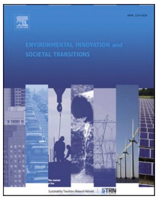
Citation (APA)
Bergsma, J., Wiarda, M., Pruyn, J., & van de Kaa, G. (2026). Anticipatory governance of a maritime mission using a real-time mission-oriented transition assessment. *Environmental Innovation and Societal Transitions*, *60*, Article 101128. https://doi.org/10.1016/j.eist.2026.101128

Environmental Innovation and Societal Transitions 60 (2026) 101128

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist



Research article

Anticipatory governance of a maritime mission using a real-time mission-oriented transition assessment

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ARTICLE INFO

Keywords:
Mission
Sustainable shipping
Wicked problems
Anticipatory governance
Transition
Transformative innovation policy

ABSTRACT

Anticipatory governance supports mission-oriented innovation policy by identifying, mitigating, and preparing for barriers that impede socio-technical transformations. While recent research introduced the Mission-Oriented Transition Assessment as a formative approach to mission governance, we insufficiently understand how this approach helps govern missions over a sustained period. This study applies a 'real-time' Mission-Oriented Transition Assessment to yield longitudinal insights into how mission barriers are foreseen, constructed, and responded to by stakeholders. We do so in the context of the Dutch maritime mission 'Climate neutral shipping by 2050′. The results of 14 assessments over a period of 1.5 years with 124 stakeholder representatives show how 19 mission barriers are collectively anticipated, explicated, and acted upon. As such, this paper conceptualizes and empirically explores the usefulness of a 'real-time' Mission-Oriented Transition Assessment as a formative approach to anticipatory mission governance.

1. Introduction

We are witnessing an uptake of transformative mission-oriented innovation policy (MIP) as instruments to address wicked societal problems (Hekkert et al., 2020). These MIPs are transformative innovation policies that differentiate themselves through mission objectives that are often introduced top-down but which require bottom-up ingenuity for transformative change (Haddad et al., 2022). MIPs act as mobilisation and coordination devices to redirect stakeholders towards a common goal (Janssen et al., 2021). In contrast to static approaches, missions require continuous governance as transformations unfold (Wiarda et al., 2024; Normann et al., 2024)

Along these processes, stakeholders face high degrees of uncertainty, for example, in terms of barriers for transformations. In early transformation phases, stakeholders lack insight into the possibilities and probabilities of barriers that potentially emerge, while responding to them in later transformation phases may be ineffective as path-dependencies and lock-ins set in (Collingridge, 1980; Genus and Stirling, 2018). Mission governance therefore needs to foresee and consider barriers pre-emptively through anticipatory

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https://doi.org/10.1016/j.eist.2026.101128
Received 29 September 2025; Received in revised form 3 March 2026; Accepted 10 March 2026

governance, reduce uncertainties and ambiguities, and converge stakeholders’ views on how to best address these (Wiarda et al., 2024; Wanzenböck et al., 2020).

One potential way of doing this is through reflexive and anticipatory stakeholder deliberations (e.g., with small and medium enterprises) to obtain diverse insights that inform policymakers and others. Such approaches have been labelled as Mission-Oriented Transition Assessments (MOTA), which represent a wide range of “collective appraisal[s] of current and future socio-technical changes to support stakeholders, particularly policymakers, in governing missions” (Coenen et al., 2025, p. 4). MOTA is comparable to Constructive Technology Assessment (Schot and Rip, 1997) and Sustainability Foresight (Voß et al., 2006), but tailors anticipatory deliberations mission contexts where pre-defined goals close down possible futures, and for which a complex systemic view is necessary.

While promising, the validity of MOTA to identify and better understand mission barriers remains unclear, partly because we lack empirical insights regarding its long-term use (Coenen et al., 2025). Therefore, we do not adequately understand the usefulness of MOTA to enable socially robust outcomes along long-term, pre-defined mission goals (1) and insufficiently know how mission barriers can be identified and better understood (2). As a result, mission barriers may be overlooked and could impede transformations by inducing transformational system failures, creating lock-ins, or exacerbating wickedness (Brown, 2021; Bugge et al., 2022; Henrekson et al., 2024; Klerkx et al., 2025).

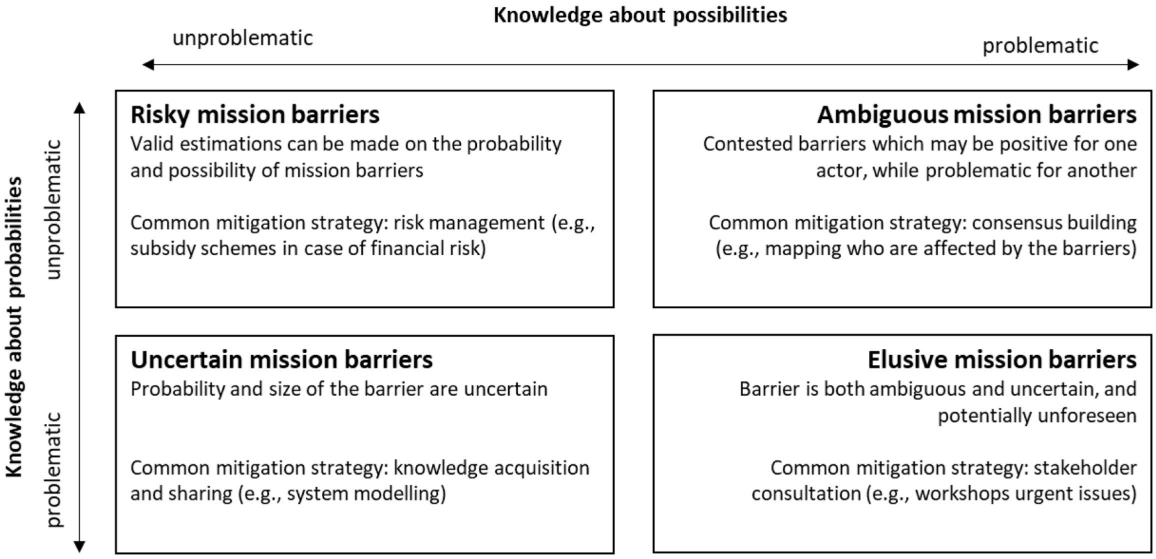
In this paper, we address these gaps by conceptually and empirically exploring the usefulness of a ‘real-time’ MOTA as an anticipatory governance approach to collectively identify, characterize, and mitigate mission barriers. Through action research, we employ 14 deliberations over a period of 1.5 years with 124 stakeholder representatives in the context of the Dutch mission ’Climate neutral shipping by 2050′, which aims to conduce a socio-technical transformation in line with the global ‘2023 IMO Strategy on Reduction of GHG Emissions from Ships’ (IMO, 2023). We specifically focus on how mission barriers are collectively anticipated, explicated, and acted upon. In what follows, we first discuss the theoretical underpinnings of the real-time MOTA (Section 2), after which we describe our methodology (Section 3), results (Section 4), and discussion (Section 5). We end with concluding remarks in Section 6.

2. Theory

In this section, we first conceptualize barriers for mission-oriented transformations (Section 2.1), after which we point at the relevance of anticipatory mission governance as an approach to pre-emptively address these barriers (Section 2.2). We then conceptualize a real-time MOTA as a longitudinal approach to anticipatory mission governance, designed to foresee, better understand, and address future mission barriers (Section 2.3).

2.1. Barriers to mission-oriented transformations: a conceptualization and typology

In recent years, scholars and policymakers have advanced the concept of *mission-oriented innovation policy* (MIP) with the ambition of bolstering adaptive capacity and systemic preparedness for societal challenges (Kirchherr et al., 2023; Mazzucato, 2018; Wanzenböck et al., 2020). In comparison to conventional ‘accelerator missions’ that drive innovative capacities, ‘transformative missions’ are policy mixes or ‘packages’ that set the conditions for transformative change and give direction to research and innovation in response to wicked problems (Hekkert et al., 2020; Roth et al., 2021; Larrue, 2021). These complex and contested problems are associated with high degrees of uncertainty (Wanzenböck et al., 2020). It is precisely the uncertainty associated with these wicked



Risky mission barriers
Valid estimations can be made on the probability and possibility of mission barriers

Common mitigation strategy: risk management (e.g., subsidy schemes in case of financial risk)

Ambiguous mission barriers
Contested barriers which may be positive for one actor, while problematic for another

Common mitigation strategy: consensus building (e.g., mapping who are affected by the barriers)

Uncertain mission barriers
Probability and size of the barrier are uncertain

Common mitigation strategy: knowledge acquisition and sharing (e.g., system modelling)

Elusive mission barriers
Barrier is both ambiguous and uncertain, and potentially unforeseen

Common mitigation strategy: stakeholder consultation (e.g., workshops urgent issues)

Fig. 1. Mapping mission barriers across the matrix. Inspired by Stirling (2010).

contexts that problematize the governance of mission-oriented transformations (Wanzenböck et al., 2020; Wiarda et al., 2024).

Policymakers are tasked with addressing (transformational) system failures (Raven and Walrave, 2020; Klein Woolthuis et al., 2005; Weber and Rohracher, 2012) and other potential hurdles (e.g., unintended disruptions and 'dark sides') that can jeopardize the success of transformative missions (Blythe et al., 2018; Geels and Schot, 2007; Turnheim and Sovacool, 2020). Such obstacles will need to be foreseen, understood, and managed pre-emptively before they culminate into impactful barriers that hamper or slow down mission efforts (Coenen et al., 2023; Wiarda et al., 2024). We understand mission barriers as *structures and innovation dynamics that block or slow down systemic changes required to attain mission goals*. Mission barriers can explain the weaknesses of mission-specific innovation systems that legitimize policy intervention (Elzinga et al., 2023), but may also represent broader issues that hinder systemic changes. Mission barriers can thus be conceptualized in different ways, including but not limited to, structural and functional barriers (Elzinga et al., 2023), transition pathway barriers (Coenen et al., 2023), and solution pathway barriers (Alamoush et al., 2023). For example, Bours et al. (2026) describe how various lock-ins block or slow down transition pathways. The socio-technical nature of systemic changes provides that these barriers are not merely technical, but can also take on different forms (e.g., societal opposition). Solution pathway barriers, for instance, may include outdated or inadequate regulations and standards that fail to sufficiently guide and consolidate directions of change, signifying what is known as 'directionality failures' (Weber and Rohracher, 2012). Mission barriers are not static but commonly emerge as transformations unfold. The nature of these barriers have different effects and implications for policy intervention (Raven and Walrave, 2020).

We argue that formulating adequate policy interventions to address mission barriers benefits from mapping them based on the knowledge that is available about their possibilities (i.e., what barriers can happen?) and their probabilities (i.e., how likely are these to happen?), and whether this knowledge is deemed problematic (invalid, unreliable, contested) or relatively unproblematic (valid, reliable, uncontested). This analytical lens (Fig. 1) is largely inspired by the broader work of Stirling (2010), and in this paper, we apply it to the more specific notion of mission barriers. As we will discuss, the usefulness of this approach is linked to the idea that problematic knowledge on either possibilities or probabilities each point towards different, concrete policy interventions. For instance, when the possibilities of mission barriers are contested, then this underscores the necessity of dealing with ambiguity and bridging stakeholder perspectives. Following Andersson et al. (2026), the 'problematicness' of knowledge can lie in factual disagreement (e.g., conflicting system models and forecasts) and normative disagreement (e.g., different personal preferences), of which some disagreements may be more fundamental, and hence problematic, than others (Wiarda et al., 2023). In addition, there may be cases where knowledge is problematic, not because of disagreement, but simply because of insufficiently reliable and valid insights. Drawing from these dimensions (Fig. 1), mission barriers may be described as *risky, uncertain, ambiguous*, or *elusive* (Stirling, 2010).

Influential economists (Keynes, 1921; Knight, 1912) and the International Organization of Standardization (2002) view the notion of *risk* as the probability of an event, multiplied by its severity. Risk assessment and management is primarily concerned with this type of impact and has proven of paramount importance in engineering. However, this focus has also received substantial criticism because there are only few settings in which the probabilities and possibilities of future events can be estimated unproblematically in ways that are relatively valid, reliable, and uncontested (e.g., machine maintenance, casino games, and insurance portfolios) (Hansson, 2009). Hence, framing all types of mission barriers as 'risks' may lead to the naïve impression that we understand possible futures in a certain and unambiguous way.

The notion of risk must therefore be separated from that of *uncertainty* because stakeholders nearly always lack reliable knowledge about the probability of future events (Knight, 1912) – especially for mission barriers in the context of wicked problems. Although there are various types of uncertainties, a lack of knowledge is often positioned as a form of epistemic uncertainty that problematizes yielding 'objective', often scientific or technological, insights. However, a lack of knowledge can also refer to other forms of uncertainty, such as normative uncertainty, due to which it is difficult to foresee future norms, values, or ethical principles, and how these relate to each other (Taebi et al., 2020). One common pitfall of working with uncertainties is that policymakers can assume that certain levels and types of uncertainty are deemed univocally acceptable by stakeholders.

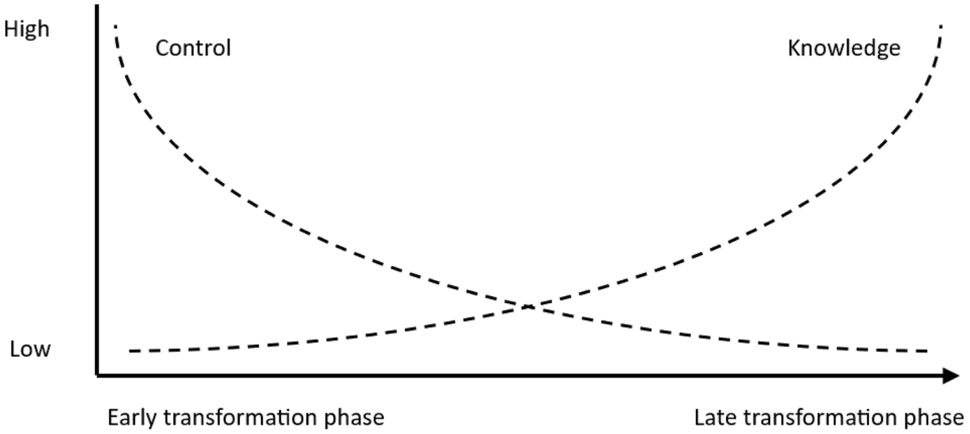


Fig. 2. Policymakers face a Collingridge Dilemma during transformations (Collingridge, 1980).

Ambiguity arises when stakeholders disagree over the framing, interpretation, or acceptability of mission barriers (Renn et al., 2011). The contested nature of wicked problems provides that such ambiguous barriers are common in these contexts (Head, 2022; Wanzenböck et al., 2020). Here, barriers may be beneficial for one stakeholder, while being harmful to others (Pesch and Vermaas, 2020). Dealing with ambiguity requires insights into the plurality and conditionality of stakeholder views and makes straight-forward answers nearly impossible (Stirling, 2010). Policymaking under ambiguity draws attention to normative notions like justice, fairness, and equity, all of which require forms of stakeholder deliberation and ethical consideration. One common way of working with ambiguity is consensus-building (e.g. Delphi method).

Arguably most problematic are those future mission barriers that we can label as *elusive* in the face of ignorance (Hoffmann-Riem and Wynne, 2002; Stirling, 2010). In such cases, policymakers are insufficiently aware of the possibility and probability of a future events, making the barrier fuzzy or unknown. In some cases, the possibility of a future mission barrier is not – or cannot – be anticipated. As a result, some mission barriers may occur without ever having been foreseen. One way policymakers can work with such elusive barriers is by acknowledging and reflecting upon the limits of their own knowledge and control (Jasanoff, 2007). Similarly to ambiguities and uncertainties, governing elusiveness benefits from pro-actively consulting stakeholders to reflexively yield novel perspectives and take stock of broader expectations. Yet, policymakers will need to acknowledge that transformations remain largely unpredictable.

In this context, the so-called Collingridge Dilemma (Fig. 2) suggests that policymakers will have serious difficulties gaining insights in the probabilities and possibilities of future mission barriers during early transformation phases (Collingridge, 1980; Genus and Stirling, 2018). As transformations unfolds, policymakers will have a better understanding of these mission barriers but their impacts become more difficult to mitigate or adapt to once path-dependencies (David, 1995, 1994), convergence (Wanzenböck et al., 2020), and lock-ins (Unruh, 2000) limit the extent to which these barriers can be addressed. Mitigating and adapting to mission barriers will therefore require policymakers to explore the possibilities and probabilities of barriers in early transformation phases while they can still meaningfully govern them in the present (Wiarda et al., 2024).

As a result, various authors have pleaded for anticipatory governance (Guston, 2014; Coenen et al., 2025; Mason-D’Croz et al., 2025) of transformative missions using forward-looking policy approaches (e.g., strategic intelligence, foresight, etc.) as a means to address mission barriers before this becomes too late (Coenen et al., 2025). As Tõnurist & Hanson put it, missions ”may also cause lock-in and myopia” and as such “we also need to explore how anticipatory innovation governance fits in with other government innovation activities” (Tõnurist and Hanson, 2020, p. 29). Anticipatory governance can assist policymakers in identifying, better understanding, and addressing future barriers before these slow down mission efforts.

2.2. Anticipatory mission governance

Anticipatory governance is a well-developed and widely adopted approach that helps deal with this Collingridge dilemma as it focuses on developing and leveraging “a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies [and other types of innovations] while such management is still possible” (Guston, 2014, p. 1). Therefore, it is an approach to govern risks, uncertainties, ambiguities, and elusiveness by shaping futures in the present (Muiderman et al., 2020). While there are different approaches to anticipatory governance, they generally centre around foresight, engagement, and integration (Barben, 2007). Muiderman et al. (2020) identified four different streams of anticipatory governance: (1) assessments of probable and improbable futures to inform policy planning; (2) explorations of plausible futures to build adaptive capacity and preparedness; (3) inclusive imaginations of pluralistic futures to co-create alternative futures; and (4) examinations of the performativity and implications of future imaginaries. In the context of missions, we therefore understand anticipatory mission governance as *a broad approach that aims to identify, understand, envision, shape, and prepare for the future consequences that transformative missions may induce or experience.*

Because mission barriers largely lay beyond policymakers’ sphere of control, a theory of change (Weiss, 1997) can help understand “how and why a desired change is expected to occur in a specific problem context” (Belcher et al., 2020, p. 3). It helps understand how barriers can be addressed, and whether this can be done directly (sphere of control), indirectly (sphere of influence), or through rippling effects (sphere of interest). Against such a theory of change, anticipatory mission governance fits in a theory of action by pointing at the importance of collaborative capabilities that help address barriers across different spheres of influence and interest (Wieser et al., 2025).

Drawing from the anticipatory governance literature, policymakers and other stakeholders can deal with mission barriers and their impacts in a variety of ways. Knowledge-seeking strategies aim to better understand the possibilities and probabilities of future impacts (Coenen et al., 2025). This may, for instance, shift future impacts from the category of ’elusiveness’ to forms of ‘uncertainty’ or ‘ambiguity’. While cost-benefit analyses, expert consensus, and risk assessments are suitable for acquiring insights into risks, the usefulness of such approaches are rather limited for anticipatory mission governance because risks in the Knightian sense are rarely prominent in the context of wicked problems (Stirling, 2010). Uncertainties, ambiguities, and elusiveness, however, form a more common challenge, and better understanding them generally requires continuous inclusive and reflexive approaches that open up anticipatory mission governance to a greater range of perspectives (Wiarda et al., 2024). Accordingly, scholars have introduced such approaches for the context of mission-oriented projects (i.e., ASIRPA approach; (Matt et al., 2023)) and missions at large (i.e., MOTA approach; (Coenen et al., 2025)). In some cases, anticipatory mission governance thus requires that policymakers leverage the distributed know-how and moral judgement across stakeholders. Anticipatory approaches may also provide a better understanding of what levels and types of uncertainties are acceptable, and how policymakers can best deal with ambiguity.

Mitigation and adaptation strategies are generally forms of responsiveness to mission barriers, and create “a capacity to change shape or direction in response to stakeholder and public values and changing circumstances … while recognizing the insufficiency of knowledge and control" (Stilgoe et al., 2013, p. 1572). However, when the impacts of mission barriers are ill-understood or when mitigation is not possible, policymakers can complement previous strategies by bolstering a systemic adaptability and resiliency that will reduce vulnerabilities across stakeholders (Hamarat et al., 2012; Janssen and Voort, 2016; Woodruff, 2016).

2.3. Real-time MOTA conceptualization

In this paper, we aim to continuously assess which mission barriers may emerge. To do so, we use a MOTA as our entry point, which has been described as "a collective appraisal of current and future socio-technical changes to inform stakeholders, particularly policymakers, on how to govern missions" (Coenen et al., 2025, p. 4). MOTA builds forth on the Responsible Mission Governance framework by incorporating the procedural principles of anticipation, inclusion, reflexivity, and responsiveness as a way of coping with the uncertainty, complexity, contestation and intractability of the wicked problems that missions intend to address (Wiarda et al., 2024). As such, MOTA is an anticipatory approach that uses reflexive deliberations – encompassing elements of reading, reacting, discussing, reflecting and envisioning – with diverse stakeholders to obtain particular insights in the context of missions. The nature of these insights can differ, depending on the purpose of the MOTA used. For instance, insights may take the form of stakeholder concerns but can also include perspectives on mission barriers (e.g., inadequate regulatory development). As a result, MOTA aims to bolster the social robustness and alignment of proactive decisions by raising awareness among stakeholders, particularly policymakers (Coenen et al., 2025). Together, stakeholders in the deliberations represent a microcosm – a simplified set of actors that is fairly representative of those found 'in the wild' (Fishkin, 2018). The outcomes of MOTA can inform a range of stakeholders but are particularly relevant for mission governance. MOTA was inspired by earlier approaches such as Technology Assessment (Schot and Rip, 1997) and Sustainability Foresight (Truffer et al., 2008; Voß et al., 2006) but is tailored to the context of missions, where pre-defined goals reduce the perceived openness of possible futures. Based upon the theoretical background of Section 2, we introduce a 'real-time' element by continuously reflecting on the outcomes of previous activities between stakeholders. Therefore, we define real-time MOTA as *a long-term, formative and collective appraisal of current and future socio-technical changes to support stakeholders, particularly policymakers, in anticipatory mission governance*. Adding real-time elements suggests processes similar to those shown in Fig. 3. Our real-time MOTA is therefore a sequence of MOTA workshops that are conceptually identical to that of Coenen et al. (2025), but for which the substantiation of procedural elements may somewhat differ (see Section 3.2).

Coenen et al. (2025) used socio-technical scenarios as input for their work, but the authors also point out that other exercises could be used. For our real-time MOTA, we use more open thematic discussions to collectively identify mission barriers that impede long-term objectives for system changes. Fig. 4 further clarifies the real-time MOTA process, for which the starting point is established during a preparation phase (from session $n = -1$, to session $n = 0$). In this research, the starting point consists of a pre-defined mission, a structure for following sessions, a literature-based shortlist of mission barriers, and an invitee list for purposively sampled stakeholders to be present. Similar to Coenen et al. (2025), this first phase serves to structure and scope the MOTA workshop but differs from their work by specifically focussing on mission barriers. After the preparation phase, the sequence of MOTA workshops start ($n + 1$) after which this continuous process eventually dissolves (e.g., when the mission goals are achieved or when the mission has ended). The intermissions between workshops offer opportunities to evaluate the responsiveness of stakeholders to the insights of preceding MOTA workshops. During these intermissions, we follow Coenen et al. (2025) by analysing the discussions, which subsequently form input for the next MOTA workshop that ensues. Section 3.2 of our methodology section provides a more elaborated account of how the conceptualization of the real-time MOTA is operationalized.

The mission barriers that are foreseen during the real-time MOTA are categorised according to our typology, adapted from Stirling (2010); Fig. 5), and are addressed accordingly. For example, if the mission barrier is contested (i.e., ambiguous mission barrier), then providing a process to resolve opposing views can prove meaningful. Depending on the situation, more actions can be considered such as policy reformulations. Mission barriers continuously evolve as they are identified, discussed and addressed. The aim of a real-time MOTA is to facilitate a process in which elusive mission barriers transform into more risk-based ones where both the probability and possibility can be assessed fairly unproblematically (see Fig. 5).

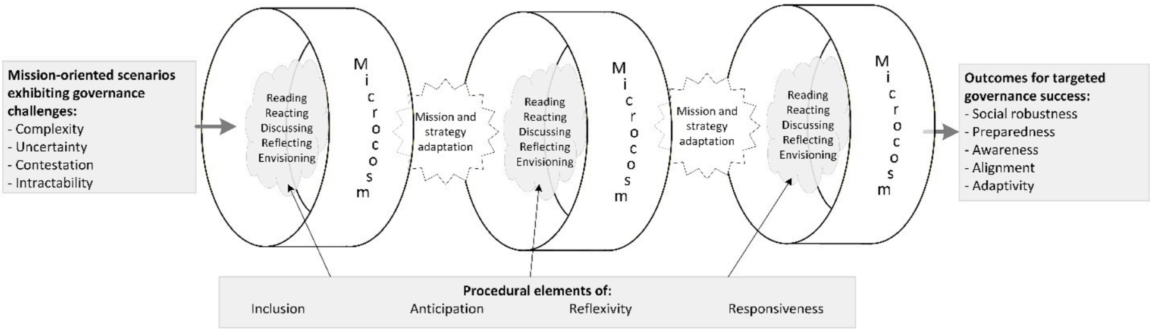


Fig. 3. Conceptual outline of a real-time MOTA (adapted from Coenen et al., 2025).

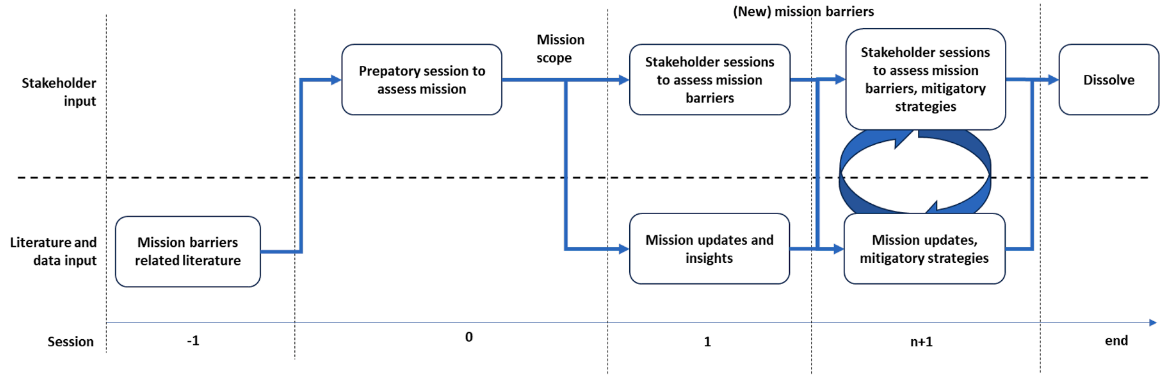


Fig. 4. Real-time MOTA process.

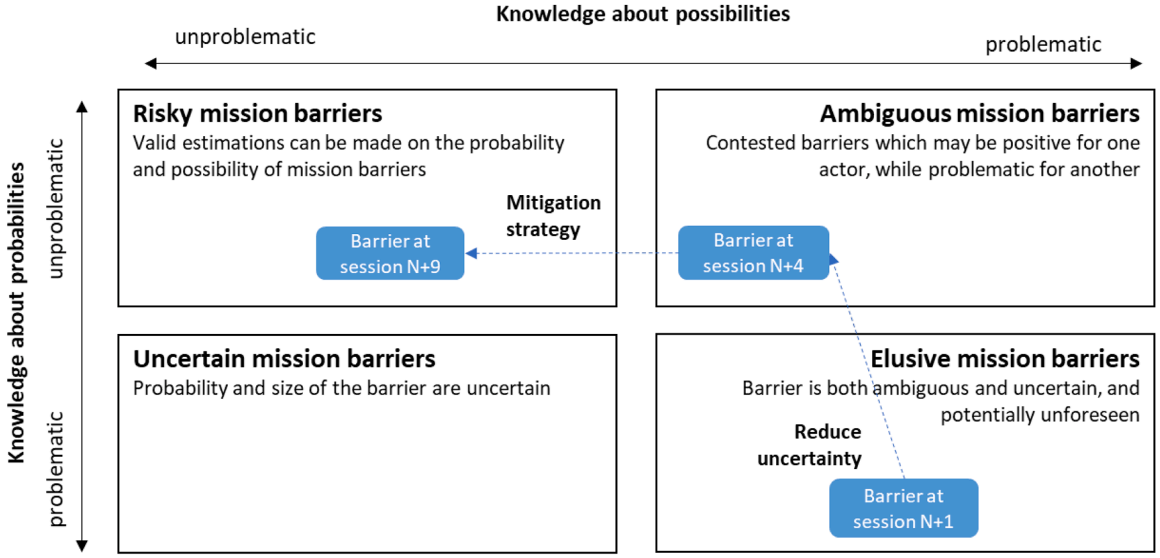


Fig. 5. Example of a possible mission barrier pathway during a real-time MOTA process.

3. Methodology

In this section, we describe the application of real-time MOTA as an approach to anticipatory mission governance. We start with the case selection and description (Section 3.1), followed by the data collection and analysis of our action research (Section 3.2)

3.1. Case selection and description: ‘climate neutral shipping by 2050′

Given the aim to conceptualize and empirically explore the usefulness of a real-time MOTA as an anticipatory approach to identify and better understand mission barriers, we selected the Dutch mission ‘Climate neutral shipping by 2050′. This innovation policy can be understood as a mission because it is a “goal-oriented policy approach that addresses specific wicked societal challenges by actively inducing, guiding, and accelerating systemic changes, facilitated by inclusive and adaptive governance that integrates diverse perspectives and fosters novel solutions across contexts and scale” (Coenen et al., 2026, p. 1).

This national mission is largely motivated by global agreements (e.g., *Greenhouse Gas Strategy*) and European ambitions (e.g., *Renewable Energy Directive, FuelEU Maritime*) but was enacted by Dutch ministries in 2023. It echoes ambitious and time-bound goals of the International Maritime Organization to induce bottom-up and relatively open-ended solutions. These goals include, among others, a reduction in operational greenhouse gas emissions for maritime shipping by 100 % before 2050. To achieve this, a radical transformation of Dutch shipping is required, including changes across energy, logistics, port, and shipbuilding sectors.

At the time of writing, the Dutch top consortia for Knowledge and Innovation (TKI) pertaining to the maritime sector acts as the orchestrating ‘systemic innovation intermediary’ (Janssen et al., 2020) to foster collaboration in research and innovation through funding and networking, particularly between firms (e.g., small and medium-sized enterprises), research institutes, and the public sector. Supra-national regulations such as the *Alternative Fuels Infrastructure Regulations* also encourage socio-technical change. In addition to this TKI, the Dutch government is in the process of formulating national policy instruments that could strengthen the directionality of transformative change and help mitigate mission barriers.

To accomplish this, the Ministry of Infrastructure and Water Management initiated a steering group, consisting of influential organizations within the mission context, to develop of a roadmap – 'Roadmap Sustainable Energy Carriers for Shipping'. This roadmap intends to gather and outline strategies that both accelerate system changes and mitigate mission barriers. The Netherlands Enterprise Agency (NEA) was tasked to host sessions and formulate the roadmap (Nusselder, 2024), which represents the process that the real-time MOTA of this paper served to support.

The recency of the mission in combination with the abovementioned developments mean that the maritime mission corresponds with explicit transformative intentions that are increasingly matched with transformative processes. Up till now, it is still too early to determine whether the mission will culminate into substantial transformative effects. Following the conceptualization of Coenen et al. (2026), the maritime mission can therefore be understood as a 'catalysing mission' that aims to set the conditions for transformative change, and which eventually may turn into an 'ideal(ized) mission'.

This case is particularly relevant because shipping is widely seen as a 'hard-to-abate' domain that is characterized by path-dependencies and geopolitical competition (Wesseling and Meijerhof, 2023). Furthermore, the future success of policy frameworks and solutions for its mission goals are uncertain and contested. As reported by Wesseling and Meijerhof (2023) in their analysis of the Dutch Green Deal for inland shipping, seagoing shipping, and ports, the respective mission is characterized by a limited market formation and destabilization, while there is a greater demand for reflexive governance. We are "missing business models among shippers to adopt, particularly more radical, sustainable innovations" (Wesseling and Meijerhof, 2023, p. 16). A few barriers have been identified: lacking market-oriented policy support; limited willingness of end costumers to pay a premium; shipping companies wating for a dominant energy carrier to emerge; and charterers paying for the energy carriers taking away the incentive of shipping companies to invest (Wesseling and Meijerhof, 2023). In the meantime, stakeholders strongly disagree what (mix of) sustainable technologies and alternative energy carries are needed for the mission (e.g., biodiesel, LNG, methanol, hydrogen, batteries, ammonia, etc.). Niche technology developments linked to these energy carriers (e.g., fuel cells) are present, however current policies insufficiently make these economically feasible (Stolper et al., 2022). More incremental innovations, such as scrubbers and drop-in fuels, are most common for the reduction of emissions. All these challenges culminated into demand articulation failures, resulting in a 'chicken and egg' issue for the availability of energy carriers, port infrastructure, and mature proven technologies. The mission now finds itself in a critical phase, given the long lifetime assets of ships (25+ years) and the long lead time of energy infrastructure developments (Bergsma et al., 2021). This requires immediate collective reflection to foresee and better understand mission barriers and determine collective action. As such, the mission 'Climate neutral shipping by 2050' represents a rich empirical case for our real-time MOTA.

3.2. *Identifying mission barriers using real-time MOTA: data collection and analysis*

The research design of our case study draws from passive to moderate participant observation (Musante and DeWalt, 2010) during the real-time MOTA, initiated by The Netherlands Enterprise Agency (NEA). Participant observation is a data collection method "in which researchers take part in everyday activities related to an area of social life in order to study an aspect of that life through the observation of events in their natural contexts" (Given, 2008, pp. 599–600). As we will discuss in detail, the authors were formally involved in the expert control group. The real-time MOTA was organized in three phases: a preparation phase (1), workshop phase (2), and data analysis phase (3). For the preparation phase, NEA invited a subset of 12 representatives from branch organisations, government, and research institutes who were asked to interpret and clarify the mission. Beforehand, these stakeholders could share relevant literature with one another (Bergsma et al., 2021; Stolper et al., 2022). Thereafter, the representatives determined that mission barriers could be differentiated per solution pathway (e.g., biofuels vs. ammonia), and NEA therefore asked stakeholders to identify barriers per solution pathway. Stakeholders commented and discussed each barrier until soft consensus was obtained, on what adequately described how the barrier affects the mission.

For the workshop phase, NEA invited 124 stakeholder representatives that were assigned to at least one of three workgroups (WG) that, in total, conducted 14 sessions over a period of 1.5 years. In addition, an executive steering group (SG) was created that contained 15 of the 124 stakeholder representatives. This steering group was considered the owner of both the real-time MOTA process and its outcomes, thereby ensuring support for the execution of the ensuing mitigation strategies. Furthermore, an additional expert control group (CG) was established that was responsible for the consistency and quality of the outcomes. In conducting the research, we were part of the expert CG as participant observers. CG members were selected for their ability to support discussions and methodological consistency, and to provide various types of information (e.g., technological, regulatory, etc). The authors also supported the purposive sampling of stakeholders to create a representative stakeholder group (i.e., microcosm) using the stakeholder map of Stolper et al. (2022) (e.g., feedstock provider, maritime customers; see Appendix A, Fig. 6). Over time, topics such as goals, regulatory developments, safety norms, and price developments were discussed, resulting in output which enabled the characterization of mission barriers. To create a manageable group size (−/+ 30 participants), the 124 stakeholders were split up based on three categories of sustainable energy carriers (see Appendix A, Tables 4 and 5). This categorisation is based upon how extensive the required regime changes are before adoption (e.g., regulatory, technical, infrastructural). The first workgroup focused on 'drop-in' energy carriers which require little regime changes (e.g., biofuels). The second discussed energy carriers applicable with limited regime change (e.g., methanol), and the third group was responsible for energy carriers which require major regime changes (e.g., hydrogen). In total five rounds took place, in which the same themes were discussed throughout multiple sessions per categorized workgroup (e.g., mission goal, regulation, finance). Furthermore, the CG and SG members had separate meetings to discuss interim outcomes of the overall process. In parallel, information was gathered through desk research to support the discussions upon request.

Prior to each session, stakeholders were informed about the themes to be discussed (e.g., safety, norms, and permits) in order to give participants time to prepare. Independent facilitators moderated the sessions during which all participants were given the opportunity to share their knowledge and concerns. During the sessions, discussions were moderated from a perspective that 'all should be heard', thereby encouraging constructive dialogues. In contrast to Coenen et al. (2025), the workshops of this study were facilitated by professional moderators. The meeting minutes were shared among participants afterwards, and were collectively evaluated for validity during each follow-up session. These follow-up sessions also offered the opportunity for each participant to respond to previous discussions with new information. During most sessions, thematic introductions were given by experts, who were invited by NEA to 'set the scene' and create a more level playing field. As passive to moderate participant observers, the authors had limited influence over the set-up of these discussions that were organized by NEA.

For our data analysis, 14 sessions (as part of the five rounds) were transcribed in the form of meeting minutes and field notes (also known as jotted notes or analytical notes; (Bernard, 2006), with each session resulting in texts of approximately 2000–8000 words. We used a combination of deductive and inductive thematic analyses to identify mission barriers (Braun and Clarke, 2006, 2019). To identify these, we used our definition of mission barriers as our coding rule, namely "*structures and innovation dynamics that block or slow down systemic changes required to attain mission goals*". Mission barriers were initially deductively identified in the literature (Bergsma et al., 2021) as a starting point for deliberations in the preparation phase (e.g., on the lack of available sustainable energy carriers). During this preparation phase and the sessions that followed, a few other mission barriers emerged that were not identified in the literature (e.g., lack of available feedstock for sustainable energy carriers). Both these deductively and inductively identified mission barriers were subsequently characterized according to our theoretical framework as risk, uncertainty, ambiguity, or elusiveness (Fig. 1). The characterization was based on (in)direct remarks by stakeholders on the possibilities (i.e., what can happen) and their probabilities (i.e., their likelihood), and whether they deemed the knowledge and associated claims problematic (invalid, unreliable, contested) or unproblematic (valid, reliable, uncontested). Characterizations were based upon remarks annotated in the transcripts and field notes. For example, if stakeholders expressed disagreement about mission barriers, then this signified ambiguity as illustrated by a discussion between an energy provider and the Ministry of Infrastructure and Water Management. The energy provider stated: "there is ambiguous regulation, among which, unclear requirements for numerous subsidies", with a policymaker rejecting this claim: "regulation for a 'Climate neutral shipping by 2050′ is clearly laid out in the sector agenda, including some examples". Such observations suggest that both parties recognize that regulation will have a probable effect on the mission, but that they disagree whether this effect is advantageous to the mission goal as one party deems it confusing. Hence, the availability of regulations was coded as an ambiguous barrier. The first author coded the outcomes and co-authors checked these for their face validity. The transcripts were also used to reflect on the mission barriers found with the stakeholders, which created continuous updates.

Table 1
19 Barriers affecting the mission towards climate neutral shipping by 2050. Barriers with an '*' were identified after the first session.

Mission barrier	Description
01. Lack of sustainable energy carriers	A lack of sustainable energy carriers for shipping leads to fewer investments in sustainable ships.
02. Uncompetitive prices of sustainable energy carriers	Uncompetitive and unstable sustainable energy carrier prices lead to fewer investments from fuel producers and shipowners.
03. Lack of feedstock for sustainable energy carriers*	A lack of (approved) feedstock sources deters investments from fuel producers.
04. Lack of port infrastructure	A lack of port infrastructure development due to high costs and low demand leads to fewer investments from fuel producers and suppliers.
05. Lack of onboard technology	A lack of ship/motor technology due to high development cost and low demand leads to minimal investment by suppliers and shipowners.
06. Lack of fuel production technology	A lack of fuel production technology due to high development costs and low demand leads to minimal investment from fuel producers.
07. Lack of collaboration across value chain	A lack of stakeholder collaboration across the value chain reduces the capacity to share financial risk, which leads to reduced investment willingness across the value chain.
08. Lack of private funding	A lack of private investment capital due to, e.g., high-risk profiles from unproven technologies and unknown profitability, limits investments by shipowners and fuel producers.
09. Lack of public funding	A lack of government subsidies and investments in sustainability limits competitiveness of sustainable solutions.
10. Unclear rules and regulations on fuel production	Unclear, unstable, and inconsistent regulations for fuel production increases financial risk for fuel producers.
11. Unclear, rules and regulations on onboard emissions	Unclear, unstable, and inconsistent regulations on fuel usage and emissions increases the financial investment risk for shipowners.
12. Lack of certification of ships and engines	Lack of certification and standardisation of ships and powertrains limits the scalability of sustainable shipping solutions.
13. Lack of certification of fuels*	Lack of certification and quality standards for fuels limits the scalability of sustainable energy carriers.
14. Lack of enforcement of regulation*	Lack of regulatory enforcement leads to non-compliance, negatively affecting compliant stakeholders. Authorities need sufficient knowledge and capacity to enforce and supervise rules and regulation.
15. Lack of market demand	Lack of demand for renewable fuels and vessels leads to minimal investment across the value chain.
16. Lack of mission clarity	Unclear mission and regulatory framework results in a lack of transparency and weak directionality which increases investment risk across the value chain.
17. Lack of qualified people	Lack of human capital leads to delays, increased costs, and potential investment cancellations across the value chain.
18. Lack of social acceptance*	Lack of societal acceptance of energy carriers, like ammonia in port areas, can delay or cancel investments across the value chain.
19. Lack of international alignment*	Lack of international alignment limits the capacity to manage regulatory complexity and set a long-term strategy.

Finally, the concluding session was organized to validate the identified mission barriers and prioritize them based on their impact on the mission. First, three groups of participants were created and asked to independently reiterate and explain each mission barrier, after which all participants collectively determined which barriers are most impactful. Participants received nine stickers and were given the opportunity to assign a maximum of two stickers to each barrier to signify the gravity of their impact. The three most impactful mission barriers were all discussed in the same three participant groups, tasked with formulating mitigation strategies to address them. The session concluded with a plenary discussion on the outcomes.

4. Results

The results are structured in two parts. First, we describe the mission barriers that have been identified by means of the real-time MOTA and report how the possibilities and probabilities of these barriers changed during the real-time assessment (Section 4.1). Finally, we discuss strategies that have been suggested by stakeholders to reduce uncertainties and resolve ambiguities (Section 4.2).

4.1. Mission barriers and their characteristics

During the 14 sessions across the five rounds, stakeholders described 19 mission barriers. Table 1 outlines the expected impacts of each barrier on perceived requirements for the transformation, e.g., sustainable investment decisions, regulatory developments, and inclusive governance. Five of these barriers were identified after the first session (barrier 3, 13, 14, 18, 19), whereas the other barriers were already identified in the preparation phase.

Throughout the real-time MOTA, mission barriers were characterized by whether the available knowledge on their probability and possibility were considered problematic by stakeholders. Our analysis of the 19 mission barriers resulted in 11 elusive barriers (barrier 1–5, 7, 9, 11, 15, 16, 19), of which two were identified in round 3 (barrier 3) and round 4 (barriers 19). During the real-time MOTA, stakeholders believed they reduced uncertainties in relation to two *elusive barriers* (barrier 3, 5), but failed to agree on possible implications, leaving them ambiguous. Furthermore, five *ambiguous barriers* (barrier 10, 13, 14, 17, 18) were foreseen of which three were initially elusive (barrier 13, 14, 18). None of the ambiguous barriers were later perceived as a *risk*. Although no *uncertain barriers* were found, our analysis did point at three possible *risks* (barrier 6, 8, 12). The lack of uncertainties indicates that for most mission barriers, stakeholders believed that they could adequately assess the likelihood that they would affect the transformation. In the remainder of this section, we will provide four examples of mission barriers to illustrate the paths that they followed according to the stakeholders. Table 2 shows the pathways of all anticipated mission barriers during the real-time MOTA.

Firstly, stakeholders foresaw a lack of onboard technologies (elusive barrier 5) because they argued that it is highly uncertain whether such technologies can become commercially viable, and because they disagreed on which technology should become dominant. As stated by one of the powertrain suppliers: "Ideally, there is one technology that is used, which is easy to apply and has no variations". However, forecasting which technology will likely impact the maritime sector positively was deemed problematic, in part, as there are many emerging sustainable technologies (e.g., energy carriers and powertrain configurations) that could help achieve the mission goals. Given the limited resources and market size, however, stakeholders did agree that it is not economically feasible to develop them all. As a consequence, this could mean that even if solutions do become economically feasible due to policy development (e.g. IMO GFI), technology adoption could still remain stagnant as a dominant design might requires fewer technology-agnostic policies. Furthermore, the primary stakeholders, suppliers and shipowners, are too dependent on energy infrastructure and market demand. Therefore, parallel to sessions 2–4, a comparative technology assessment for the energy carriers was conducted to reduce

Table 2
Barrier pathways during the real-time MOTA. Elusive (☆), ambiguity(☐), uncertainty(Δ), and risk(O).

Mission Barrier	Round 1	Round 2	Round 3	Round 4	Round 5
Meeting workgroups (WG)	1 | 2 | 3	1 | 2 | 3	1 | 2 | 3	1 | 2 | 3	4 | 5
01. Lack of available sustainable energy carriers	☆	☆	☆	☆	☆
02. Uncompetitive price of sustainable energy carriers	☆	☆	☆	☆	☆
03. Lack of available feedstock for sustainable energy carriers*			☆		☐
04. Lack of available port infrastructure	☆	☆	☆	☆	☆
05. Lack of available onboard technology	☆	☆	☆	☆	☐
06. Lack of available fuel production technology	O	O	O	O	O
07. Lack of collaboration across value chain	☆	☆	☆	☆	☆
08. Lack of available private funding	O	O	O	O	O
09. Lack of available public funding	☆	☆	☆	☆	☆
10. Unclear rules and regulations on fuel production	☐	☐	☐	☐	☐
11. Unclear rules and regulations on onboard emissions	☆	☆	☆	☆	☆
12. Lack of available ships and engines	O	O	O	O	O
13. Lack of fuel certification*			☐	☐	☐
14. Lack of available regulation*		☐	☐	☐	☐
15. Lack of market demand	☆	☆	☆	☆	☆
16. Lack of mission clarity	☆	☆	☆	☆	☆
17. Lack of available qualified people	☐	☐	☐	☐	☐
18. Lack of social acceptance*		☐	☐	☐	☐
19. Lack of international alignment*		☆	☆	☆	☆

uncertainty regarding their economic viability and their potential to reduce greenhouse gasses. This yielded knowledge regarding their technology readiness levels, ship compatibility, operating expenses (OPEX) and capital expenditure (CAPEX) costs. Nevertheless, *ambiguity* persisted as stakeholders disagreed on which energy carriers should be used, partly because (too) many valid options remained open. Stakeholders believed that robust mitigation strategies require policy mixes that govern both infrastructure and on-board technology development, rather than managing these separately.

Barrier 18 (lack of social acceptance) was considered an *ambiguous* barrier. Stakeholders agreed that societal acceptance will have a probable effect on the transformation and that the public sentiment can be fairly estimated. From these estimations, however, it was clear that stakeholders disagreed about the possible dangers associated with novel technologies (e.g., ammonia or nuclear). For example, various stakeholders mentioned that "good but not overly strict regulations regarding ammonia safety are important; in addition, safety perception and risk acceptance also matter". An ammonia producer added that “any fuel can be dangerous" but that it primarily matters how it is handled. To address these concerns, consultations took place among stakeholders to share expertise and concerns in relation to the social impact of sustainable energy carriers. The explorative nature of these consultations meant that different stakeholder views were revealed but not yet bridged or resolved, leaving the mission barrier *ambiguous*.

Furthermore, stakeholders disagreed on how to deal with outdated rules and regulations for fuel production (barrier 10). Stakeholders unproblematically agreed on the likelihood of such rules and regulations obstructing the mission, but policymakers and industrial actors could not align their long-term commitment towards the development of future fuel feedstock regulation (e.g., instability on which feedstock can be used for fuel production as part of the Renewable Energy Directive). A bio-fuel producer stated that "current subsidies [SDE++] have strict and narrow criteria which lead to higher costs and reduced cost-efficiency". These insights were deemed essential and dealing with such views motivated stakeholders to set out mitigation strategies in the 5th session.

Barrier 6 (lack of fuel production technologies) exemplified a *risk*. The probability was deemed unproblematic because stakeholders viewed such technologies as available, tested, and sufficiently understood in terms of their respective benefits and drawbacks. Furthermore, the possibilities were also unproblematic because there are only limited fuel production technologies, and other factors (e.g., location, sustainable energy availability) were generally more decisive in the feasibility and competitiveness of the solution. In practice, development issues nevertheless occurred, for example, because integrating the technology into existing grids is considered complex. This results in relatively long lead times before fuel production facilities become operational.

4.2. *Mitigation strategies*

In the last session stakeholders selected barriers that they believed should be mitigated by means of interventions that could reduce *uncertainties* and *ambiguities*. Stakeholders collectively set out eight mitigation strategies for some of the barriers (Table 3), with strategies differing in the extent to which stakeholders prioritized them. Four out of eight mitigation strategies (1, 5–8) aim to reduce

Table 3

Barrier priority as determined by stakeholders of the mission arena during real-time MOTA. The mitigation strategies show those that have been defined as both urgent (action required <1 year and higher impact) by the steering committee.

Mission Barrier	Mitigation strategy	Intended effect
01. Lack of sustainable energy carriers 02. Uncompetitive prices of sustainable energy carriers 03. Lack of feedstock for sustainable energy carriers* 07. Lack of collaboration across value chain	1. Create more extensive collaborations across the value chain.	Reduce ambiguities by increasing interaction with, amongst others, energy providers.
04. Lack of port infrastructure	2. Organize an approach for the development of shore power infrastructure for shipping.	Reduce uncertainties by increase short term infrastructural development.
05. Lack of onboard technology	3. Organize an approach for the development and application of energy saving measures onboard and onshore, in addition to the energy carriers replacement approach.	Reduce risks by increasing techno economic feasibility of the solution.
08. Lack of private funding	4. Increase opportunities for the financing of innovative project.	Reduce risk by broadening financial instrument.
09. Lack of public funding 15. Lack of market demand	5. Promote sustainable purchasing by governmental stakeholders for sustainable maritime services.	Reduce risks by increasing of demand.
10. Unclear rules and regulations on fuel production 13. Lack of fuel certification*	6. Strengthen the Dutch feedstock and energy carrier policy, especially towards fuel standards.	Reduce ambiguities by increasing long term clarity.
11. Unclear rules and regulations on onboard emissions 19. Lack of international alignment*	7. Allocate additional resources to increase the Dutch participation on international level, both publicly and privately.	Reduce ambiguities by increasing policy impact.
16. Lack of mission clarity	8. Develop an inclusive transformation monitoring tool.	Reduce ambiguities and uncertainty by increasing coordination.

ambiguities associated with nine mission barriers (1–3, 7, 10, 11, 13, 16, 19). Three out of eight strategies aim to further reduce *risks* affecting four barriers (5, 8, 9, 15). Finally, one out of eight strategies (2) focused on reducing *uncertainties* directly affecting one barrier (4).

To mitigate *ambiguity*, stakeholders proposed interventions and the allocation of resources that could resolve contestation. Mitigation strategy 1 stimulates collaborations across the value chain to promote the commercial viability of possible energy carriers for relatively small-scale shipping companies. As such, this strategy addresses a demand articulation failure by synergistically promoting demand and supply of sustainable energy carriers. An example of this is the introduction of so-called 'green corridors for sustainable shipping between ports,' which enable mutual understandings on specific routes.

Mitigation strategies related to what can be done in the 'here and now.' For example, mitigation strategy 2 enforces charging infrastructures that ports must comply with when handling large container and passenger vessels in 2030. This electrification of ports yields know-how (e.g., fast tracking standardisation procedures) that is relevant for the adoption of other energy carriers as well, which reduces some uncertainty. This nevertheless does not directly mitigate barriers to social acceptance, as the normative characteristics of one energy carrier differ significantly from others.

Third, strategies to reduce risks largely focus on investment risks. Currently, the demand for sustainable energy carriers is limited due to additional costs that make these carriers uncompetitive with fossil fuels. Stakeholders believed that by introducing financial instruments such as sustainable purchasing or government guarantees, the gap between sustainable and fossil fuels can partially be bridged.

5. Discussion

In this paper, we conceptualized and conducted a real-time Mission-Oriented Transition Assessment (MOTA) as a deliberative approach to anticipatory mission governance. This longitudinal approach concerns a sequence of MOTA workshops, with each workshop producing insights that formed input for subsequent workshops. More specifically, we applied the real-time MOTA to the Dutch mission 'Climate neutral shipping by 2050′ to collectively foresee, better understand, and address future barriers that could obstruct or impede mission efforts. Overall, the real-time MOTA revealed how stakeholders identified and discussed mission barriers, moving them from our typology of 'elusive' barriers to 'uncertain', 'ambiguous', or 'risky' ones that are less problematic to address through mitigation strategies. In what follows, Section 5.1 reflects on the theoretical and practical contributions, after which Section 5.2 specifically outlines case-specific recommendations for the Dutch maritime mission. Lastly, Section 5.3 discusses important limitations and avenues for future research.

5.1. Theoretical and practical contributions

Our work contributes to theory and practice surrounding anticipatory mission governance by developing and testing a real-time MOTA. This approach contributes to the assessment of (future) mission barriers, and how to approach mission governance adaptively over time. Although similar approaches exist for mission-oriented projects (Matt et al., 2023) and specific technologies (Guston and Sarewitz, 2002), policymakers still lacked an approach that could be applied to mission-oriented transformations at large. Through our application of the real-time MOTA, we find that stakeholder deliberations help acquire and co-produce insights regarding future mission barriers – both in terms of their possibilities (i.e., what barriers could happen?) and probabilities (i.e., how likely are they to happen?). The real-time MOTA appears particularly well equipped to identify elusive barriers and to collectively reconstruct them as risky, uncertain or ambiguous barriers. Moreover, the results show how stakeholders collectively formulated mitigation strategies to address them. Although these barriers and strategies did not always go uncontested (both in terms of factual and normative disagreement), they helped uncover different stakeholder expectations and revealed problematic knowledge gaps that require intervention. As such, we conclude that real-time MOTA is particularly effective as an explorative approach for anticipatory governance, rather than an approach to overcome disagreement.

Similar to the work of Coenen et al. (2025), our real-time MOTA brought together a wide range of stakeholders and helped facilitate constructive dialogues (Cuppen, 2012) that could reduce information asymmetries among them. This was partly enabled by the breaks in-between the 14 sessions, giving stakeholders the opportunity to gather evidence to support earlier claims during heated debates. For example, when considering the mission barrier regarding confusing regulations for onboard shipping emissions, stakeholders believed that a lack of data was mainly at the core of this issue. An overview of the different regulations and their impact (see Appendix A, Fig. 7) reduced both some uncertainty and ambiguity as the impact to each stakeholder became clearer. While stakeholders agreed that certain barriers were likely to occur, they more often disagreed about the implications that such barriers may have for the mission-oriented transformation, which therefore underlines the normative and contested nature of mission barriers.

Discussions that related to ambiguous barriers oftentimes revealed contradicting interests and conflicting values among participants. For instance, participants expressed divergent views on the mission's solution-space as some advocated methanol energy carriers for shipping while others preferred those using ammonia. Information on their technology readiness level and regulatory status converged the feasibility-related discussions but did not manage to resolve normative disagreements. Future actions might therefore need to be taken agonistically, while recognizing the validity of stakeholder views (Popa et al., 2021; Scott, 2021). When discussing problematic knowledge regarding the probabilities of elusive mission barriers, the *modus operandi* was to acquire more knowledge. For example, the lack of safety licences for the implementation of sustainable energy carriers was unanimously deemed a barrier for the transformation, but it was highly uncertain when sufficient expertise would be available to the various authorities that were co-responsible for setting these. Stakeholders drew from previous experiences with LNG energy carriers to use existing know-how for the licensing of future sustainable energy carriers.

In the context of our empirical case, the real-time MOTA was a formal part of the Ministry's governance process, and outcomes (e.g., mitigation strategies) therefore had an explicit 'landing place' for participating civil servants (Wesseling and Meijerhof, 2023). Although the approach was intended as a formative approach, we observe that not all outcomes fed back into policymaking. This can partly be explained because stakeholders disagreed about who 'owned' the mission's roadmap. While many stakeholders argued that the steering group is formally responsible for this roadmap and for determining the necessary directionality of the mission, the group was financially dependent on the Ministry. Simultaneously, the Ministry was only willing to take responsibility for the mitigation strategies once stakeholders showed sufficient commitment. As a result, a 'waiting game' emerged that left tasks unaddressed, giving rise to a so-called 'problem of many hands' where it became difficult to assign and share responsibilities (Thompson, 2005). This fragmentation of ownership arguably led to coordination failures and subsequently directionality failures (Weber and Rohracher, 2012). The real-time MOTA revealed such dynamics by facilitating collective discussion around (political) responsibilities, power, and agency, and the approach may therefore be of use to further study the politics of missions (de Graaff et al., 2025).

Based on our conceptual and empirical work, we argue that approaches to anticipatory governance represent important public sector capabilities because they stimulate learning, sense-making, expectation management, and more (Kattel et al., 2024; Velasco, 2023). These capacities play a prominent role in the monitoring and co-assessment of missions and are crucial for a 'theory of action' that explains how missions succeed through policy interventions (Wieser et al., 2025). Anticipatory governance thus shares similarities with reflexive governance, potentially contributing to the notion of responsible mission governance (Wiarda et al., 2024). Anticipatory governance also bears relevance for transformative innovation policy more broadly, as the aforementioned public sector capabilities are relevant beyond the realm of mission-oriented innovation policy.

5.2. *Case-specific implications for the Dutch maritime mission*

The real-time MOTA furthermore resulted in various concrete implications for our empirical case – the Dutch maritime mission. Stakeholders agreed that they should prioritize resources towards coordinating climate-focused rules and regulations, assess business cases of sustainable shipping across the value chains, and ensure the availability of alternative energy carriers. To achieve this, a rapid follow-up of mitigation strategies, combined with a continuation of this approach is recommended (Nusselder, 2024).

In addition, stakeholders expressed the importance of reflexive monitoring towards the mission goals. This would entail continuous assessments of technological readiness levels (e.g., time to market) and institutional readiness levels (e.g., emergence of standards and regulation) that could help stakeholders determine whether and when solutions are economically viable. This is important because it was believed to help overcome the current 'waiting game'. Not only did the real-time MOTA encourage this process, but it also accelerated the gathering and sharing of information that enabled learnings and discussions among stakeholders. Stakeholders furthermore pointed out the need for infrastructural developments that underpin the electrification of ports. This may include charging stations for container vessels, amongst others. Such charging stations are expected to have a significant effect on the greenhouse gas emissions of the maritime sector and would further stimulate forms of experimentation and learning that could contribute to the mission-oriented transformation. Overall, the results reinforce the relevance of policymakers implementing continuous processes of knowledge gathering and sharing (e.g. real-time MOTA).

5.3. *Limitations and future research*

This research comes with several limitations that should guide the interpretation of our work. First, this paper reports some of the preliminary results of a 1.5 year-long real-time MOTA but it is important to note that the respective MOTA could continue in the coming years to further support the mission until 2050. As a result, some mission barriers have been anticipated, but the extent to which these will materialize in practice remains prone to uncertainty. By extension, there are limited insights into the application of mitigation strategies, and to what extent these enable or limit potential problem-solution pathways (Wanzenböck et al., 2020). Future research should therefore examine the implementation and effectiveness of these strategies in response to (future) mission barriers and their overall impact on the transformation.

Second, the anticipated barriers and their characterization (i.e., risky, ambiguous, uncertain, and elusive barriers) are largely based on the observed interpretation of stakeholders (e.g., whether they disagreed or not). This means that findings could also be consciously influenced by stakeholders in ways that delegitimize certain solution pathways and emphasize barriers to serve vested interests (Klerkx et al., 2025). As a result, the characterization of mission barriers should be viewed as a collective construct that is inherently political and (inter-)subjective, warranting caution in their interpretation and use. Future research could explore whether more nuanced differences between our barrier characterization would be helpful.

Third, we have conducted the real-time MOTA with Dutch stakeholders. While 'Climate neutral shipping by 2050′ is a Dutch mission, it has undeniable links and dependencies with actors, institutions, and infrastructures outside of the Netherlands. Participants indicated to be familiar with such ‘external’ factors, but the sole inclusion of Dutch stakeholders admittedly comes with limitations that affect the validity of our work.

Fourth, although we used real-time MOTA to anticipate mission barriers, we also see merit in using the approach for other purposes such as the identification and discussion of the aforementioned alternative problem-solution pathways (Wanzenböck et al., 2020), mission politics (Kok and Klerkx, 2023), public concerns (Wiarda et al., 2024), and the functioning of mission-specific innovation systems (Wesseling and Meijerhof, 2023; Elzinga et al., 2023), next to advancements on anticipatory governance (Mason-D’Croz et al., 2025). We speculate that both theory and practice could benefit from a broader use of real-time MOTA.

Fifth, the aim of our paper has been to apply the MOTA in a real-time fashion to better understand how anticipatory governance helps identify and better understand mission barriers in terms of their possibility and probability. A relevant continuation of our work could be to apply a more complex system approach (e.g., causal loop diagrams) to better understand the dynamic interplay between mission barriers. Admittedly, this requires an extended operationalization of real-time MOTA that specifically accounts for the ambiguity of mission barriers.

Finally, although our case-specific mission towards climate neutral shipping started as a ‘mono-mission’ with clear prioritization above other topics, current geopolitical tensions require reconsideration of priorities towards competitiveness, safety, and strategic autonomy. As a result, mono-missions might become ‘multi-mission’, in which one topic cannot be clearly prioritized above others, and for which multiple missions might impose conflicting or complementary directionalities. This fundamentally changes the dynamics, as drivers enabling the mission do not always align (e.g., budget for defence vs. sustainability). It is therefore also recommended to research potential dynamics of multi-missions and how a real-time MOTA could contribute to navigating these.

6. Conclusion

In this paper, we have conceptualized and applied a real-time Mission-Oriented Transition Assessment (MOTA) as a longitudinal and formative approach to anticipate, better understand, and potentially mitigate future barriers affecting mission efforts. We applied the real-time MOTA to the context of the Dutch mission ‘Climate neutral shipping by 2050′, which aims to reduce operational greenhouse gas emissions for maritime shipping by 100 % before 2050. 124 Stakeholders collectively foresaw, examined and addressed 19 mission barriers across 14 sessions over a period of 1.5 years. The results suggest that real-time MOTA can bolster policymakers’ ability to anticipate and respond to barriers as a mission-oriented transformations unfolds. On the one hand, the real-time MOTA appears to be an effective tool in the anticipation of mission barriers. On the other hand, the approach struggles to resolve factual and especially normative stakeholder disagreement over the implications of mission barriers and how to best address them. We therefore conclude that real-time MOTA could contribute to early-stage anticipatory mission governance before mission-oriented transformations have played out.

Acknowledgements

This work was supported by the Rijksdienst voor Ondernemend Nederland (RVO). The opinions expressed in this article reflect only the authors’ view and in no way reflect RVO's opinions. We would like to thank Tom B.J. Coenen for his conceptual support during this research.

CRediT authorship contribution statement

Jurrit Bergsma: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Martijn Wiarda:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Jeroen Pruyn:** Writing – review & editing, Supervision, Conceptualization. **Geerten van de Kaa:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

A.1. Structure and stakeholders involved in the sessions

Table 4
Simplified representation of discussion agenda per session per workgroup.

Workgroup stakeholders	Session 1: Kick off	Session 2: Ship powertrain and safety (Onboard application)	Session 3: Bunkering and infrastructure (onshore application)	Session 4: Production and availability of energy carriers	Other: Ship type
WG1: Drop-in energy carriers applicable with little to no regime changes	Consensus on goal of the roadmap Consensus on energy carrier grouping	Consensus on outcomes session 1 Inventorization of norms and safety regulation	Consensus on outcomes session 2 Inventorization required bunker development	Consensus on outcomes session 3 Inventorization of energy carrier availability	(Dis-) advantages of energy carriers Drivers and barriers
WG2: Energy carriers applicable with limited regime changes	Clarification of (inter) national regulation for energy carriers Inventorization of relevant studies for this workgroup	Inventorization of required technological changes Inventorization of required certification	Inventorization of norms and safety regulation Inventorization of required financing	Inventorization of feedstock availability Inventorization of price development	Most applicable option
WG3: Energy carriers applicable with major regime changes		Inventorization of required financing Inventorization of relevant studies for this workgroup		Inventorization of well to wake sustainability Inventorization contestation with other sectors Inventorization of required financing	

Table 5
Stakeholders per subgroup totalling 124 stakeholder representatives over the various round and sessions.

	Steering Group | Executive			Control Group | R&D leads	
No	*Code*	*Type*	*No*	*Code*	*Type*
1	GO1	Government	1	GO1	Government
2	GO2	Government	2	GO2	Government
3	FS1	Renewable fuels | Branch organisation	3	FS1	Renewable fuels | Branch organisation
4	MS1	Maritime suppliers | Branch organisation	4	MS1	Maritime suppliers | Branch organisation
5	SO1	Shipowners | Branch organisation	5	SO1	Shipowners | Branch organisation
6	RO1	Research organisation	6	RO1	Research organisation
7	FS2	Energy for mobility and industry | Branch organisation	7	RO3	Research organisation
8	ES2	Energy | Branch organisation			
9	FS1	Fuel storage | Branch organisation			
10	RO2	Research | Branch organisation			
11	FI1	Financial institution			
12	FS3	Fuel supplier			
13	PO1	Port | Branch organisation			
14	BO1	Sustainable shipping | Platform			
15	SP1	Logistics | Branch organisation			
	Stakeholder sessions (WG1-5) | R&D Management/leads			**Stakeholder sessions (WG1-5) | R&D Management/leads**	
No	*Code*	*Type*	*No*	*Code*	*Type*
1	GO1	Government	41	SO10	Shipowners | Branch organisation
2	GO2	Government	42	GO4	Government
3	FS1	Renewable fuels | Branch organisation	43	FS9	Fuel supplier
4	MS1	Maritime suppliers | Branch organisation	44	FS10	Fuel supplier
5	SO1	Shipowners | Branch organisation	45	FeS2	Feedstock Supplier
6	RO1	Research organisation	46	FS11	Fuel supplier
7	RO3	Research organisation	47	SY3	Shipyard
8	FS3	Fuel supplier	48	SO11	Shipowner
9	FS2	Energy for mobility and industry | Branch organisation	49	FS12	Fuel supplier

(*continued on next page*)

Table 5 (*continued*)

	Steering Group | Executive			Control Group | R&D leads	
No	*Code*	*Type*	*No*	*Code*	*Type*
10	FS1	Fuel storage | Branch organisation	50	FP1	Fuel producer
11	FI1	Financial institution	51	SY4	Shipyard
12	FS4	Fuel supplier	52	SO12	Shipowner
13	RO4	Research organisation	53	FS13	Fuel supplier
14	SO2	Shipowner	54	FP2	Fuel producer
15	SO3	Shipowner	55	ES1	Energy Supplier
16	SY1	Shipyard	56	FS14	Fuel supplier
17	MS2	Supplier	57	PO4	Port
18	SO4	Shipowner	58	ES2	Energy Supplier
19	PO2	Port	59	CO1	Consultant
20	SO5	Shipowner	60	SH1	Shipper
21	SO6	Government	61	ES3	Energy Supplier
22	MS3	Supplier	62	ES4	Energy Supplier
23	SO7	Shipowner	63	GO5	Government
24	PO3	Port	64	GO6	Government
25	FS5	Fuel supplier	65	PO5	Port
26	FS6	Fuel supplier	66	SO13	Shipowner
27	FS7	Commodity trader	67	PO6	Port
28	SY2	Shipyard	68	IS1	Energy infrastructure supplier
29	SO8	Shipowner	69	CO2	Consultant
30	MS4	Supplier	70	SY5	Shipyard
31	MS5	Supplier	71	MS8	Supplier
32	MS6	Supplier	72	SD1	Ship Designer
33	FS8	Fuel supplier	73	SY6	Shipyard
34	SO9	Shipowner	74	SD2	Ship Designer
35	FI2	Financial Institution	75	SY7	Shipyard
36	MS7	Supplier	76	SO14	Shipowner | Branch organisation
37	FeS1	Feedstock Supplier | Branch organisation	77	SO15	Shipowner
38	GO3	Government	78	SD3	Ship Designer
39	FI3	Financial Institution	79	SO16	Shipowner
40	CS1	Class Society	80	SO17	Shipowner

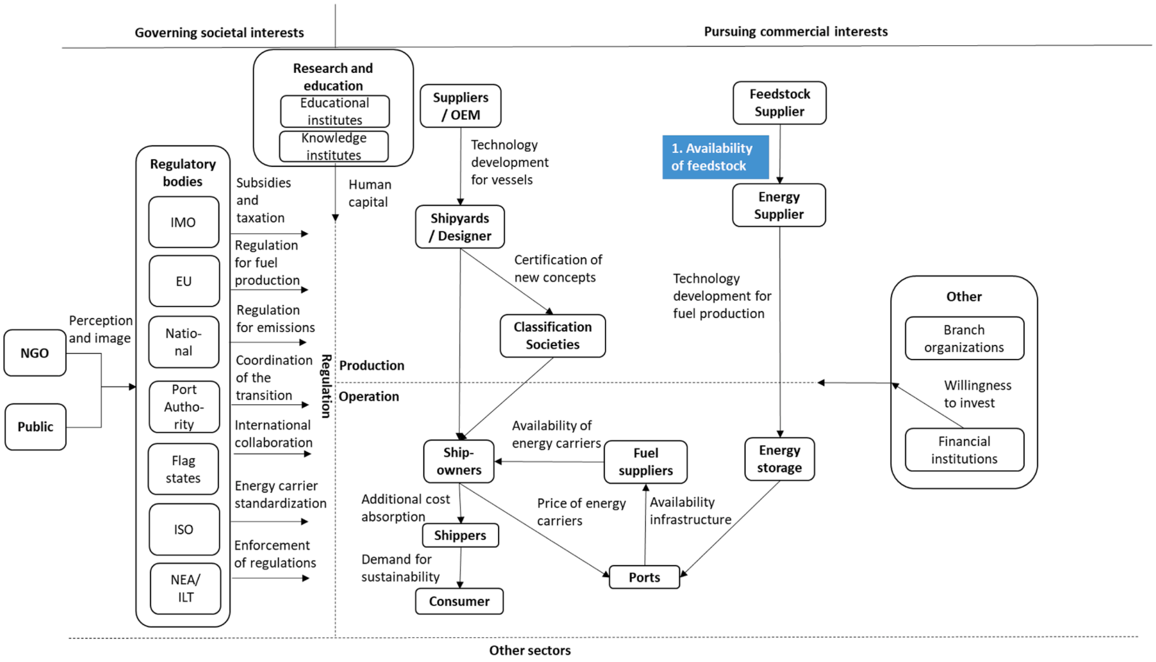


Fig. 6. Stakeholder map of mission.

A.2. Analysis results to increase insight

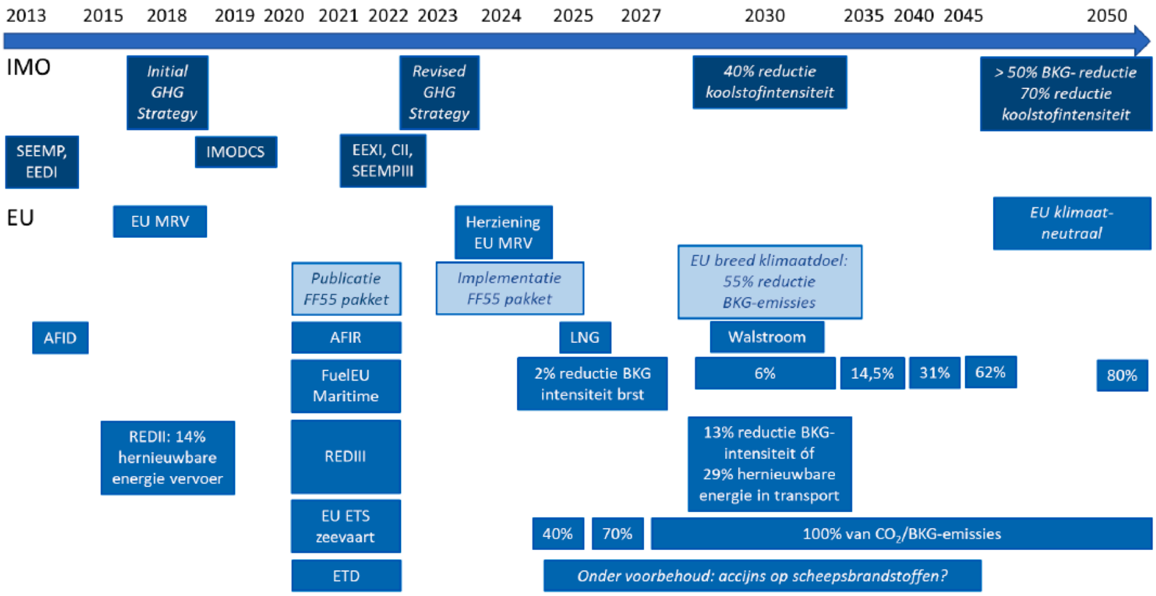


Fig. 7. Status quo of rules and regulation on IMO, European, and national level (Nusselder, 2024).

Data availability

The data that has been used is confidential.

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