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Transforming mobility: The Dutch smart mobility policy as an example of a transformative STI policy

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Abstract

The recent orientation toward societal challenges in Science, Technology, and Innovation (STI) policies has exposed the limitations of contemporary governance to deal with these endeavors. For this reason, it has been urged a shift toward the so-called 'transformative change' approach, drawn from socio-technical transitions literature. This research suggests that this approach can be considered an emerging policy paradigm, and studies the implications of its adoption in STI policy. For doing so, we developed a conceptual framework based on policy sciences and STI policy literature, and used to study a policy resembling this societal challenge orientation: the Dutch smart mobility policy. Our case study suggests that the transformative change approach can be considered a new paradigm in STI policy, as novel theories, approaches, and mechanisms are being used to govern this policy. This research contributes to a better understanding of transformative approaches, by empirically looking the changing role of governance in societal challenge-led STI policies.

Key words: STI policy; transformative change; societal challenges; policy paradigms; paradigm shift; smart mobility.

1. Introduction

Science, Technology, and Innovation (STI) are being increasingly acknowledged for their potential contribution to address contemporary societal challenges, such as climate change and sustainability (OECD 2015). This acknowledgement has led to a strategic orientation toward grand challenges in STI policies and directives of various Organisation for Economic Co-operation and Development (OECD) Member States, and European Commission programs like Horizon 2020 (European Commission 2016; OECD 2015). This orientation has fostered a debate on the governance of such novel type of STI policies (see Edler and Boon on 'demand-side policy instruments', Mazzucato (2016) on 'mission orientation', and Schot and Steinmueller (2018) on 'transformative change'). The ensuing debates criticize the current governance of STI policies because of their focus on economic rather than desirable societal outcomes, as well as because it limits state intervention to market failures and systemic problems, and neglects systemic changes at a societal level (Mazzucato 2016; Schot and Steinmueller 2018; Weber and Rohracher 2012). For these reasons, several scholars have called for a paradigmatic shift in STI policies (Mazzucato 2016; Weber and Rohracher 2012). This shift is expected to result in radical policy change, including new interpretative frameworks for STI processes, policy objectives, intervention rationales, and policy instruments (Borrás and Edquist 2013; cf. Flanagan et al. 2011).

To tackle the aforementioned deficiencies, one approach gaining support in recent years is the so-called 'transformative change' approach (Schot and Steinmueller 2018; Steward 2012; Weber and Rohracher 2012). This approach suggests tailoring STI governance to meet its grand challenges orientation by incorporating socio-technical transitions insights (Steward 2012; Weber and Rohracher 2012). These insights can improve STI governance in several ways: they align economic and societal goals, broaden policy interventions from firm and sectoral level to a societal level, and provide a normative orientation in STI policies by mobilizing sustainability transitions theories. Recently, this approach has been deepened by theoretical developments delineating new policy objectives, intervention rationales, and policy instruments (Daimer et al. 2012; Lindner et al. 2016; Weber and Rohracher 2012).

Although the transformative change approach has gained ground within the STI community, previous studies have limited focus on actual policies. This means we still do not know how this approach will impact STI governance in practice. This article aims to fill this gap between theory and practice by analyzing a case study underlining our claim that the transformative change approach is informing

policy design: the Dutch smart mobility policy. Established in 2013 to foster technological innovations in the fields of traffic management, travel information, and in-vehicle technologies, this policy resonates with the transformative change approach in various ways. First, it incorporates three societal challenges as policy goals (quality of life, accessibility, and safety), which are expected to be achieved by diffusing smart mobility technologies. Second, the novel governance approaches to this policy have broadened the scope of policy interventions beyond traditional innovation policies. Lastly, it is framed as a transition policy, aimed at transforming step-by-step the current socio-technical regime to create a new one (de Mooij 2013).

Our research aims to answer the question 'can the Dutch smart mobility policy be regarded as a STI policy for transformative change?' and, if so, 'what governance mechanisms were used to achieve this transformative orientation?' To answer these questions, we conducted an extensive literature review of policy sciences and STI policy literature, and developed a conceptual framework outlining the anticipated transformations of the adoption of this paradigm. While the policy sciences literature provides a comprehensive understanding of generic policy paradigm shifts, the STI policy literature adds insights in the specificities of the STI domain. There is sound evidence that intervention rationales should be broadened to justify policy interventions in transformative policies (Mazzucato 2016; Schot and Steinmueller 2018; Weber and Rohracher 2012). Accordingly, our framework shows how a novel understanding of STI processes informs policy design and implementation, and creates new policy interventions and instruments. Finally, we apply this framework to our case study, to test whether the Dutch smart mobility policy can be considered a STI policy for transformative change.

The structure of our article is as follows: in the next section, we present the theoretical background and transformative change literature. Section 4 describes the framework development and Section 5 the methodology. In Section 6, we apply this framework to Dutch smart mobility policy, before ending with topics for discussion and conclusions.

2. Theoretical background

One approach to studying the governance of STI policies is to look into the theoretical perspectives informing policy choices. In the mid-twentieth century, classical mission orientation guided policy choices, for example, in agriculture and defense (Foray et al. 2012; Sampat 2012). Thereafter, a neoclassical perspective on innovation dominated, with a strong focus on market failures, followed by an evolutionary structuralist view, namely the Systems of Innovation (SI) perspective (Bach and Matt 2005; Chaminade and Edquist 2010). These theories are central in STI governance for two main reasons. They allow policymakers to mobilize theoretically sound arguments to 'make sense' of STI policies (Laranja et al. 2008), for example, by linking problematic conditions requiring governmental intervention to 'market failures' or 'systemic problems' (Bach and Matt 2005). In addition, they legitimize policymakers interventions, considering them scientifically sound knowledge sources (Weber and Rohracher 2012: 1040). Although scholars have coined different terms for these perspectives—Schot and Steinmueller (2018) talk of 'framings', Chaminade and Edquist (2010) refer to 'approaches', and Laranja et al. (2008) call them '(meta) rationales'—they resemble what policy sciences consider policy paradigms[1]; in other words, widely shared frameworks of ideas allowing policymakers to meaningfully understand a policy, provide guidance for their actions, and suggest possible responses to policy problems (Hall 1993; Hogan and Howlett 2015).

The policy paradigm concept was developed in the late twentieth century to explain how ideas and theories influence policy change (Hall 1993), and similar notions have been increasingly incorporated in STI policy studies (Chaminade and Edquist 2010; Laranja et al. 2008; Schot and Steinmueller 2018). This concept suggests that policymakers share dominant 'world views', which influence a policy's governance. They are therefore able to conceptualize the relevant problems requiring governmental action, set policy outcomes and objectives, and suggest adequate activities and means to achieve those ends (Daigneault 2014; Hall 1993). Consequently, a paradigm also indicates certain aspects *not* considered relevant for policymaking. Because paradigms are widely shared, they induce stability, predictability, incrementalism, and consensus in policymaking (Béland and Cox 2013).

Policy paradigms are stable over long time periods, but occasionally change, especially when a paradigm's theoretical insights and policy realities become discrepant (Wilder and Howlett 2015). This occurs when policy anomalies (e.g. cumulative policy failures) delegitimize the existing paradigm and policymakers see novel nonhegemonic paradigms as a better way to cope with new policy realities (Capano 2003). In these paradigm shifts, multiple dimensions of policymaking encounter radical changes, ranging from policymakers' values, assumptions, and principles, to the emergence of new problems that require policy intervention (Daigneault 2014; Kern et al. 2015). Nevertheless, certain dimensions of the old paradigm will remain after the shift, due to policy legacy and path-dependency.

3. The emergence of the transformative change approach

In STI policy, the Neoclassical and System of Innovation theories fit into what policy sciences consider dominant policy paradigms. The Neoclassical approach, rooted in mainstream economics, has been a major paradigm since the post-war era. To overcome its deficiencies, the SI paradigm was adopted in the 1980s (Edler and Fagerberg 2017).[2] To date, both paradigms remain influential for STI policies with an economic focus (Laranja et al. 2008). Nevertheless, in recent years, they have been contested by the emergence of grand societal challenges as central rationales for public policy. As a result, STI policies are strategically oriented toward addressing contemporary grand challenges and persistent negative societal conditions, such as unemployment and inequality (Schot and Kanger 2018; Schot and Steinmueller 2018). This novel orientation has been coined the 'strategic turn' (Weber 2012) or 'normative turn' (Daimer et al. 2012) in STI policy.

This strategic or normative turn exposes the limitations of the two dominant paradigms to address societal challenges. First, both paradigms have a strong economic focus, and ignore any normative orientation, despite normativity being a key element of addressing societal challenges (Daimer et al. 2012). This is especially so because societal challenges are often considered 'wicked problems', for which market mechanisms or systemic approaches are not sufficient (Amanatidou et al. 2014). Second, these two paradigms emphasize technological innovation, even though other types are required such as social innovation (Daimer et al. 2012). Third, they reduce state intervention to administering, fixing, regulating, facilitating, or de-

Table 1. Framework dimensions and their relationship with existing literature.

	Author	Overarching policy goals	Interpretative frameworks	Intervention rationales	Strategic tasks	Policy instruments
Policy paradigms literature	Daigneault (2014)		Ideas about the nature of reality	Problems that require public intervention	Ideas about policy ends and objectives	Ideas about policy ends and objectives
	Kern et al. (2015)		Interpretative frameworks, Governance institutions		Objectives of policy	Instruments
STI policy literature	OECD (2010)	(Implicit)		Rationales	Strategic tasks	Instruments
	Schot and Steinmueller (2018)	(Implicit)	Innovation model and actors	Rationales/justification for policy intervention	Policy practices	Policy practices
	Borrás and Edquist (2013)	Ultimate objectives/goals		Direct policy objectives	Key activities	Policy instruments
	Laranja et al. (2008)		Consideration of technology and space, policymakers role	Public intervention rationale	Objectives and level of intervention	Policy instruments
	Cunningham et al. (2016)	Policy goals and objectives	Targets			Instruments and implementation
	Bach and Matt (2005)		Main features	Circumstances that do not work well	Principles of state intervention	
	Chaminade and Edquist (2010)		Underlying assumptions, strength/weaknesses of a paradigm	Main rationale, Government intervenes to	Focus	

risking private sector activities (Mazzucato 2016: 141). Fourth, the dominant paradigms ignore policy interventions that grand challenges require, for example, in the use, functionality, and values of technologies in society. Finally, the dominant frameworks do not acknowledge the social desirability of innovations (Kuhlmann and Rip 2018), suggesting that STI investments are not necessarily consistent with social and environmental values (Schot and Steinmueller 2018). For these reasons, several scholars have called for a shift to the 'transformative change' paradigm (Schot and Steinmueller 2018; Steward 2012; Weber and Rohracher 2012). They suggest that socio-technical transitions thinking can make STI policy more suitable for addressing societal challenges (Steward 2012; Weber and Rohracher 2012; Grin et al. 2010), for example, by allowing a better alignment between STI policy and sustainability goals.

We already see evidence of STI policies aligned with this transformative approach. For instance, the European Union (EU) fosters social innovation initiatives and new mission-oriented approaches (e.g. FP9) to meet societal demands (BEPA-EU 2011; Mazzucato 2018); and several OECD countries have prioritized societal challenges in their STI directives (OECD 2014). What remains understudied is how we can better understand the impact of this paradigm shift both conceptually and practically. Our first step was to create a conceptual framework to study this impact.

4. Proposed framework to study paradigm shifts in STI policy

To understand how a paradigm shift in STI policy may look like, we develop the framework that can be used to test the various implications of such a shift. We applied the notion 'conceptual framework' in a similar fashion to Ostrom (2011; also see Schlager 2007), to refer to a tool for identifying the major elements and their general interrelationships for studying particular phenomena (Sabatier 2007). Such a framework is a starting point for investigative research (allowing later refinement) and should be as comprehensive as possible to address particular research questions (Schlager 2007).

We conducted a literature review on the concepts 'paradigm shift' and 'policy paradigm' in policy studies literature, to pinpoint how we could apply these to the STI domain. We found that a policy paradigm is composed of several (policy) 'layers', referred to in the literature as 'dimensions' (Daigneault 2014; Hall 1993), ranging from ultimate policy goals to policy instruments. By studying the theorized layers in STI policy literature, we identified five layers that feature systematically: overarching policy goals, interpretative frameworks, intervention rationales, strategic tasks, and policy instruments. Table 1 shows how these layers are linked with the literature. We present each layer in the following subsections, and their connection with similar concepts in STI and policy sciences literature.

4.1. Overarching policy goals

STI policies are rarely established for the production and diffusion of STI *per se*, but are rather oriented to major goals, such as competitiveness, economic growth, or to support strategic areas like defense (Cunningham et al. 2016; Schot and Steinmueller 2018). Equally, Hall (1993) indicated that major motivations such as economic stagnation, have a direct impact on the paradigms adopted in economic policymaking. In line with Borrás and Edquist (2013), we labeled these motivations and objectives 'overarching policy goals'. Generally, these goals are determined in political processes, beyond STI policy communities. They also denote how policymakers conceptualize the relationship between STI policy and society (Kuhlmann and Rip 2018). Today, we are witnessing how novel overarching objectives are defined in STI policy, as innovation is acknowledged as 'essential' for addressing societal challenges (Weber and Truffer 2017). Several OECD reports (OECD 2011, 2015, 2016a) recognize STI policy's emerging role in contributing to address societal goals, and the Horizon 2020 program focuses on

seven strategic societal challenges. These novel objectives suggest a paradigmatic shift in STI policy.

4.2 Interpretative frameworks

In his seminal work, Hall (1993) suggested that a change in overarching policy goals in economic policy during the 1970s and 1980s was followed by a shift from Keynesianism to neoliberalism. In the same period, STI policy adopted a new systemic evolutionary perspective to strengthen the competitiveness of national economic systems (Bach and Matt 2005). We call these theories 'interpretative frameworks'. They provide a scientific understanding of actual policymaking, by mobilizing theories, frameworks, models, and the like, to explain knowledge production and diffusion. However, they are seldom 'just' theories, as they also implicitly contain high-level philosophies and assumptions that are translated into policy design (Laranja et al. 2008). They may suggest an 'appropriate' role of the state *vis-à-vis* nonstate actors (Chaminade and Edquist 2010), or indicate suitable forms for governing STI processes (Kern et al. 2015).

Dominant paradigms change when their interpretative frameworks no longer fit new policy realities, creating an opportunity space for adopting new ones (Hogan and Howlett 2015). In STI policy, societal challenges have created this space, and several scholars have proposed new frameworks to deal with them (Mazzucato 2016; Schot and Steinmueller 2018), including the transformative change approach. This approach has been nurtured by insights from socio-technical transitions literature (Steward 2012). In an attempt to understand how to achieve major transformations toward sustainability in contemporary societies, the transitions literature suggests that technologies are embedded in socio-technical configurations which fulfill societal functions like mobility, health, and energy (Grin et al. 2010), and major socio-technical change ('transition') can only occur if these configurations are also changed. Thus, institutions (sets of rules), user practices, and legal or cognitive frameworks come into play, as well as the frameworks of researchers and innovators leading to technological change (Dosi 1982). Additionally, the transformative change approach mobilizes Multi-Level Perspective (MLP) insights. The MLP suggests that transitions are non-linear processes, resulting from the interactions with wider contexts ('landscape developments'), emerging innovations ('technological niches'), and unstable or weak dominant socio-technical configurations ('socio-technical regimes') (Geels and Kemp 2012).

The transformative change approach has various advantages for dealing with societal challenges. It broadens the concept of innovation to new areas, for example, frugal, low-tech, or social innovations (Daimer et al. 2012). The focus on nontechnical (e.g. social) components of STI is stronger (Rogge et al. 2018). It raises questions about how to better align STI processes with societal goals (Schot and Steinmueller 2018). In addition, it suggests 'issue-centred policies', linking STI with other sectors, for example, transport or energy (Weber and Rohracher 2012).

4.3 Intervention rationales

'Intervention rationales' play a key role in legitimizing STI policy intervention (Laranja et al. 2008). They are the problematic conditions that require policy intervention (Bach and Matt 2005). If such conditions are not expected to resolve themselves, they become intervention rationales. Rationales link conditions with their underlying theoretical causes (Edler et al. 2016a), and form the basis of policy actions.

Up till now, 'market failures' and 'systemic failures' ('structural system failures') have been the two major intervention rationales in STI policy. While market failures legitimize public intervention where resources are poorly allocated by market parties from a societal perspective (Chaminade and Edquist 2010; Mazzucato 2016), systemic problems suggest interventions to target the conditions that 'negatively influence the speed and direction of innovation processes' (Wieczorek and Hekkert 2012: 74). These interventions may not encompass all the policy interventions required for transformative change. Weber and Rohracher (2012) argue that new rationales should be derived from MLP and socio-technical transition thinking. They suggest four new 'transformational system' failures relating to (deficits in): directionality, demand articulation, policy coordination, and reflexivity, which we explain in more detail.

The *directionality* failure indicates that the two dominant paradigms do not internalize a normative orientation function that transformative STI policies require, in terms of 'social, economic, and environmental sustainability' (Schot and Steinmueller 2018). To date, directions of change are largely defined by market parties, but this is problematic as they cannot internalize the high uncertainty and risks with transformative policies (Mazzucato 2016). Thus, scholars have suggested that policymakers (along with societal stakeholders) set directions of change in transformative policies (Daimer et al. 2012; Mazzucato et al. 2015). Policymakers could determine directions by selecting the societal goals that the STI policies are expected to help achieve (Weber and Rohracher 2012). Providing 'directions of change' in STI policy is not an entirely new concept, as exemplified in the Apollo Program and Manhattan Project, however, their directions were defined in technical rather than societal terms (Foray et al. 2012).

The *demand articulation* failure indicates that societally-desirable innovations can fail due to a lack of anticipation and learning regarding user needs, as well as 'complementary social, organizational or institutional innovations' (Weber and Rohracher 2012: 1043). This failure is linked with the state's entrepreneurial role, revisited by Mazzucato (2013), who identified that public authorities had a major role in fostering technologies with limited markets. In her view, authorities should have a more active market-creating role to address societal challenges (Mazzucato 2016). Authorities also create complementary assets for innovation processes, such as institutions and networks (Mazzucato and Semieniuk 2017). The demand articulation failure has been tackled by focusing on user-centered innovations from the very early stages of innovation, blurring the dominant dichotomy between producers and consumers (Daimer et al. 2012).

Policy coordination refers to the need for coherent policy implementation at national, regional, and sectoral levels (Weber and Rohracher 2012). This coherence is needed as STI is becoming a cross-cutting domain which impacts and is impacted by other domains and multiple governance levels (Cunningham et al. 2016). It has significantly increased the number of actors involved in this domain (Kuhlmann and Rip 2018), and as suggested by Lindner et al. (2016: 15), transformative STI policies require 'interactions across all types of pre-established boundaries, intra- and inter-organizational, intra- and inter-sectoral, intra- and international'. According to Weber and Rohracher (2012), three different types of coordination are required: vertical coordination (between multiple levels of governance), horizontal coordination (between different

actors on the same governance level), and for timing various policy interventions. This coordination is expected to occur within the public sector and between the public and private sector (Weber and Rohracher 2012).

The final transformational failure refers to *reflexivity*. Reflexivity is 'the ability of the [innovation] system to monitor, to anticipate and to involve actors in processes of self-governance' (Weber and Rohracher 2012: 1044). Addressing societal challenges through STI means dealing with high levels of complexity and uncertainty, particularly as there is no clearly defined technological pathway to achieve socially-desirable outcomes (Schot and Steinmueller 2018). Transformative policies force policymakers to internalize and reflect upon developments and, if necessary, adapt to new realities. Thus, STI policy should be able to cope with uncertain and unforeseen circumstances. This failure can be addressed if policymakers take account of the values and orientation of STI actors, align individual and collective goals, recognize conflict, moderate it, anticipate uncertain outcomes, and experiment (Lindner et al. 2016).

4.4 Strategic tasks

Policymakers translate these rather abstract intervention rationales into 'strategic tasks' (OECD 2010). For example, provision of knowledge and support services to innovation firms are strategic tasks for addressing systemic problems (Borrás and Edquist 2013). In other words, they are the type of actions that public authorities can adopt (Bach and Matt 2005), like delivering infrastructure for STI systems, and generating basic knowledge. As OECD (2010: 257) suggests, these tasks are a 'broad direction of policy intent' considering timing, capabilities, and targets.

We can outline certain characteristics of these strategic tasks for transformative change. The normative dimension of STI policy requires processes of deliberation and negotiation between multiple societal actors. Transformative change scholars want more focus on new modes of participatory governance for STI policies (Daimer et al. 2012; Weber and Rohracher 2012). STI scholars suggest a better representation of societal actors throughout the entire process of transformative STI policies (Kuhlmann and Rip 2018; Lindner et al. 2016), including policy evaluation (Amanatidou et al. 2014). Another strategic task, experimentation (Lindner et al. 2016), plays a central role in transitions literature. According to Rogge et al. (2018), experimentation is needed to test the feasibility of projects, and to enable policy learning (also in terms of new socio-technical configurations).

4.5. Policy instruments

Finally, we refer to the concept of policy instruments. They are the tools or techniques developed by policymakers to achieve STI goals and support STI processes (Borrás and Edquist 2013; Edler and Fagerberg 2017), for example, fiscal incentives, credits, and public procurement schemes. Policy instruments are not directly related to overarching policy goals (Borrás and Edquist 2013), but associated with the strategic tasks and intervention rationales suggested by the policy paradigm. Theoretically speaking, policy instruments should match at least one intervention rationale and one strategic task (OECD 2010). STI scholars have developed the concept of 'instrument mix' (Borrás and Edquist 2013; Cunningham et al. 2016) to clarify that multiple policy instruments can be used simultaneously to implement STI policies. The changes in policy instruments are important in a paradigm shift, particularly as they reflect how policymakers perceive the relationship between governing and governed parties (Flanagan et al. 2011; Le Galès 2011).

In transformative STI literature, scholars discussed the relevance of demand-side policy instruments (Edler and Boon 2018) to complement existing largely supply-sided policy instrumentation. Soft instruments (e.g. future-oriented exercises, including foresight and backcasting) are valued as they enable negotiation and consensus building in policymaking (Lindner et al. 2016). Other instruments stimulating participation are required, as a broad network of actors is valuable for directing STI policies. Finally, Kivimaa and Kern (2016) identified niche support instruments and regime destabilization instruments. While the former accelerate and nurture emerging technologies, the latter aim to apply pressure on existing socio-technical regimes to change.

4.6 Rounding up: proposed framework to study paradigm shifts

To summarize, we present our framework for studying a shift in STI policy in Fig. 1. We identified that a paradigm shift occurs when the existing paradigm cannot cope with policy realities (e.g. new societal issues), leading to cumulative policy failures (Rayner 2015). New theoretical approaches are therefore needed to overcome these failures. Having reviewed the literature, we suggest that STI's expected

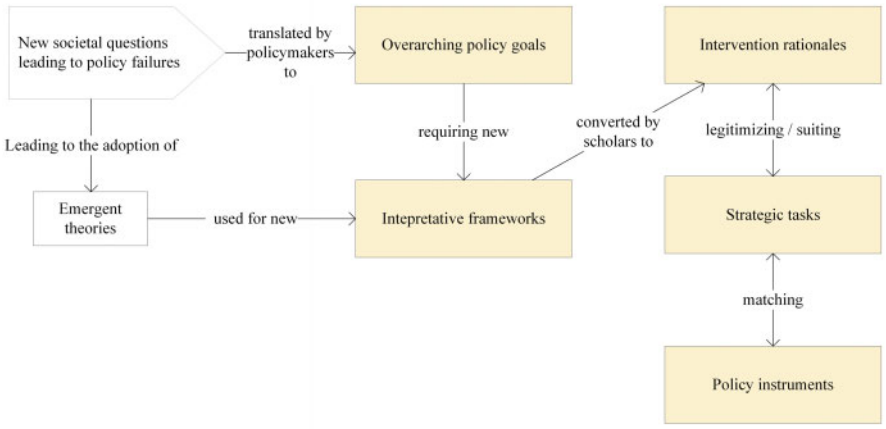

Figure 1. Proposed framework for studying transformative change.

contribution to societal challenges is a novel condition that cannot be addressed by the two existing dominant STI policy paradigms; several scholars agree that a new paradigm can be developed on the basis of MLP and socio-technical transitions theories (Schot and Steinmueller 2018; Weber and Rohracher 2012).

Incorporating new theories in STI policymaking implies changes to each of the five layers of its policy design and implementation. As STI policy is intrinsically linked to broader societal and political issues, we expect that a paradigm shift would see these issues being translated into new overarching policy goals, implying a profound change in each (policy) layer. This change would go hand in hand with the adoption of new interpretative frameworks. In the previous section we showed that this may already be happening in STI policy. As suggested by Chaminade and Edquist (2010), there is an inherent link between theories and intervention rationales. This link between intervention rationales, strategic tasks, and policy instruments has been explicitly recognized by the OECD (2010), suggesting a nested relationship between the three layers: intervention rationales influence strategic tasks, which subsequently impact the choice of policy instruments, and vice versa (OECD 2010: 256–7).

In actual policymaking, these layers may be present in a less coherent manner, and their relationships may be fuzzy, nonmechanistic, and nonrationalist. For instance, intervention rationales can serve as *ex-ante* or *ex-post* justifications for policy interventions, and contingencies may influence policy implementation (Flanagan et al. 2011). Our framework can be a starting point to 'make sense' of actual policymaking, identifying the most relevant elements in the literature.

5. Methods

In order to answer our research question 'can the Dutch smart mobility policy be regarded as an example of a STI policy for transformative change?', we applied our framework to the case study. We analyzed primary documents and carried out fourteen interviews with policymakers. The documents provided reliable information on our case study and the interviews allowed us to explore how policymakers frame and interpret the policy. We obtained smart mobility policy documents via organizations' websites, programs and projects, and the Dutch government search engine (overheid.nl). The interviewees' background is diverse as shown in Table 2.

Interviewees were selected based on their knowledge of Dutch smart mobility initiatives. However, they are not necessarily directly involved in smart mobility policy. Some work for independent mobility research institutes or universities. We consider that their limited engagement with this policy guarantees capturing enough critical voices and avoids potential bias in interviewee responses. The authors are aware that, due to the early stages of this policy, the circle of actors with knowledge of smart mobility policy is limited, and the same applies to the diversity of opinions. It is also therefore beyond our scope to study the effectiveness of this policy.

Table 2. Background of interviewees.

Interviewee	Background
1	Director of smart mobility research area, university
2	Policymaker, Intelligent Transport Systems, I&M
3	Policymaker, strategy and innovation, I&M
4	Researcher, transport institute
5	Researcher, transport institute
6	Advisor, infrastructure, I&M
7	Researcher, spatial/transport planning, I&M
8	Project leader, automotive campus
9	Project leader, automotive campus
10	Project leader, triple-helix platform
11	Advisor, smart mobility platform
12	Public official, behavioral change program
13	Public official, behavioral change program
14	Stakeholder, high-tech company

We applied our framework as follows: we explored whether our case study policy goals required a new approach in order to be successful, indicating a potential paradigm shift, and what policy instruments were applied to operationalize this approach. After identifying the emerging approaches in our case study, we discussed these with the interviewees. Their responses enabled us to determine how these approaches were related to novel strategic tasks, as well as to the intervention rationales suggested by Weber and Rohracher (2012). Coding the responses was guided by the five layers of our framework and using qualitative research software. We applied triangulation techniques (e.g. with primary documents) to validate the interviews; and to guarantee reliability and validity, this research was presented at various STI policy venues, and discussed with policymakers.

6. Is the smart mobility policy in the Netherlands transformative?

To assess whether Dutch smart mobility policy can be considered transformative, we first review the overarching goals and interpretative frameworks in STI policy, then present the strategic tasks and policy instruments per intervention rationale.

6.1 New overarching policy goals in STI policy

The Netherlands is considered an international transport hub in Europe, connecting overseas with mainland Europe via the Port of Rotterdam and via Schiphol Airport in Amsterdam. Moreover, it is a densely populated country with a robust and well-developed mobility infrastructure (Connecting Mobility 2016a). The country expects that increasing traffic levels will lead to 'delays and uncertainty caused by increased congestion, health risks through emissions and noise, and lower safety levels for all road users' (AutomotiveNL, Connekt, and DITCM 2012: 5). One solution for these anticipated negative consequences of future mobility is smart mobility. Interviewees consider smart mobility as an emerging mobility solution strongly geared to implementing information technologies (Interviews 1, 2, 4, and 5). According to Marsden and Reardon (2018), smart mobility requires deep social and organizational change, as it disrupts how mobility is organized and impacts everyday mobility. Smart mobility differs from previous approaches, since rapid IT developments enable a deep reconfiguration of the mobility system (Interview 2).

In 2013, the head of the Ministry of Infrastructure and Environment (hereafter I&M)[3] announced to Parliament her intention to promote smart mobility innovations and position the country as a frontrunner in this area (I&W 2013). Moreover, she announced the action program 'Better Informed on the Road' (hereafter BGOW). This program aims to achieve smart transition mobility in the Netherlands by: (1) improving traffic information and traffic management; (2) contributing to the public goals of accessibility, quality of life, and safety; (3) improving the efficiency and effectiveness of traffic management; and (4) strengthening the Dutch smart mobility business sector (I&W 2013, 2015a). To achieve these objectives, public and private roles in the mobility system had to be

redefined (Connecting Mobility 2016a); this is because market parties have to take over activities currently under the umbrella of public authorities, such as traffic information management and diffusion (de Mooij 2013).

6.2 New interpretative frameworks

The Dutch smart mobility policy has two characteristics resembling the normative turn in STI policy: first, it considers societal goals as central elements and some policymakers strongly believe smart mobility can help to address societal challenges (de Mooij 2013). According to policymakers, smart mobility technologies are expected to 'speed up the transition towards a more sustainable mobility' (Interview 1). Policymakers share a strong technological optimism regarding smart mobility innovations, and documents suggest that policymakers' activities are focused on capturing the 'societal value' of these innovations to unleash their full potential (AutomotiveNL, Connekt, and DITCM 2012; Connecting Mobility 2016a). However, the smart mobility policy was also meant to promote the Netherlands as a leading competitor in this emerging technological field (Interview 2). One interviewee suggested that while smart mobility can help to reach international agreements on reducing CO_2 emissions (e.g. by saving fuel consumption), at the same time it can strengthen the Dutch mobility business sector (Interview 10) (Smart Mobility Embassy 2018). In other words, the societal and economic benefits go hand in hand in smart mobility policymaking (AutomotiveNL, Connekt, and DITCM 2012; de Mooij 2013; I&W 2016a).

The second characteristic is that unlike previous mobility policies, Dutch smart mobility is framed as a transition policy (Connecting Mobility 2016a; de Mooij 2013; I&W 2016a). It requires the 'dismantlement of the current constellation ([of] services, technology, organization and finances) and the step-by-step introduction of a new constellation' (de Mooij 2013: 13). This transition orientation means that public bodies have to phase out the current mobility system to enable the emergence of a new one (I&W 2016a). Such orientation is clearly visible in reports and policy documents, including a transition road map for smart mobility (de Mooij 2013) and reports by public research bodies on the societal impacts of mobility policy (Tillema et al. 2015, 2017). The framing in these documents resonates with academic literature on smart mobility governance, suggesting that this requires and will result in new socio-technical configurations (Docherty et al. 2017; Marsden and Reardon 2018). For instance, self-driving vehicles require novel legal frameworks for operation, an increase in user acceptance, new market segments and business models, as well as novel insurance and liability arrangements. They are also expected to result in new mobility patterns, urban space usage, and approaches to mobility infrastructure (Cohen and Cavoli 2018; Docherty et al. 2017; Fraedrich et al. 2015). There is clear evidence of these views in policy documents (AutomotiveNL, Connekt, and DITCM 2012; Connecting Mobility 2016a, 2016b; Connekt 2016a; I&W 2016a).

This transition approach to STI is also apparent in the institutional setup of smart mobility policy. While traditional STI policies mostly focus on stimulating economic growth and are normally the responsibility of the Economic Affairs Ministry (EZ), smart mobility policy was originally developed by I&M to respond to specific societal challenges. This policy also broadens up STI to players ignored in previous mobility innovation policies (e.g. IT companies, user organizations, and implementing agencies). Intermediary organizations such as the Royal Dutch Touring Club (ANWB) played a key role, for example, for user involvement (ANWB 2015). The fact that I&M opened up the policy has led to a shift from a top-down approach to a cocreating one (Interview 3). This cocreation is presumably a key factor in smart mobility policy because 'the only way to achieve it [a transition] is by working together' (Interview 10), especially thanks to its system-wide scope. In contrast with previous policies, the government today works more as a facilitator of the transition. For instance, it promotes international agreements and standards on deployment issues like liability, safety, and privacy (Connecting Mobility 2016a), and ensures international interoperability of smart mobility systems (EU 2016). The Dutch government facilitates development by offering its national mobility infrastructure as a 'test-bed' for experiments in which companies and governments can learn by doing.

6.3 Strategic tasks and policy instruments for each intervention rationale

Our next step was to explore which strategic tasks and policy instruments policymakers use to address the four previously mentioned transformational system failures: directionality, demand articulation, policy coordination, and reflexivity. Although market and structural system failures still underpin the Dutch smart mobility policy, we now focus on the transformational features of this STI policy.

6.3.1 Directionality

Smart mobility policy, aimed at a socio-technical transition in the mobility sector, has a clear direction determined by policymakers, setting the route of action. A major task is identifying and linking innovations (in terms of goods and services) and societal challenges. We can trace this strategic task back to 2012, when several Dutch organizations presented the 'Towards a Smart Mobility Roadmap' report. It explored the technological choices for addressing societal issues, such as safety and emissions, and linked them with services that can be offered to road users (AutomotiveNL, Connekt, and DITCM 2012). In a similar fashion, the 'DITCM Roadmap for Cooperative Driving' (2015) linked technologies with their potential societal impacts, and the necessary market conditions for their upscaling. The technologies expected to contribute to societal challenges relate to those in which the Netherlands excels, such as High-Tech System Materials and Logistics (EZ 2013). Correspondingly, universities are focusing research on smart mobility technologies in which 'universities have strengths', such as semi-conductors, data science, and electronics in the Eindhoven region (Interview 1).

A second strategic task is establishing general guidelines for the nontechnical changes in smart mobility transition. The aforementioned BGOW strategic action program, resulting from the 'Towards a Smart Mobility Roadmap' report, highlights six transition pathways[4]: (1) developing individual smart mobility services; (2) changing the role of roadside systems, (3) integrating traffic and travel information, (4) developing Business-to-Business and Business-to-Consumer strategies, (5) opening mobility data, and (6) developing new types of public and private collaboration (de Mooij 2013). To safeguard these pathways, the 'Five November Group' was established, consisting of experts on smart mobility technologies who work 'as keepers of the roadmap' (Interview 2), contributing their individual expertise and visions on this policy. In addition, the organization 'Connecting Mobility' was established to catalyze and evaluate the smart mobility transition based on these pathways (I&W 2016b).

Another strategic task was to perform *ex ante* evaluations of the impact of technologies in order to increase public support. In this way, policymakers can assess whether a specific technology will be deemed socially desirable. For example, with the triple-helix platform Connekt, policymakers identified the societal value of any technology that could be supported in the pre-commercial stage. However, at the time of the interviews, there was no formalized assessment method for Connekt, only a discretional evaluation in response to the question 'does it [the technology] have an added value and what problem does it solve?' (Interview 10). Policymakers also used future-oriented exercises to perform this assessment. Based on the level of automation and upscaling of car sharing, Tillema et al. (2015) assessed through scenarios the social, spatial, and economic impacts of self-driving cars. This report was later augmented with a stakeholder exercise proposing transition routes for each scenario, and recommended strategies for public intervention, for example, monitoring and evaluating, researching, experimenting, and regulating ('Paths to a self-driving future', Tillema et al. 2017).

Our interviews suggest that Dutch policymakers are reluctant to make 'very explicit technological choices' (Interview 3). Instead, they leave these choices to the market (Interviews 1 and 2), a bigger country (Interview 3), or a supranational body (Interview 2). This may be because policymakers recognize that the Netherlands is too small 'for making technological choices' (Interview 3), or previous suboptimal choices in the mobility system are still impacting today, such as in roadside systems (Interview 2). However, policymakers want to develop 'the original ideas of the [smart mobility] system [. . .] [in] the Netherlands' (Interview 10). Since the country has no large car manufacturers (OEMs), it may benefit more from being a 'test-ground' for smart mobility (Interview 3). One exception is the truck industry in which a Dutch company produces 14.6 per cent of the total amount of European trucks (DAF trucks 2017). In truck technologies, for example, platooning, the Dutch government has a different position, and is taking the lead by demonstrating business cases for applying these technologies (I&W 2015b).

6.3.2 Demand articulation

The creation of new markets seems particularly significant in our case study. The entire institutional setup of smart mobility policy aims to promote demand articulation in which public parties play a key role. Policymakers are engaged in de- or re-regulation strategies for implementing novel technologies. Indeed, they have granted exemption procedures for exceptional road transport (I&W 2015c). These procedures allow, under governmental supervision, automated driving to be tested. Otherwise testing would be impossible, as it would violate the Vienna Convention on Road Traffic, which requires a driver at all times in any vehicle (ANWB 2015). This legal change allowed more than twenty-seven real-life experiments in the Netherlands by 2016 (I&W 2016a). Such procedures reduce 'the barriers to learn' from testing in an actual mobility infrastructure (Interview 3). The capacity to have de-regulated environments has been acknowledged as a key factor for testing autonomous vehicles (KPMG 2018). Additionally, governmental authorities have established an automotive campus to enhance experimentation with automotive technologies, including autonomous driving (Automotive Campus 2016). Experimentation informs policymakers about the design features that safeguard public values (e.g. in terms of safety or legal requirements), while allowing market parties to explore the feasibility of new mobility products and services, for example, by testing business cases.

Experimentation is an important strategic task for demand articulation, since it remains unclear how smart mobility innovations can be implemented in the future (Interview 4). One interviewee said that the newness of various smart mobility approaches implies that 'we mostly learned by doing' (Interview 13). Consequently, pilot tests have been carried out to see how public and private parties can work together to enable smart mobility market applications. For instance, in Praktijkproef Amsterdam, public and private parties collaborate in integrating car and road systems to improve traffic flow and safety (Praktijkproef Amsterdam 2018). Similarly, behavioral change programs have been established to influence the demand for motorized mobility, offering financial incentives for daily commuting. Using IT devices, participants are rewarded based on the actual commuting distance (Beter Benutten 2016). Policymakers also expect to increase demand by focusing on experiments whereby intellectual property rights can be transferred to other parties to enable rapid market development (Interview 12).

Another identified strategic task is enabling new public–private partnerships (PPPs) for developing innovative services. Nowadays, policymakers acknowledge the large overlap in operating public and private services (e.g. traffic information services such as TomTom). This overlap could be optimized by enhancing cooperation under new PPPs. Ideally, public authorities could then 'embrace' rather than 'compete' with market products (Interview 1). By collaborating with market parties, policymakers expect to improve mobility services, allowing them to focus on aspects which private parties are not expected to deliver (Interview 3), for example, cycling infrastructure. Policymakers cooperate with private parties to determine the areas where markets could potentially take over the current public management, reducing the disturbance to the market by the intervention of the public sector (Interview 2). As a result, PPPs are expected to encourage private investments in areas like travel information and mobility services.

These partnerships, unlike traditional PPPs schemes, are largely characterized by going beyond concessions. Concessions generate limited risks for private parties, as profit and costs are guaranteed during the concession period (Interview 2). In contrast, new PPPs schemes allocate risks to both public and private parties, for example, via mutual investment. By sharing risks with private parties, public authorities aim to enhance the cocreation of solutions with potentially high returns in the future. There is no dominant scheme in novel PPPs but rather 'ad-hoc' arrangements, and this seems to be deliberate. A multiplicity of arrangements allows policy learning in the various ways public and private parties can cooperate (Interview 6).

Finally, we also identified a strong focus on user-centered design in smart mobility applications. At a general level, the BGOW road map suggests that improved 'traffic flow, safety and quality of life [. . .] [will] be possible when road users have access to better information' (de Mooij 2013). This user-centered approach has been implemented in several ways. The 'Beter Benutten' program aims to 'create a market for mobility services' (Interview 13), by enhancing the adoption of smart mobility innovations through behavioral changes (e.g. by financial incentives or other types of rewards) (Beter Benutten 2017). Additionally, a round table of experts on 'Human Factors and Behavior' in smart mobility technologies has been established, to advise policymakers and industry on aspects such as comfort and safety (Smart Mobility Community for Standards and Practices 2018a). User-centered design is also achieved by developing projects in which parties collaborate and

share their experiences about how to incorporate more users and identify any obstacles to adopting new technologies from a user perspective (Interview 10).

6.3.3 Policy coordination

Coordination is a central feature in the Dutch smart mobility policy, as illustrated in the call for structural cooperation at a national and European level to accelerate the deployment of smart mobility solutions (I&M 2016a; Kennisinstituut voor Mobiliteitsbeleid 2016), and for coordination between public and private parties (de Mooij 2013).

The I&M ministry works as a main coordinator in this transition, and aims to 'connect separate projects and niches' with similar goals (Interview 3). One example is Connecting Mobility, an organization in which stakeholders cooperate and know each other's activities (Connecting Mobility 2016b). Smart mobility organizations, including Connecting Mobility, aim to enhance stakeholder engagement, for example, with municipal transport authorities, the Dutch road agency, user representatives (the Royal Dutch Touring Club), and mobility consultancy projects (Beter Benutten 2017; Connekt 2016b). At international level, policymakers participate in projects to harmonize implementation, such as the Cooperative Intelligent Transport System corridor, in which Germany, Austria, and the Netherlands aim to optimize freight transport (Rijkswaterstaat 2015).

Another Dutch government strategy is decentralizing decision making for smart mobility. Although the general guidelines for the transition are part of the BGOW road map, this policy contains numerous decision-making mechanisms. Most of the current projects are small scale and take local characteristics into account, like traffic flows, built environment, etc. Each region participating in the program (Beter Benutten 2017) has its own local decision-making body that takes account of these characteristics. This program has a local 'administrative trio' as governing body, consisting of a representative from the ministry, local/regional government, and from the market sector. This corresponds with the Ministry's view that societal actors should be more involved in decision making in order to deal with major societal problems (see 'Learning by doing: Governmental participation in an energetic society', van der Steen et al. 2014).

This decentralized approach involves coordination activities at the national level via consulting groups. The Five November Group functions as a high-level expert group advising the Ministry on transition pathways (Interview 2). Moreover, six roundtables have been established to identify the factors that affect smart mobility implementation (Smart Mobility Community for Standards and Practices 2018b). Networking platforms also enhance public and private coordination. For instance, Connekt stakeholders deal with societal challenges related to mobility, and Connecting Mobility works as a catalyst for stakeholder cooperation (Connecting Mobility 2016a; I&W 2016b).

Policymakers also provide long-term coordination, for instance, by implementing agendas and future-oriented exercises. In 2013, the Ministry announced an implementation agenda (de Mooij 2013), aligning strategic interventions with smart mobility policy goals. Furthermore, stakeholder workshops have been organized to assess what type of policy interventions are required over time to achieve smart mobility scenarios (see 'Paths to a self-driving future', Tillema et al. 2017). This coordination is both operational and strategic, leading to concrete policy actions (Noordegraaf et al. 2016). It has regularly resulted in a relatively high level of commitment to future developments in smart mobility technologies. For example, the 'Declaration of Amsterdam on Cooperation in the Field of Connected and Automated Driving' (2016) was signed by all ministries of transport at EU level. It aims to enable high-level dialogue and cooperation with the harmonization of regulations and thus 'legal consistency' in the EU, in terms of security, privacy and data protection from a user perspective, interoperability of smart mobility systems, and cooperation between various mobility agents (EU 2016). This declaration, albeit an informal mechanism, is a mean of coordinating implementation strategies within the EU.

6.3.4 Reflexivity

The fourth intervention rationale is the lack of reflexivity. To solve this, policymakers aim to involve the wider public in the transition and enable self-governance processes. A major strategic task is establishing autonomous organizations in which public authorities together with stakeholders cocreate smart mobility projects. Although supported by I&M, these organizations are autonomous, and treat different parties (knowledge institutes, governments, companies, etc.) equally. For instance, Connekt works under a membership scheme, funded equally by public, private and knowledge institutes. The role of public officials in Connekt is to 'listen to the members' and 'see if there are any possibilities' for collaboration (Interview 10).

We also observed that with this novel governance approach, public authorities do not want to lead a transition, but facilitate one. Policymakers are aware of their limited decision-making capacity. Accordingly, state authorities aim to create a big playing field within well-defined and well thought boundaries (Interview 1). This is done by translating market needs into public action, such as the aforementioned exemption procedures. These procedures originated as a proof of concept from market parties to the I&M Ministry, showing that it was technically feasible to develop automated driving in the Netherlands. As a result, I&M asked market parties for suggestions about how to allow the development of this technology, or, in other words, 'what can we [as public authorities] do to make it happen?' (Interview 10). This also works the other way around, by translating public interests into potential market applications. For instance, the Five November Group was commissioned to develop a road map for implementing smart mobility technologies, taking into account societal factors and the role of public authorities (Interview 10).

Engaging stakeholders in broader consultation platforms is also a strategic task for providing reflexivity to the policy. For instance, the Five November Group was set up because policymakers 'wanted their knowledge, wanted their point of view, but not precisely the one from the company' (Interview 2). Also the organization Connecting Mobility is engaging with a broad set of societal stakeholders (DITCM Innovations 2015). Some of these platforms let policymakers hearing 'what is happening in companies, what their concerns are, and other technological developments' and 'what is happening in the field of smart mobility [. . .] [allowing policymakers to] create better policies' (Interview 10). These platforms mainly provide nonbinding policy advice. They also allow Dutch smart mobility stakeholders to share and discuss reasons for success and failure, and thus stimulate learning (Interview 10).

In order to stimulate a smart mobility transition, policymakers connect several spheres of action, thereby maintaining the 'momentum' of smart mobility innovation. They do this through demonstration projects, such as the Truck Platooning Challenge. This challenge aimed to make visible to a wider audience the feasibility of

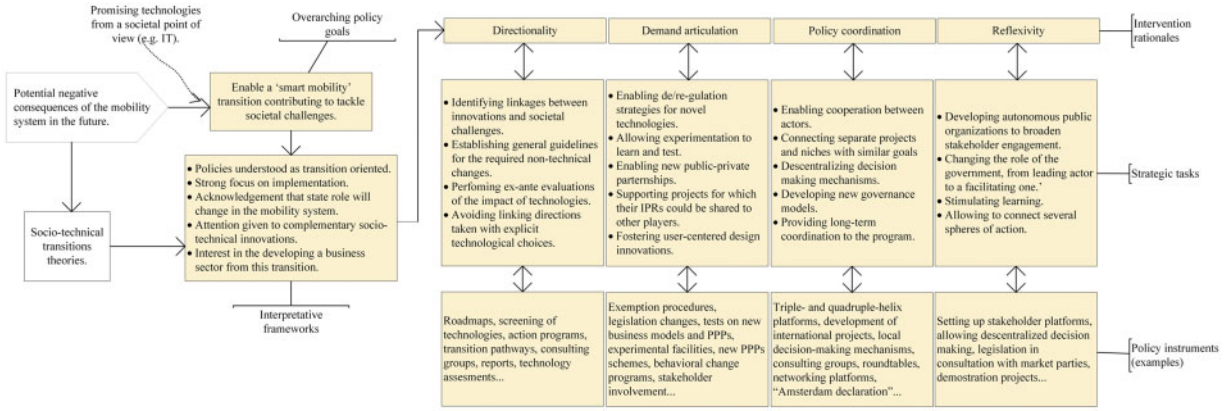

Figure 2. The Dutch smart mobility policy, according to the proposed framework.

automating freight transport and its potential benefits (DITCM Innovations 2015), as well as to raise public awareness that novel smart mobility technologies are actually being developed (Interview 10).

7. Discussion

By applying our framework to the case study, we found several elements that certainly resonate with the transformative change approach. Figure 2 summarizes our main findings, for example, that new overarching policy goals have been developed, followed by new interpretative frameworks. Consequently, we identified novel strategic tasks and policy instruments aligned with the four intervention rationales, that is, the four transformational system failures suggested by Weber and Rohracher (2012). Our analysis of the Dutch smart mobility policy provides insights into current developments in the field of STI governance that are interesting for discussion.

The Dutch smart mobility policy has established societal goals which go hand in hand with economic ones. Moreover these goals are strongly safeguarded by the ministry and linked to top STI sectors in the Netherlands. The policy mobilizes expertise in which the Netherlands excels (electronics, high-tech, and IT) and that are crucial for the Dutch economy (transport and logistics). This finding confirms recent approaches to transformative policies (OECD 2016b), and suggests a reorientation of STI to prioritize societal areas without forgetting the economic goals of STI processes. Our case study also showed that smart mobility is framed as a transition-oriented policy, and that policymakers mobilize transitions thinking for its governance. We found that novel interpretative frameworks have emerged in this policy to deal with its transition orientation. Consequently, several design elements match the transitions literature (Edler and Boon 2018; e.g. 'learning-by-doing', niche empowerment, regime destabilization, market creation, etc.; cf. Geels and Kemp 2012; Grin et al. 2010).

An interpretative framework defines the anticipated role of state authorities in STI policy. In transformative change literature, this new state role is a main topic of investigation (Boon and Edler 2018; Mazzucato and Semieniuk 2017). Our case study offers a tentative solution. We observed that public authorities take on a key role as 'orchestrators' of the transition (by setting up institutions or demonstrations projects), indicating the state's broader and more active role. Aligned with contemporary scholarship, our research suggests that state intervention occurs at every stage of the innovation chain, from production to consumption (Mazzucato 2016), and that a central activity is accelerating the creation of markets for emerging technologies (Schot and Steinmueller 2018).

Additionally, the emerging role of the state is not filled in a classic top-down perspective, but is shifting from a hierarchical to a 'first among equals' approach (Boon and Edler 2018). By opening up decision-making mechanisms to new stakeholders, the state authorities' main role is to safeguard the societal benefits of innovation. For instance, policymakers do not dictate missions or select technologies, but act as wardens of societally desirable paths for market technologies. They also engage in novel schemes for public–private collaboration, mobilizing private sector expertise to foster innovations. This reduction of hierarchy also reconceptualizes the state's authority in STI policy (Borrás and Edquist 2013). Although this approach suggests that public and private parties negotiate on equal terms, public parties still have the 'final word' in selecting or prioritizing the technologies that deserve public support.

Our case study shows that the four transformative system failures identified by Weber and Rohracher (2012) are a valuable starting point for mapping strategic tasks and policy instruments. Regarding directionality, we identified that the key tasks are performing an *ex-ante* evaluation of existing technologies and linking societal challenges with technological innovations. Moreover, enabling new public–private partnerships seems important for demand articulation. In recent debates on transformative change, demand-oriented policy instruments seem to play a central role (Edler and Boon 2018), and our research highlights instruments influencing demand such as behavioral change programs. New governance models have been developed for policy coordination. Finally, for reflexivity, policymakers are developing new autonomous organizations and allowing stakeholder self-governance.

We identified two strategic tasks associated with each transformational failure: experimentation and stakeholder engagement. Experimentation is a key asset for learning-by-doing, for which policymakers are opening up the infrastructure to test potential technologies in real-life situations. This approach may be easily replicated in other settings, and accelerate transformative policies dealing with other societal challenges. Stakeholder engagement makes private parties' expertise available to the public domain, suggesting an increasing role of public and private cooperation. It fosters interaction among relevant societal actors in this policy domain and can play a role in legitimizing policy.

We observed deliberation between stakeholders in the case study, but limited contestation, tensions, and conflicts. As one interviewee suggested, in 'political terms, no one is really against' this policy (Interview 3). This contrasts with socio-technical transition literature (Loorbach 2010), for two reasons. First, we believe this is due to specific conditions in the Netherlands. The country lacks a 'big smart mobility player' shaping smart mobility activities like other countries (car manufacturers in Japan or Germany). Moreover, the Netherlands has a typically consensual decision-making model, which enhances cooperation rather than conflict (Interview 10). Although these institutional characteristics may explain the apparent lack of conflict, we believe that the policy was designed this way intentionally. The policy's broad scope allows a comprehensive range of projects and stakeholders to participate. As its implementation has been limited, the policy is still in an experimental phase. Conflict and contestation might emerge once the ministry starts favoring the implementation of certain innovations at the expense of others (Interview 10). This argument resonates with that of other interviewees, who suggested that despite agreeing that smart mobility technologies can help tackle societal challenges, some applications will lead to greater conflict in the near future (Interviews 4, 5, and 7). For instance, while vehicle fleet automation seems to be a widely accepted solution to current auto-mobility problems, applying it to prioritize individual transport will probably be challenged by environmental and social groups, due to its impact on urban space and quality of life (Interview 7). Finally, we acknowledge that this research focuses on a limited circle of actors who are knowledgeable about smart mobility policy. It is important, therefore, that further research includes actors who approach smart mobility from a societal perspective.

As expected with a paradigm shift, the 'instrument toolbox' at policymakers' disposal is broadening. According to policy paradigms literature, the adoption of a new paradigm involves developing new instruments, rather than redeveloping old ones in new contexts. We identified high-level consultation groups as 'keepers' of the transition road map (Five November Group) and the Amsterdam Declaration as two novel instruments. Further research is required to chart and conceptualize new instruments for transformative change strategic tasks and intervention rationales. Improving our understanding of transformative change instruments may be a starting point for a rigorous analysis of how to govern societal challenge-oriented STI policies. We should add, however, that policy instruments are not easily transposed to others contexts, as they depend on multiple underlying factors (Edler et al. 2016b; Le Galès 2011).

8. Conclusion

To answer the research question 'can the Dutch smart mobility policy be regarded as a STI policy for transformative change?', we created a conceptual framework inspired by policy studies. In particular, we applied the concept of 'policy paradigms' by Hall (1993) to study the current normative shift in STI policy. We found that Dutch smart mobility policy has new overarching policy goals, new interpretative frameworks, new intervention rationales directly linked to four transformational failures, and related novel strategic tasks and policy instruments. Therefore, we consider that Dutch smart mobility policy is an example of a transformative change policy. We note, however, that our research focused on an early phase of this policy's development. This implies that our case study cannot shed light on the important issue of how to shift a 'transition' from the experimental to the scaling-up phase.

Despite this limitation, our article contributes to the transformative change literature in several ways. The framework we developed enables future improvement and refinement, by redefining relationships, identifying new layers, or mapping new strategic tasks and policy instruments. It can also be used to conduct comparative studies for identifying different approaches to strategic tasks and policy instruments in countries that embrace the transformative change approach. In addition, this article provides an empirical illustration of transformative change, which is limited in the academic literature. We were able to identify central elements of policy design, while at the same time discover specific mechanisms used for transformative change governance. We could also chart the strategic tasks and policy instruments linked with transformational system failures.

This article also outlines further research areas. STI literature may benefit from mobilizing concepts and approaches from other disciplines to study the governance layers in STI policies. In turn, STI policy may benefit from looking into other policy sciences theories and frameworks. We highlight the need to conceptualize new policy portfolios in STI policies for transformative change. An important research goal is to determine which policy instruments can enhance transformative change approaches more effectively than others. Moreover, as our framework was applied to one case study, comparative cases studies are required to distinguish the national, institutional, and domain-specific characteristics of our study, and transition-oriented policy designs in general. Our framework could be used for that purpose. Future research could focus on specific elements or stages of transformative change policies (e.g. agenda setting, implementation, legitimation) to gain a better understanding of the policy processes involved. Particularly relevant is the area of policy evaluation and assessment, because we found limited formalized methods to evaluate this policy's effectiveness.

Another avenue for future research concerns the trade-off we discovered between stimulating the development of smart mobility technologies, striving for economic growth, and addressing societal challenges. Nonsmart technology approaches to societal challenges such as stimulating cycling may have a greater societal impact, but the economic benefits are limited compared to smart mobility solutions. The Dutch smart mobility policy we studied does indeed address societal challenges by stimulating new emerging technologies that improve economic welfare. Such a 'techno-centric' approach allows technological innovation to prevail over other types of innovation (e.g. social or institutional). Future research could seek alternative innovation solutions to societal challenges, and thereby investigate which approach receives most political and societal support.

Notes

1. We use the term 'policy paradigms' to denote the frameworks of ideas informing policy choices. It should be noted that a variety of terms have been used to refer to this framework, as explained throughout the text.
2. For an extensive review on the differences between these paradigms, see Chaminade and Edquist (2010) and Schot and Steinmueller (2018).
3. As of 2018, the Ministry of Infrastructure and Water Management (I&W).
4. For Smart mobility policymakers, transition pathways are narrow in scope, particularly compared to their use in socio-technical transitions literature. For instance, Geels and Schot (2007) differentiate between four pathways taking into account

agency and depending on the interaction patterns from the macro-, meso-, and micro-levels ('transformation', 'reconfiguration', 'technological substitution', and 'de-alignment and re-alignment').

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