural response, so the backbone response of the [water] utility can be very often to say: ‘ok, let’s put a pipe underground’” (interview #6).

The third logic, the market logic, was in principle closer to the hydraulic logic, as the reduction of flood damages by traditional underground infrastructures was seen as an economic priority; however, the water sensitive logic interpretation of CCA as an opportunity quickly captured its attention. The core market logic narrative was that a new surface-based approach to stormwater management would ultimately serve as a tool for economic growth. The ambition was that innovative green infrastructures would make Copenhagen an international leader in sustainability; an attractive city for investment, tourism and specialized workers that would, in turn, contribute to economic development. Additionally, the new stormwater management would make the city a show-room for export of Danish technology and design (CM, 2015, p. 14).

3.3.5. Phase 5: Dominance of the ambiguous space

The framework’s four actor strategies for asserting dominance over the ambiguous space were at play in the Copenhagen case. As described earlier, the environmental department champions lobbied for the introduction of CCA into the municipal plans because they recognized that it was a useful tool to boost their water sensitive logic agenda, while it did not receive great attention from other logics. “[At the conference] we grasped that it was a really interesting task and there was nobody that would take it” (interview #1). The environmental department became the unofficial *owner* of CCA; they actively contributed to fix the association between the concept, the environmental department, and the water sensitive translation across the regime.

It certainly was a stroke of luck that the cloudburst hit exactly when the CCA Plan (CM, 2011a)—guided by the environmental department—was about to be released. Before that, the city planners estimated that it would take some years to gather the necessary political and economic support for the plan to be implemented. Instead, it immediately jumped to the top of the political agenda.

Right after the cloudburst, advocates of the water sensitive logic intensively publicized their translation of CCA at municipal, national and international arenas as a positive message of common interest, innovation and sustainability. The environmental department internally referred to this labour as *communication tasks* (Steffensen, 2013), which were mainly carried out by champions through their already established networks. An environmental department manager recognized in 2019 that “doing the storytelling about what adaptation could bring, also of positive things to the city, was a reason why it was easy... not easy, but it was possible for us to get to a political decision” (interview #12). Even though other frontrunner cities like New York or Rotterdam also worked very hard to impose the water sensitive translation of CCA—even taking into account that New York also had a great disruptive event (Hurricane Sandy in 2012)—this interviewee claimed that Copenhagen made a faster transition because they may have been better at “telling the story”.

Another environmental department staff member refers to the storytelling strategy of his colleague: “She told the tale that we are going to green the city, that we are going to make exports, that we are going to help building the roads new [...] she hyped this very much [...] she also went onto the international scheme, or in the international discussions on this, and used the success that she had already gained to hype it even more”. Internationally, the environmental department staff members participated in many conferences

and events where they presented their CCA plans as a case of success. As they drew international attention towards Copenhagen, these champions tapped into the positive self-image of local decision-makers. Several interviewees remark that politicians were proud of their projected identity, and they were pressed to meet the expectations created in those adaptation plans through generous support and resourcing.

At the same time, the water sensitive logic champions tried to build synergies with other logics and with the overarching political agenda of the municipality. In the words of an environmental department manager in 2012: “It is really a matter of trying to understand and get into those you talk to [...], why are they here [...] and try to understand how this [our translation of CCA] can support any issue of their agenda” (interview #1). The *accommodation* of the hydraulic logic and market logic into the water sensitive logic translation were two essential processes in the transition. The narrative provided by the water sensitive logic was not fanatic, had an inclusive character, and constantly referred to the CCA as both a hydraulic and economic issue. From a hydraulic logic perspective, the water utility assumed that surface management of stormwater was necessary to cope with increasing stormwater volumes and reduce the load of the sewers to protect its sanitary function. Meanwhile, the accommodation of the market logic was based on two narratives: one, that surface management was cheaper than traditional underground infrastructures, and two, that CCA would bring net economic gains for the city through additional benefits like pollution removal, rises in property values, tourism or increased employment (CM, 2014). It could be said that part of the success consisted in making other logics join the path marked by the water sensitive logic without obliging them to abandon their original identity. For instance, a manager of the environmental department reflected on the logic of the water utility in 2019: “Well, they [the water utility] are still thinking very much hydraulic, that is their goal, because that is what they need to do. They are just thinking about hydraulic issues in a different way” (interview #12).

Regarding other competing interests, water sensitive logic advocates always insisted on finding synergistic solutions. For example, even though the traffic department was, in principle, sceptical of the use of roads as floodways, the environmental department champions convinced them that CCA was actually an opportunity to renew and improve the roads network. Another environmental department staff member (2019) commented on the accommodation labour of one of his colleagues: “she was good to work the system in many angles and make of this a story where we all benefited” (interview #5). Evidence of the successful integration of translations is the immediate approval of the cloudburst management plan (CM, 2012) in the city parliament, without debate and with unanimous support.

This accommodation of other logics was not an easy process and should not be taken for granted. For example, previous environmental plans in Copenhagen, like the development of Agenda 21, were carried out exclusively by the environmental department, with very little interest in involving other municipal agencies. This department was viewed with mistrust by other agencies, which labelled their members as narrow-minded, as they put environmental concerns above any other problem (technical or economic), inhibiting collaboration and ultimately resulting in limited success (Jensen et al., 2013).

All the previous work converted the water sensitive logic advocates into *obligatory passage points*, gatekeepers of a sort, which funnelled and guided the collaboration network. For example, the environmental department was granted responsibility for the subsequent cloudburst plans (CM, 2012), which will shape the transformation of the city over the following 20 years.

3.3.6. Phase 6: Standardization and emancipation

An important part of the concretization work led by the environmental department was to define *standard parameters* for future infrastructures that were imbued with the water sensitive logic (see e.g. CM, 2013). For example, it was required that new infrastructure should be as green, visible, and multifunctional as possible. In addition, projects should provide a net socioeconomic benefit for the whole community and create synergies with other projects or municipal plans.

Soon after the cloudburst, the water sensitive logic advocates recognized that their translation needed to be materialized into *demonstration projects* to give some tangible support to their narrative. Some interdisciplinary predictive models were developed to represent the solutions being promoted (Fryd et al., 2012), but the most publicized demonstration project was Skt. Kjelds neighbourhood, renamed as the Climate Neighbourhood (Klimakvarter), which was selected to be a frontrunner in the city’s CCA. It was devised as a symbolic project that encompassed all the characteristics of the water sensitive logic, served as a platform for interdisciplinary experimentation and learning, and it was presented internationally as a showroom of exportable innovations (CM, 2016). The idea of the Climate Neighbourhood attracted international attention and has already been exported to other cities like New York and Beijing.

The ultimate concretization of the water sensitive logic translation was the political approval for implementing the cloudburst management plan for the next 20 years, which includes 300 stormwater management projects with a budget of EUR 1.3 billion (Ziersen et al., 2017).

An environmental department manager interviewed in 2019 believes that planning processes guided by the water sensitive logic have become rooted in the municipality and are increasingly being taken for granted, but the corresponding design and implementation of infrastructures are still maturing. Nonetheless, she recognizes that this assimilation will eventually occur, as it has for Copenhagen’s bicycle infrastructure:

In the beginning, when you started building bicycle lanes: ‘oh, where are the cars going to be?’ and so on. And now, nobody questions [...] that you need to have a bicycle infrastructure in place almost before anything. When it is snowing in Copenhagen you clean the bicycle lanes before you clean the street [...] So it is really, really embedded in the DNA, both in the management and in the construction that is going on in the city. [Climate change] Adaptation is so new that we are still, I mean, starting walking. A bit insecure, and sometimes stumbles (interview #12).

However, at a certain point it is likely that the new social structures will become so firmly rooted in the regime that they will *emancipate* from the boundary object. Unfortunately, the timeframe of our case study does not allow us to empirically confirm this hypothesis, but it could be argued that previous boundary objects used in Copenhagen's stormwater sector have been emancipated. For example, *ecosystem protection* (a previous boundary object) was firmly materialized as a formal requirement for phosphorus removal and reduction of sewer overflows (Sørensen et al., 2006), which are now taken for granted and have a limited presence in today's public debate.

3.3.7. Phase 7: Emergence of residuals

Looking back, we could argue that CCA was a residual of climate change mitigation, and climate change mitigation was a residual of sustainability, both of which encompassed the region of ambiguousness that its predecessor could not materialize. We suggest that in the case of CCA, the residual ambiguity might be the link between green infrastructures, quality of life and economic growth, which is difficult to concretize. However, this ambiguity is valuable, as the different logics can cooperate without giving up their own interests and assumptions. The “green shift” or “green economy” (grønn omstilling) (Floater et al., 2014) is a new boundary object that has arisen in Copenhagen in the last years, functioning as an excellent nirvana concept and a renewed expression of the ecological modernization philosophy (Jensen et al., 2013).

4. Discussion and conclusion

In this article, we have presented the Copenhagen case study as an empirical and comprehensive application of a new framework for explaining the role of boundary objects in sustainability transitions (BOIST) (Table 3). The framework supports a narrative that describes how the concept of CCA (a boundary object) was introduced by advocates of the water sensitive logic as leverage to slowly transform Copenhagen into a greener city. However, the occurrence of a catastrophic cloudburst (a disruption) led to a sudden emergence of fear for climate change and urgency for adaptation of the stormwater system (a selection pressure). CCA rapidly gained public salience and the different logics started to shape their particular interpretations (translations). Advocates of the water sensitive logic effectively diffused their translation of the concept, promoting their story, accommodating values and interests from other logics, and carrying out demonstration projects that concretize the regime transformation, imposing the vision of livability over the narrower vision of hydraulic efficiency.

The framework provides two simultaneous levels of analysis for this case study. First, at the systemic level, where a socio-technical transition is understood as a reconfiguration of the regime's institutional logics, triggered by a boundary object; a transition from the absolute dominance of the hydraulic logic to a more balanced configuration of logics. The second is an analysis at the agency level, showing how actors purposefully use boundary objects to (1) articulate a selection pressure, (2) concentrate the necessary resources to make effective a socio-technical transition, and, most importantly, (3) build cooperation across conflicting logics. The framework demonstrates how a boundary object behaves as coalescent element in sustainability transitions, serving as a point of agreement and cooperation for disparate institutional logics without constraining their valuable diversity. The environmental, livability, hydraulic and economic perspectives are each able to develop their disparate translations of CCA, while still engaging in collaborative work.

Our case study has been selected to empirically demonstrate the deductively constructed framework, and in other practical applications some elements may not be as easily identifiable. Most notably, our case study happens to portray a sudden and well-defined disruption, the cloudburst, which is well suited for our demonstration purposes. However, the framework does not exclude the possibility that also minor or very gradual changes (minor disruptions) can be hyped by boundary spanners, articulating them as selection pressures that require urgent action. For example, before the cloudburst, climate change was articulated in Copenhagen as a very gradual selection pressure that demanded a reduction in greenhouse gas emissions. To address this need, the environmental department created the Copenhagen's Bicycle Strategy 2011–2025, which focused on the boundary object “World's best bicycle city” (CM, 2011c). This ambiguous vision managed to coalesce the interests of not only the environmental logic, but also that of mobility, public health, economic, political, and not least, the livability logic. From 2010 to 2018 the percentage of citizens using bike transportation increased from 36 to 62 % (CM, 2019) and Copenhagen has repeatedly ranked between the most livable cities of the world, partly thanks to its bicycle culture (Nikel, 2019).

Therefore, we argue that the proposed framework may improve the understanding of highly placed-based transitions—as, we assume, boundary objects are involved in many of them. At the same time, it may help to identify actor strategies or policies to drive these transitions in a certain direction, for example through introducing useful boundary objects, translating them, diffusing them or using them to accommodate conflicting logics. In more academic terms, we believe that our framework is a solid starting point for a new range of studies that focus on the role of boundary objects in transition management, both contributing to the growing application of institutional theory (Fuenfschilling, 2019) and the emerging focus on agency perspectives (e.g. Fischer and Newig, 2016; Wittmayer et al., 2017) in the field of sustainability transitions.

However, it is also important to recognize that transitions are complex phenomena that cannot be completely explained by a simple framework of reduced scope like ours (Holtz, 2011). Our research—both for explanatory and policy design purposes—may be integrated into larger simulation models that attempt to reproduce possible pathways in which a transition can unfold (de Haan et al., 2011; de Haan and Rogers, 2019; de Haan and Rotmans, 2011), or even be combined with models from other disciplines to inform strategic planning (Rauch et al., 2015), constituting a promising idea for future research.

Our globalized society is relentlessly increasing its diversity and complexity, generating interdependent, unstructured, and pervasive problems that create new conflicts among an expanding number of logics. While in the past—with limited diversity and

complexity—the definition of problems and selection of solutions used to be undisputed, already today and more intensely in the future, the difficult accommodation of disparate goals, values and worldviews may pose a serious barrier for sustainability transitions. Therefore, we anticipate that boundary objects will become increasingly relevant, and hope that our framework becomes a valuable conceptual element in the toolkit of sustainability transitions.

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