The interplay of competencies and governance settings in dealing with uncertainty

A comparison of mobility as a service in the Netherlands and Australia

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The interplay of competencies and governance settings in dealing with uncertainty: A comparison of mobility as a service in the Netherlands and Australia

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A B S T R A C T

Actors experience considerable uncertainty when developing and realizing mobility innovations that can contribute in the transition to a sustainable transport system. Although the role of uncertainty and its handling is mentioned as important in the literature on transitions and innovations, there is a lack of understanding how uncertainty affects decision-making processes and actors themselves. This paper investigates the interplay of uncertainty competencies and governance settings in four innovation cases of Mobility as a Service (MaaS). Our findings demonstrate it is difficult to sustain MaaS beyond a research trial, because actors experience too much uncertainty about governance questions of long-term responsibilities and role distribution. Although individual actors possess effective project management skills and willingness to innovate in a trial context, they are unable to bring MaaS to a next level because MaaS is not seen as a part of a larger design quest in which stakeholders experiment and play with uncertainty through different institutional configurations.

1. Introduction

Most actors working on innovations in fields such as mobility struggle with uncertainty; they feel a lack of knowledge as an individual or group to make good decisions (Abbott, 2005). Dealing with this uncertainty in decision-making processes is particularly taxing in a novel and complex socio-technical innovation context (Köhler et al., 2019). Paradoxically, actors feel the need to gather information to base their decisions upon, but inherent to an innovation, due to its novelty, is that there is insufficient information available.

Current approaches to deal with uncertainty build on actors' craving for more knowledge, and they are often of analytical nature by focusing on the development of new model-based tools and approaches (Marchau et al., 2019) . Such tools range from traditional scenario planning methods (in which a policy is chosen which does rather well across different plausible futures) to more Assumption Based Planning based methods (which focus on reducing the policy from failing in various possible futures). Examples of the latter include Robust-Decision-Making (RDM) in which policies are tested against a very large number of futures to identify the most robust option, and Dynamic Adaptive Policy Pathways (DAPP) that focuses on establishing decision-making pathways to guide future actions

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([Kwakkel et al., 2016](#)).

However, there is a lack of understanding about the practical decision-making context in which such methodologies are applied, which consists of institutional, organizational, and individual factors ([Stanton & Roelich, 2021](#)). Based on a literature review on uncertainty frameworks as used by scientists, [Bevan (2022)](#) concludes that the body of literature is highly heterogeneous in form, aim and application. Because of this theoretical heterogeneity, uncertainty frameworks should be seen as tools for examining uncertainty as understood by actors in the field. It is therefore recommended that it would be worthwhile to investigate actors dealing with uncertainty more from an empirical, real-world perspective, with a focus on how practitioners operationalize uncertainty. Uncertainty often is labeled broadly to all kinds of elements that seem difficult or ambiguous in the development process of innovations, without making an explicit categorization of factors or conditions.

Expectations, promises and imaginaries towards innovations are described in literature as relevant factors in the governance of innovations ([Konrad & Böhle, 2019](#)). Such factors help to explain how innovations change and unfold over time. In addition to these described factors, we suggest that *uncertainty competencies* and *uncertainty settings* play a key role in the governance and implementation of innovations ([Akse et al., 2023](#)). We define uncertainty competencies as an actor's ability to make decisions under uncertainty that prove to fit the existing governance context. Uncertainty settings are defined as this context of (formal and informal) governance rules that structure the decision-making process under uncertainty. So, where uncertainty is about the experience of lack of knowledge to make decisions, competencies and settings are conditional factors that influence how uncertainty is dealt with. For example, the establishment of the Dutch Delta Committee can be traced back to an institutionalized culture of fighting against water and uncertainty reduction (uncertainty competencies) through quantitative models and expert judgement (uncertainty settings) ([Van 't Klooster & Veenman, 2021](#)). However, systematic comparison of multiple (innovation) cases with respect to uncertainty in practice is lacking.

Therefore, the aims of this paper are twofold. Firstly, this paper applies a practical perspective on decision-making uncertainty through understanding uncertainty through the interpretation and actions of decision-makers themselves. Through understanding the interplay of uncertainty competencies and settings in the governance of innovations, the role of uncertainty in the governance of innovations is made explicit. Secondly, researching current decision-making practices enables to reflect upon and improve the usability of the earlier-mentioned methodologies to uncertainty in literature. Apart from finding robust and adaptive policies from a more rational perspective, it is crucial to understand the *socio*-technical nature of uncertainty as well.

To study governance of uncertainty in practice, we analyzed uncertainty competencies and settings in four distinct cases of one mobility innovation, namely Mobility as a Service (MaaS). MaaS in its ultimate form provides users with a one stop shop app through an internet platform for all their mobility needs, with which one can plan, reserve, and pay for trips. It promises to integrate the fragmented transport landscape and could help make sustainable modes more attractive, through creating a tailored package for travelers ([Jittrapirom et al., 2017](#)). But, there are still many uncertainties for those actors involved in deciding on the specific service to offer ([Hensher, Mulley et al., 2021; Smith & Sørensen, 2023](#)). The research question of this paper is: How does the combination of actors' uncertainty (in)competencies and local uncertainty settings affect decision-making processes for a mobility innovation like MaaS? It is particularly interesting to study a new mobility innovation like MaaS that is experimented with in multiple countries, as different institutional contexts and governance approaches might lead to different experiences and ways of dealing with uncertainty ([Hirschhorn et al., 2019](#)). We will firstly describe our proposed theoretical framework of uncertainty competencies and settings and review existing literature on uncertainties related to MaaS in [Section 2](#). This will also include more elaborate examples of the two terms. [Section 3](#) will explain the research approach used in this paper. Then in [Section 4](#), we will present the results of an international case study comparison of two Dutch and two Australian MaaS schemes. Discussion points and conclusions are given in [Section 5](#) and [Section 6](#) respectively, including further research recommendations.

2. Theoretical framework and literature review

2.1. Existing frameworks regarding actor behavior and uncertainty

Which elements would be necessary for a framework to better understand the process of decision-making behavior under uncertainty? [Akse et al. (2023)](#) have applied a conceptual model putting actors in innovation processes in the center. It suggests an iterative perspective on actor interactions in decision-making under uncertainty. This iterative nature is rooted in the fact that choices regarding uncertainty management of one actor trigger experiences and influence choices under uncertainty of other actors ([Gomes et al., 2021; Hanna et al., 2020](#)). The focus of this paper, however, is studying the relevant *conditions* that structure decision-making under uncertainty.

Recent literature describes useful theoretical approaches and frameworks about these conditions, which will be briefly reviewed here. [Poeppelbuss et al. (2021)](#) use a theoretical model derived from the microfoundations movement (see [Felin et al., 2015](#) for an overview) to describe iterative uncertainty reduction practices in smart service innovation processes. This model consists of a macro-level, on the level of the service ecosystem with a specific institutional logic, a micro-level with actor action formation mechanisms and a meso-level that translates macro logics to micro actions and the other way around ([Storbacka et al., 2016](#)). [Machiels et al. (2021)](#) adopt three theoretical perspectives to explain uncertainty avoidance in large projects, which are the resource constraint-model (rooted in theory on bounded rationality and limited cognitive capacity ([Simon, 1965](#))), the strategic behavior model (rooted in literature on human bias of costs and benefits ([Flyvbjerg et al., 2018](#))), and the institutional model (describing formal and informal rules that structure decision-making routines and logics ([Dewulf & Biesbroek, 2018; Klijn & Koppenjan, 2016](#))). Finally, [Meijer et al. (2007)](#) discern perceived uncertainties and motivation as factors that are key for making decisions. Relevant internal

factors (such as the differences in actor frames, experiences, and skills) and external factors (technological developments and institutional change through policies and standards) consequently influence which uncertainties are perceived and how motivated actors are to deal with uncertainties.

2.2. Uncertainty competencies and uncertainty settings

In sum, when we consider the uncertainty in the future behavior of a system as a given, two relevant types of factors condition decision-making under uncertainty on that system, namely uncertainty competencies of those involved in the decision-making and uncertainty settings in which they operate. Competencies are defined as an actor's ability to make decisions under uncertainty that prove to fit the existing governance context and can be traced back to actors and their desired action mechanisms via earlier experiences, biases, attitudes, routines, and capabilities to handle uncertainty. Secondly, both formal and informal institutional uncertainty settings refer to the macro 'rules of the game'. Formal settings in the form of contracts, policies and regulations can be both a source of uncertainty and a strategy to deal with uncertainty (Akse et al., 2023). Informal settings such as trust and leadership can be ways to pull an innovation through uncertainty.

The way in which uncertainty is playing a role in innovations and the chosen strategies for dealing with uncertainty are not developed void of an organizational/cultural environment. An often-used distinction is the one between the Anglo-Saxon model and the Rhineland model (see for example Koppenjan and de Jong, 2018 or Heurkens, 2012). In the core, the difference can be explained in how uncertainty is addressed. In the Anglo-Saxon model much is expected from private-led, competition-driven innovation. Uncertainty is an integral part of this framework, as some competitors will be smarter or luckier (depending on your perspective) facing that uncertainty, leading to market coordination: the market will let an innovation survive. Public regulation is there to follow the market process. In the Rhineland model, much is expected from public-coordinated innovation. Uncertainty exists also here, but a set of public and private actors respond to that uncertainty through the organization of coordinative support instead of competitive survival. From the 1980s, the Rhineland model has been under pressure, as neoliberalism spread the Anglo-Saxon governance views over Europe and beyond (see for example Menz, 2005). In more recent years, it seems that the cooperative public-private approach is back, mostly driven by the understanding that the narrow focus of market-driven approaches on financial gains and market share is not in line with the challenges of current transitions such as moving from reducing externalities to a regime shift or moving from impact assessment to institutional change (Pel, 2022; Veeneman, 2022). We see a resurgence of attention for more cooperative models, that classically fit the Rhineland model. In that context, it is interesting to see how uncertainty plays a role in the decision-making of a mobility innovation like MaaS, clearly positioned on the public-private interface.

When designing a MaaS solution for travelers in a certain region, there is always an interaction between public players (for example in their role as transport authority, infrastructure owner, or transport policy makers), and private players (for example transport service operators, shared vehicle providers, platform developers, investors and more). In that interaction between the private and the public, a confrontation occurs between the above-mentioned competitive and coordinative model, both in how individual actors deal
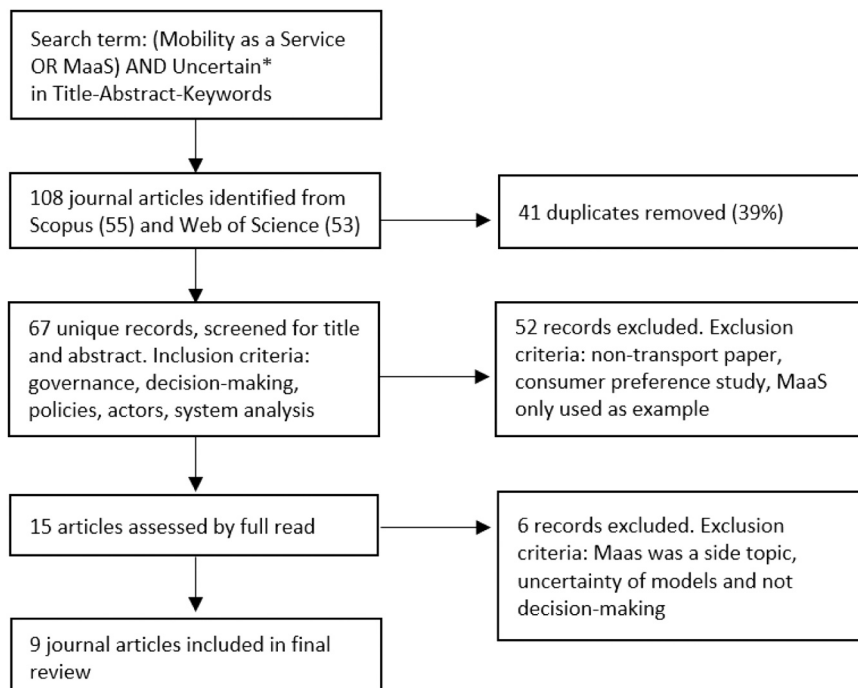

Fig. 1. Systematic review methodology.

with uncertainty, and how the governance context structures that process. This paper examines how the interactions between the private and public actors are structured by the individual competencies and governance settings.

2.3. MaaS and uncertainties: a systematic review

To get an overview of the growing amount of literature of MaaS that specifically mentions uncertainty, a systematic review was conducted. The aim of the review was to summarize which uncertainties are described related to MaaS, and what theoretical approaches are used to describe these uncertainties. Related search terms were entered into the most common scientific databases, namely Scopus and Web of Science (van Wee & Banister, 2023). Google Scholar was excluded, as this review only included peer-reviewed articles in the results, thereby excluding conference proceedings, book chapters and other grey literature, like policy reports, urban plans, and white papers. The search methodology process is shown in Fig. 1. Ultimately, only 9 articles did fit the conditions and were included in the full review. These journal articles have been selected as they deal particularly with uncertainties in the context of MaaS, and they also were clear about how these insights about were developed (e.g., by a pilot, group panel discussions, etc.), and possible solutions in dealing with uncertainty surrounding MaaS.

The uncertainties mentioned in the journal articles can be categorized into two main groups. The first group discusses uncertainties concerning the governance of MaaS, with questions about roles of stakeholders, collaboration schemes, viable business cases, policies, and the management of uncertainty itself. This group of articles also proposes new theoretical frameworks and perspectives to describe and understand such governance problems, such as a framework for governmental policies and MaaS (Smith & Hensher, 2020), a framework for conflict and cooperation (Mladenović & Haavisto, 2021) and a framework of co-existing and competing institutional logics (Guyader et al., 2021).

A second smaller group of uncertainties are about the impacts of MaaS on transport system outcomes and conditions for implementing MaaS, including its societal effects and consumer uptake through subscription packages. For example, Hensher, Mulley et al. (2021) mentions the uncertain effect of MaaS on sustainability goals, which is according to the authors dependent on scaling-up and offering enough benefits to travelers to use MaaS. The potential of MaaS to achieve societal goals like reducing road parking depends on the uncertain assumption that travelers will use shared vehicles within a MaaS scheme (Jittrapirom et al., 2018).

Different ways for handling uncertainties are proposed. Some articles remark that uncertainty is inherent to the experimentation and learning culture of a MaaS trial (Guyader et al., 2021). Testing MaaS through a trial was in fact a way for stakeholders to handle uncertainties about what MaaS could or could not deliver. However, the trials themselves also induce other uncertainties, or are not able to produce appropriate answers to mitigate uncertainties about MaaS (Hult et al., 2021). Another approach to uncertainty is proposed by Jittrapirom et al. (2018), who use uncertainty as design premise for building an adaptive plan that performs well for multiple futures instead of one static future. Such an approach resonates with Mladenović and Haavisto (2021), who call for the envisioning of pathways for alternative mobility futures because of irreducible uncertainty, rather than trying find ways to fit a MaaS scheme into existing institutional governance settings.

Although all articles mention uncertainty surrounding MaaS implementation, no article has analyzed MaaS specifically through an uncertainty perspective. Uncertainty seems relevant according to all journal articles, but also easily labeled to anything that is difficult and ambiguous. It is therefore worthwhile to unpack decision-making behavior under uncertainty in MaaS cases and add to the existing literature on the uncertainties relevant for the governance of MaaS. Several uncertainties have been mentioned in relation to MaaS, summarized in Table 1.

2.4. Expectations

Based on the review of MaaS and uncertainties, in combination with the framework of competencies and settings, we pose several expectations that can be tested empirically. Regarding uncertainty competencies, we expect that MaaS will be led by proactive leaders, also referred to as a champion (Hensher, Mulley et al., 2021). The MaaS trials are expected to be temporary and experimental, and based on the literature review we expect that they are not able to reduce uncertainty. Uncertainties are expected to be about a combination of governance and the role of MaaS in the transport system. Regarding uncertainty settings, we expect that for the Anglo-Saxon model uncertainty would be key in the market coordination process, whereas in the Rhineland model uncertainty would be shared between public and private actors.

Table 1
Summary of systematic review regarding Uncertainties and MaaS.

Uncertainty About	Mentioned by
Governance of MaaS, in terms of the division of roles between public and private actors, who takes the lead, collaboration rules and policies	(Esztergár-Kiss et al., 2020; Hensher, Mulley et al., 2021; Hult et al., 2021; Jittrapirom et al., 2018, 2020; Smith & Hensher, 2020)
Societal effects of MaaS, mainly in the area of sustainability	(Hensher, Mulley et al., 2021; Jittrapirom et al., 2020; Mladenović & Haavisto, 2021; Smith & Hensher, 2020)
Business model of MaaS, mainly on finding a viable business case	(Hensher, Mulley et al., 2021; Hult et al., 2021; Mladenović & Haavisto, 2021)
User uptake of MaaS, including trial participation	(Guyader et al., 2021; Jittrapirom et al., 2018)
Definition of MaaS, on what elements constitute a MaaS solution	(Jittrapirom et al., 2017; Jittrapirom et al., 2020)
Managing uncertainty in the MaaS context	(Guyader et al., 2021; Hult et al., 2021)

3. Methodology

Based on the theoretical insights of the literature review and theoretical frameworks by Poeppelbuss et al. (2021) and Machiels et al. (2021) on decision-making behavior under uncertainty, we composed a framework of uncertainty competencies and uncertainty settings for empirical analysis of MaaS innovation cases in practice. This framework was used for the interpretation and categorization of the empirical data. The main research question that guided the data gathering was: How does the combination of actors' uncertainty (in)competencies and local (institutional) uncertainty settings affect decision-making processes for mobility innovations? Although other empirical papers also have looked into decision-making under uncertainty in practice this paper takes a distinct perspective. We focus on interactions of public and private actors, whereas other papers by Zandvoort et al. (2019), Bijlsma et al. (2011) and van den Hoek et al. (2014) focus on government actors only. Also, in this paper we are not focusing on content (e.g., types of uncertainty, see Meijer et al., 2007 and Machiels et al., 2023), or process (e.g., strategies of dealing with uncertainty, see Van 't Klooster Veenman, 2021), but on conditions structuring these decision-making practices (Rauws, 2017). Moreover, we compare these conditions for one type of innovation, in different international contexts.

To answer the research question of this paper an embedded multiple case design was set up, in which multiple cases are compared as well as two initial units of analysis within each case (Yin, 2012). This methodology has been chosen to maximize the possible differences in observed uncertainty competencies and settings, given the same type of MaaS innovation. An overview of the case study design is displayed in Fig. 2. All cases involve the development of a MaaS trial, in which multiple actors were involved. All four innovation cases studied were exploratory, meaning that all actors did not have any experience with MaaS before. Two different governance settings were compared, namely an Australian governance context and a Dutch governance context. The Dutch governance approach towards (transport) innovations can be characterized as the Rhineland Model, with a leading role for the government in the collaboration with private players (Hirschhorn et al., 2019; Manders et al., 2018). The Netherlands is known for its well-established cycling culture, which counter-intuitively also leads to high entry barriers for (bike) sharing companies who are not aligned with local norms and policy cultures (van Waes et al., 2020). Similarly, UberPop has failed to become legalized in the Netherlands because of their inability to be involved in a co-creation process of drafting new policies for new taxi services (Pelzer et al., 2019). The Australian transport governance context however can be characterized as Anglo-Saxon, with more freedom for market actors to both enter and uphold transport services with less government interference (Curtis et al., 2019; Dowling & Kent, 2015). Secondly, after initial conversations with stakeholders it appeared that there were two different target groups in the four MaaS trials. Therefore, the consideration of either focusing on business travelers or students and staff of a university was also considered in the analysis.

Data was gathered using semi-structured interviews, in addition to analysis of initial project plans, evaluation documents and public research reports. All data sources are attached as an Appendix. Interview questions were firstly about trial organization (setting-up, management), and worked towards actors' experiences of uncertainty in the form of: 'Do you have a moment in the process where you felt tension and did not know how that would go away?'. This moment was consequently dissected using who-when-what-how questions. We did not use an a priori typology of uncertainty in the interviews, as we wanted to focus on the interpretation of
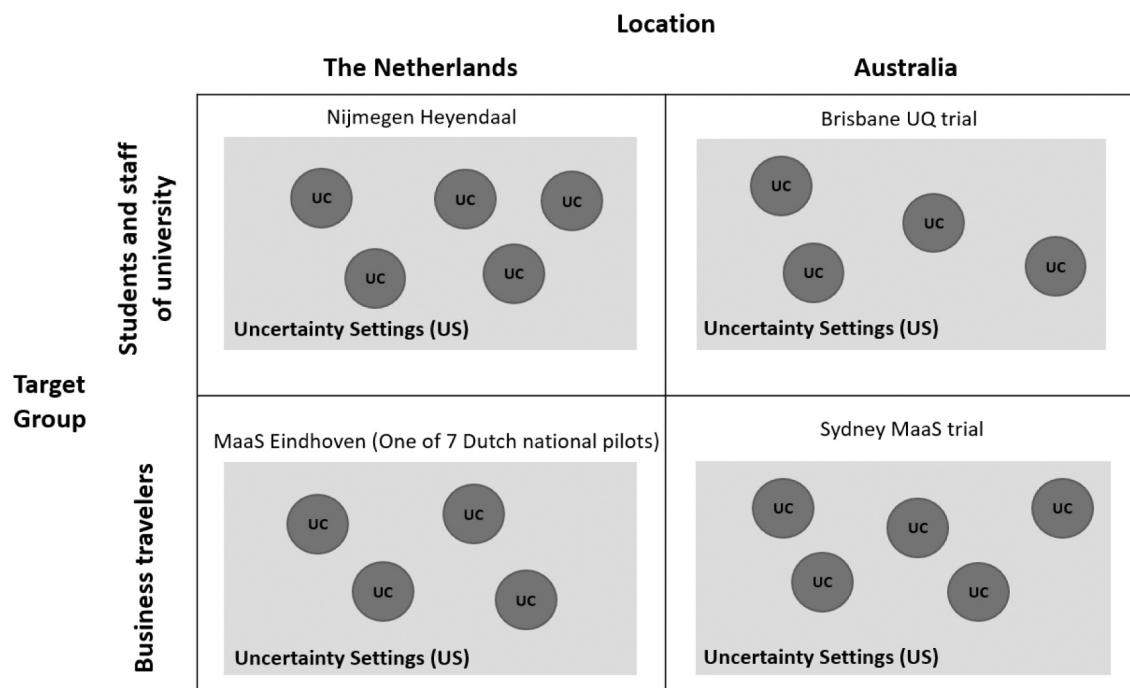

Fig. 2. Overview of four MaaS cases. US = Uncertainty Settings, and UC = Uncertainty Competencies of individual actors.

uncertainty by interviewees.

Interviews were conducted with 4–5 actors per case in the period between February 2022 and June 2023 (See Appendix for a complete overview), and we aimed for a representable range of involved governments, mobility suppliers, app developers and researchers. Interviewees were contacted via a combination of using our own personal network, through knowledgeable spokespersons and getting in touch via email. In general, contacting market actors was more difficult than with governmental actors, which resulted in the non-response of some actors. The semi-structured interviews were aimed for 60 min, but in practice they ranged from 38 min to 93 min (average = 53 min, standard deviation = 12 min). The difference in length can be explained by a closer or more distant involvement of the interviewee in the trial and the availability of time. Generally, in-person interviews in Nijmegen and Sydney were longer in length, but most of the interviews were conducted online.

Interview data was triangulated to get an overview of important experienced uncertainties and relevant uncertainty competencies and settings that conditioned such experienced uncertainty. 18 interview transcripts have been thematized. Firstly, relevant quotes from each interviewee have been listed. Then, in an iterative way these quotes have been categorized thematically by coding them deductively using the framework of uncertainty competencies and settings, and cross-compared with the other trials. As more quotes were added to the ordered code list, specific code names were defined and adjusted. By triangulating the codes with relevant documents, overarching themes have been constructed inductively within the initial structure of competencies and settings, which were relevant for decision-making behavior under uncertainty throughout all four trials. Consequently, the differences and similarities of the Australian and Dutch governance context, along with the MaaS apps for business traveler and students as a target group were compared using the earlier-developed themes.

4. Results

4.1. Four MaaS trials: an overview

We will firstly start with a brief description of each of the cases, and then present the results of a thematic analysis of uncertainty competencies and settings. Finally, we have cross-analyzed the emerging themes for all four cases. A descriptive overview of all four MaaS trials is displayed in Table 2.

The Sydney MaaS trial started as a collaboration between researchers from the University of Sydney and insurance company IAG. Researchers from Sydney were interested in evaluating the effect of various travel packages in a MaaS trial, and IAG was interested in MaaS being a product they could sell to their customers in the future. Mobility providers in the app included all public transport operators, car rental, car sharing and bike sharing companies. Funding was arranged via iMove, an Australian national research center that facilitates transport projects with industry, government organizations and universities. iMove assists in setting up a research proposal, getting a formal agreement and overseeing the project in terms of milestone delivery and documentation of results. A specific requirement related to uncertainty is filling in a risk register by all partners, which asks to outset and identify risks delivering the project and identify mitigation strategies for these risks. The MaaS app itself was developed by Skedgo, and IAG employees have been travelling with the MaaS app during the trial that ran from November 2019 till March 2020. The day-to-day project management was executed by a team of the University of Sydney and IAG. Several research papers have been produced based on data from the trial (Hensher, Ho et al., 2021; Ho et al., 2021).

The Odin Pass Trial in Brisbane, Australia, was an initiative of the federal Department of Transport and Main Roads (TMR). They wanted to understand how to implement MaaS in Queensland, whether it is something that students and university staff want and use, and what role the government could have in organizing MaaS. University of Queensland (UQ) was involved in the research trial to understand for which market there would be a suitable MaaS model. Odin Pass was set up as a separate business as a university spin-off to run the trial on a day-to-day basis, to sign contracts with all local mobility providers and give customer support to travelers. However, data generated by the trial was stored at the university. Mobility providers included in the trial were public transport

Table 2
Descriptive summary of the four analyzed MaaS trials.

	Sydney MaaS Trial	Odin Pass Trial	MaaS Heijendaal	Eindhoven MaaS trial
Location	Sydney, Australia	Brisbane, Australia	Nijmegen, the Netherlands	Eindhoven, the Netherlands
Start project	2018	2020	2016	2018
Start trial	2019	2021	2018	2020
End	2020	Running	2020	2022
Target group	Business traveller	Students and campus employees	Students and campus employees	Business traveller
Initiator	University of Sydney, IAG	TMR (Department of Transport and Main Roads)	Radboud University	Ministry of I&W (Infrastructure and Water Management)
Government involvement	No	TMR	Municipality of Nijmegen, Province of Gelderland	Municipality of Eindhoven, Province Noord-Brabant, Ministry of I&W
Funder(s)	IAG 25 %, University 25 %, iMove 50 %	TMR 50 %, University of Queensland 25 %, iMove 25 %	Province of Gelderland	Ministry of I&W
MaaS app	Tripi	Odin Pass	GoAbout	Turnn
App Developer	Skedgo	Skedgo	GoAbout	ICT Group
Number of users	100	5000	50	350

operators, e-scooters, taxis, and car sharing. Funding the trial via a contingency budget was arranged through iMove, UQ and TMR. Travelers (students and staff from UQ) could choose between different subscription models, which generated cash flow for Odin Pass that could be transferred to mobility providers. With some operators, Odin Pass could get a discount when a traveler used a specific transport service. The trial is still running at the moment of writing.

MaaS Heijendaal started as a collaboration between researchers from Radboud University and a working group formed by representatives from the Radboud hospital, province, municipality, and transport operators. The working group was formed to stimulate sustainable travel to the campus on which the hospital, university and university of applied sciences is located. There was a broad division of interests, ranging from knowing more about sustainable travel behavior, getting students and staff to travel more sustainably to the campus, and increasing ridership on public transport and sharing vehicles. It was agreed that the trial would consist of 50 travelers at a max, to avoid high losses. Funding was delivered via governmental organizations and a university research grant. The initial target group of travelers were commuters, but after it became clear that they were not interested in using MaaS the trial switched to business travelers who could get reimbursement through HR via the MaaS app. The trial intended to scale up to 1500 travelers, but this has been postponed due to Covid-19.

The final MaaS trial case was in the Dutch city of Eindhoven as part of a large national MaaS program initiated and funded by the Dutch Ministry of Infrastructure and Water Management. After market consultations and a tendering program, seven consortia were selected to organize MaaS trials throughout the Netherlands. All these trials had a pre-defined specific goal, and the goal of the Eindhoven trial was to increase sustainable travel behavior of businesses in the Eindhoven area. On a national level, a program management team ensured that there were API standards, data sharing agreements and occasions where learnings could be exchanged between all trials. Employees (ASML and the municipality of Eindhoven) used the MaaS app as part of their business travel during the trial. They could make use of public transport, bike sharing and car sharing. After the trial stopped, the app-developer did not continue with supporting the app for businesses.

4.2. Thematic analysis of uncertainties, competencies, and settings

In general, the aim of all trials was to increase knowledge about the effects of MaaS on sustainable travel behavior and to gain experience how to organize MaaS in practice. In practice, this meant that MaaS aimed to promote a shift from the private car to public transport and shared vehicles. The Australian trials have reduced uncertainty about consumer behavior, for example in the Sydney MaaS trial where research shows first evidence that MaaS can reduce car use in practice (Hensher & Ho, 2021). For the two Dutch cases, no formal assessment was conducted due to travelers' privacy reasons (Eindhoven case), or the trial did not go into the scale up phase that enabled data analysis of travel patterns (Heijendaal case). For three out of four trials, an evaluation assessment on process and learning was conducted. The Australian cases highly focused on learnings regarding the trial set-up, travel behavior and positive business cases. The Dutch evaluation reports explicitly focused on governance questions for the local and national governments in terms of what would be necessary for creating a sustainable MaaS ecosystem, and what the government should do to create that ecosystem.

The analysis of interviews and evaluation documents indicates that uncertainty about governance was high and remained high after the trials were finished, as was also the conclusion of the systematic review in the theoretical section of this paper. Although all interviewees and evaluation documents mention that much has been learned how to organize the trial, about setting up collaborations and attain more knowledge on the technological side of a MaaS apps, fundamental governance uncertainty remains about agreeing upon the roles between government, operators, brokers, and app-developers in terms of who should take the lead and how a MaaS system can fit into existing institutional (public) transport regimes. Furthermore, there is still uncertainty about a viable business case, as governments hesitate to put subsidies into small MaaS schemes with low patronage. Multiple interviewees mention that there is a chicken and egg problem of patronage being low due to the limited number of operators, but operators are only willing to join a MaaS app when there are enough travelers using the MaaS app.

Interviewees talked about uncertainty in qualitative terms, by expressing their tensions and anxieties throughout the project. Interviewees referred to uncertainty almost always as negative, difficult, or something that gave them a headache, and we noticed a large overlap in interviewees using the terms risk and uncertainty. The Australian trials did have pre-trial risk assessment, to prepare stakeholders better by producing some mitigation strategies. But, these risks were about the project itself, not about the 'broader' set of uncertainties related to MaaS.

Based on the interviews with key-actors involved in all four MaaS trials, we have cross-compared uncertainty competencies and settings that were relevant for making decisions. Seven themes have come up based on this empirical analysis, which will be elaborated upon below.

4.2.1. Actor competencies in handling uncertainty

Trust and positive expectations. Trust and experienced partnerships were mentioned as things that contributed positively to handling uncertainty in a collaborative setting. Such partnerships were labeled by interviewees as 'natural', with a 'long-established relationship', 'trusting', and working together in an agile team. Some interviewees from the new sharing companies mention that the MaaS trial was a way to build trust and strategic relationships with governments, so that they would be known as an honest, capable, and trustworthy partner. Connected with having a trusted atmosphere is also a positive vibe of building and experimentation. Actors liked having fun while doing the project and interviewees labeled themselves as optimistic and pragmatic, just trying out something new.

Proactive decision-making. Interviewees showed competencies of deciding who to involve, and who to let go in the trial, based on expectations regarding collaboration and potential impact. In Sydney, the government and local public transport operators were not

included because it would take a lot of time and effort to on board them. Also, it was expected that they would have different interests which were difficult to align with already-existing ideas. In the case of Brisbane, a separate company was created to avoid any conflict of interest between research objectives and commercial objectives. In Eindhoven, multiple mobility providers chose not to collaborate in MaaS trial, based on their estimation which MaaS apps would be worthwhile to connect with high numbers of user subscriptions. One interviewee mentioned that being more selective in involving actors in the trial was one of the learning points of the trial: 'If they are not interested to join in the trial, then I would say, the project will not carry on because it is doomed to fail'.

Ad-hoc project management. Interviewees showed competencies of doing ad-hoc project management, with rambling apps, working around existing technological hurdles. In Sydney, interviewees mention that the app was shaky, rough, and basic, stitched together with tape and paper. In Brisbane, users booked public transport with a flesh pass because the technology was not ready yet to link existing transport passes with the MaaS app. With all trials, it was underestimated how much internal capacity and technological work it would require making things work in practice. Also, along the process there was an unmasking going on of which actors did have enough technical capabilities and which actors did not have the skills to create MaaS apps, link with new MaaS apps etc.

Alignment of interests and narrative. Content-wise, collaborations were more uncertain when interests differed for multiple actors, and when alignment of these multiple interests was difficult to attain. Although different actors had different priorities, being open and understanding where they intersect was mentioned as important by interviewees. In some cases, this alignment did happen (Sydney, Brisbane), whereas in other cases this did not happen (Heijendaal, Eindhoven). For the Sydney case for example, it was mentioned that there was an alignment of narrative when different partners came together, which made it 'fit' easily into their own organization. This also has to do with the fun element that has been mentioned.

4.2.2. Uncertainty settings

Client-Contractor relationships. In all trials, relations between the consortium of government and MaaS broker on the one hand and the app-developer on the other hand were experienced as stressful, given the lack of design standards and agreements. The expectation of the app developer was that they were in a client-contractor relationship, whereas expectations of governments and operators were more leaning towards a co-creation process. Because of these misunderstandings, contracts were checked to see what was legally required from each of the actors. Also, in the case of Eindhoven and Heijendaal there was a mismatch between app-developers and governments in terms of timing and culture. When the municipality was ready to move forward, the app developer was not (Eindhoven), or the app-developer was waiting for other organizations to produce design criteria and a plan to move forward (Heijendaal). This might have to do with the problem of leadership. In the Australian cases, there was small day-to-day leadership team which could steer and decide to push the project towards the desired direction given other actors' constraints. In a Dutch context, leadership was distributed over many actors which led to indecisiveness.

Standardization agreements. API standards and data agreement strategies played a significant role in all the cases. Finding agreement was experienced as stressful and uncertain by all interviewees, as interests differed between researchers, governments, and private companies. Although all trials managed to implement an API that worked, the consequences differed between cases. In Eindhoven, the nationally agreed API created higher entry-barriers for local transport operators, who had to change their technological infrastructure but did not receive enough funding to do so. In Sydney, researchers decided pro-actively not to include a transport operator because of its readiness and ability to link with the data structure they were working in.

Exogeneous developments. In both the Australian and Dutch context, some exogeneous circumstances were relevant for introducing uncertainties in the trial. Lack of legislation and policy about the new mobility innovations was a relevant condition for increasing uncertainty levels. Covid-19 was mentioned by the majority of interviewees as important, which could not be foreseen in project plans. Other exogenous developments such as visionary political leaders or broader economic developments were mentioned as relevant but not important, as the trials took place in a protected niche for which money and resources were set. For example, the Brisbane 2032 Olympics was mentioned as an event that incentivises policy-makers to look and build for new and better transport supply, but there is no direct link between the MaaS trial and the event itself (yet).

4.3. Similarities and differences across cases

It is striking that three out of four trials started with a research institute. Most interviewees mention that before starting the trial, MaaS was a buzz word in the field that could solve many problems in the transport sector. Governmental actors wondered what MaaS could mean for achieving sustainable travel goals. Researchers saw opportunities in trials to analyze travel behavior, subscription packages and eventual effects on sustainability indicators. Companies felt that MaaS could open new business models through more data generation and targeted marketing campaigns. In hindsight, actors reflect upon this initial thrill as a hype that MaaS around 2015 till 2020 (cf. Braams et al., 2023), especially after trials have been completed.

Different governments had varied reasons to be involved in MaaS trials which can be explained by the different governance models used (the Rhineland vs the Anglo-Saxon governance model). In the Netherlands, the fear was that a big company like Uber would take over the potential MaaS market, which could lead to undesirable societal effects and less governmental influence on the future transport system. Therefore, the ministry started a mission-oriented MaaS policy program to be ahead of MaaS as a corporate development. In Australia however, governmental interviewees indicate that they did not see any problem whether a big company like Uber would dominate the MaaS market, if they would comply with Australian regulatory criteria.

The main goal of all trials was not to produce a commercially viable app that could work beyond the trial period. On the one hand, with the research trials there was a lot of validity and trustworthiness with other partners that the trial was indeed a promising idea because it was backed up by scientists. On the other hand, because of this rigidity, there was not a lot of room to move as a business

would do with changing design parameters based on non-user uptake for example. In terms of uncertainty, this meant that researchers were good at seeing the possibilities of an innovation like MaaS and using their credible authority to push innovations forward despite a lot of unknowns. On top of these content-driven goals, transport operators and businesses were involved to either establish a trustworthy relationship with government (Brisbane), or to get a better understanding about the broader implications on its business as travel trends change (Sydney, Eindhoven, Heijendaal).

Content-wise, it is interesting that it did matter who the target group of the trial was. For the business travelers, the prospects of pursuing a MaaS trial incorporated in a HR program seem more prosperous as there is win-win for both a company and an employee to travel by MaaS. This was in fact the reason for MaaS Heijendaal to shift focus from ordinary commuting travelers to business travelers. Uncertainty about the viability of the MaaS product was thus managed via a change of the whole MaaS trial set-up itself, rather than via relational or contractual governance. Also, interviewees from the Eindhoven trial and Sydney MaaS trial mention that the added service for business travelers can be key in creating a viable business case.

Although all interviewees mention that the governance of uncertainty was most important during the trial, research questions and goals of the trial were not primarily aimed at increasing knowledge about roles, standards, and other institutional settings. Documents and interviews demonstrate that the main aim of all trials was to see whether a sustainable contribution could be made for either business or student travel behavior, via different types of packaging or rewards. Interviewees from the Brisbane trial mention that because of the temporary nature of the trial, it was easier for them to start the MaaS collaboration: 'If we were implementing this permanently, we would have had to go through a lot more scrutiny'. The evaluation document of the Eindhoven MaaS trial mentions that the focus lied on finding out what MaaS could bring them in general, and not on specific learning effects, creating a level playing field and finding a viable business case in the long run.

Finally, an important difference between the Dutch and Australian cases was the presence of iMove as an external partner in terms of funding, contracts, and risk management approach. Although this role was also deliberated with the Ministry in the case of Eindhoven, the ministry was certainly not a neutral partner as iMove was. With Heijendaal, the lack of an overviewing party led to many debates about sharing agreements and design standards. It can therefore be deduced that an overviewing party can help in managing contracts and setting standards. However, this party does not have to be neutral, as both the Australian cases (with iMove) and the Eindhoven case managed (with a ministry) to come to standards and agreements.

5. Discussion

Based on the four cases and different themes regarding uncertainty competencies and settings, several patterns can be distinguished.

5.1. Competencies

In terms of competencies, we found that in all four cases the main actors are focused strongly on reducing uncertainties within the scope of the individual MaaS trial, rather than on more open innovation, discovery, and adaptation. This finding is not surprising, as it is a common response to uncertainty in decision making that is described in other empirical studies (Van 't Klooster & Veenman, 2021; Zandvoort et al., 2019). To elaborate on these findings, we found that uncertainty is perceived by actors as a project risk that endangers the continuation of the trial and can be mitigated by a more explicit division of roles, clearer contract management and explicit data agreements. This so-called 'projectification' of urban experimentation emphasizes 'delivery and implementation, strict monitoring of quantifiable outputs, and the expectation of efficient operations in a controllable and cost-efficient manner' (Torrens & von Wirth, 2021, p. 9). Interviewees indicated that they had the intention to experiment in an open way to develop MaaS, but this was based upon the early hype promises that had to be materialized in real life. The promise of MaaS was then translated narrowly in the case context as a project, and during the MaaS trials actors tried to fit that concept into existing public-private settings and agreements. This finding is in contrast with Dolmans et al. (2023), who studied a Dutch single smart city case from a collaborative innovation perspective. They found that high levels of uncertainty led to a large solution space, which made actors less bound to their own institutional logics. This difference might be explained by actors having different attitudes towards uncertainty (either embracing, positive or reducing, negative). Based on our four cases, we see a dominant response to uncertainty towards short-term project management (which includes reducing uncertainties as risks), instead of a long-term response to uncertainty based on embracing and playing with uncertainties of organizations and design of the innovation itself (Pot et al., 2019). It is hypothesized that this pattern can be explained by a mix of uncertainty avoidance of actors (also put forward by Zandvoort et al., 2019 and Van Asselt et al., 2010), the focus on accountability and short-term results, as well as the trial goals of MaaS that were concerned with travel behavior rather than institutional and governance settings.

We see a project-based management strategy of uncertainty in all MaaS trials. Choosing that strategy might make sense for actors involved to accommodate uncertainty, monitoring it closely and having a possibility to put a stop to the project once it feels too uncertain. However, when looking at the level of newness and hence the uncertainty level in the public-private cooperation, a more open approach would make more sense. Changing the approach seems hard though, even by well-intentioned public and private players who are involved in innovative trials.

5.2. Governance settings

In terms of governance settings between the Rhineland and Anglo-Saxon model, several key differences were important in

explaining the role of uncertainty in the MaaS trials. Beforehand we expected that in the Anglo-Saxon model the uncertain market coordination process would occur through competitive design and survival, whereas in the Rhineland model uncertainty would be shared between public and private actors, through coordinative design and support. The empirical findings indeed demonstrate that especially with the Odin Pass trial in Brisbane, policymakers were focused on defining adaptive standards and regulations during the trial so that the market will reorder based on these local standards. This corresponds with what Dewulf and Biesbroek (2018) call a go-alone adaptation strategy to deal with institutional uncertainty. Practically, this means that managing uncertainty of MaaS becomes a process of benchmarking and monitoring travel behavior through innovations that are introduced to the system by market players. The bigger system and design uncertainties of which innovations to develop with what type of technology are left with the market. In the Dutch context, the MaaS trials were indeed exemplars of the high interwovenness of public and private actors as part of the Rhineland model. Correspondingly, actors displayed concerted strategies of dealing with institutional uncertainty, in multi-actor negotiations as proposed by Dewulf and Biesbroek (2018). Dutch actors were already highly entrenched in existing institutional agreements of public transport concessions and policies regarding shared vehicles. Consequently, this resulted in more uncertainty because MaaS pilots pushed for changes in public-private relations that were already deeply institutionalized. The trials were too short and too narrowly defined to resolve these uncertainties, but they are mentioned as learning points in the evaluation documents or framed as new research questions. This means that such uncertainties are delegated to future research, experiments and trials, a pattern that is also mentioned by Van Asselt et al. (2010).

With other implementation trials of MaaS, like in Amstelland Meerlanden in the Netherlands or Birmingham in the UK (see Hirschhorn et al., 2019), we see far greater allignment between the existing governance of mobility and a chosen MaaS implementation. This leads to relatively swift implementations, as actors did not have to consider the tension between the existing governance structure and the MaaS implementation requirements. However, in the trials analysed in our paper, lack of alignment between a possible MaaS solution and the existing governance structure seems to have increased levels of uncertainty for those involved.

5.3. Relating our findings to different schools of thought on decision making under uncertainty

How can the results of this paper be positioned between other schools of thought that look into uncertainty and decision-making? In our view, many schools assume a singular system ontology for which uncertainty needs to be managed through system analysis. As stated in the introduction, DMDU aims to support decision-making with (mathematical) model-based tools and approaches (Marchu et al., 2019). Transition theory also applies an analytical perspective to understand the evolution of socio-technical systems (Köhler et al., 2019). In addition to the analytical schools, there are also actor-oriented schools that focus on the plurality of actor perspectives on systems, and how individual experiences and group interactions play a role in the management of uncertainty through decision-making in specific contexts (Klijn & Koppenjan, 2016; Machiels et al., 2023). This paper can serve as a cross-fertilizer for both types of schools, as we think that both the analytical and actor approaches are necessary and relevant for studying and intervening in existing systems and practices. The methodological focus of this paper on individual competencies and governance settings of decision-making unpacks relevant behavioural aspects for modelling approaches in the DMDU world. The focus of this paper on the connection between multiple governance settings and questions regarding the design of a future transport system is relevant for individual and group-dynamic schools of decision-making, as they can benefit from our findings to design (behavioural) interventions that have a system impact.

5.4. Role of expected futures

Although this paper has not explicitly incorporated the role of expected futures in the applied framework, we did notice throughout the interviews that positive expectations played a performative role in overcoming key uncertainties in the trial beginnings (Konrad & Böhle, 2019). The positive expectations towards MaaS with both governments, market actors and scientists – constituting a triple hype helix – took a lot of uncertainty away and led to the development of trial arenas in which such expectations were shared and strengthened (Alvial-Palavicino & Konrad, 2019). Consequently, positive expectations helped to create legitimacy to move on with the mobility innovation trial (van Oers et al., 2020). Then, throughout the trials, more work than expected was necessary to get a MaaS app online in the first place and, secondly, to institutionalize MaaS in the existing system of complex public-private relationships. This meant that negative project-specific expectations translated into generalized expectations about the MaaS technology, which translated into overarching expectations or frames about the role of MaaS in transport (Van Lente et al., 2013).

5.5. Limitations

The focus of this paper was on conditions structuring decision-making under uncertainty and not on the types of uncertainty and strategies for dealing with uncertainty, as they are described in Akse et al. (2023). Therefore, we did not go into a categorization of cognitive and normative uncertainties experienced by actors as described in literature (Brugnach et al., 2008; Dewulf & Biesbroek, 2018). Also, in the interviews we did not start with an uncertainty typology that is proposed by Walker et al. (2003) or Kwakkel et al. (2010). This was a deliberate choice, because we wanted to elicit the actor-dependent experience of uncertainty, in the form of tension and insecurity. To stay as close as possible to real-world decision-making under uncertainty, we started from the interpretation of uncertainty by the interviewee. The choice for Mobility as a Service as innovation-to-compare might have steered the interview conversations towards process and governance issues, as this transport innovation is about governance and public-private

relationships instead of more technical innovations or natural (water) systems (as for example studied by Zandvoort et al., 2019). Therefore, less attention was given in this paper to long-term system uncertainty and corresponding management strategies. Another limitation was that we only focused on trials that came to a trial phase. This means that our analyzed trials have been 'successful' in terms of coming to initial agreements with actors. However, there are probably many other trials that have not made it this far in the experimental phase. The consequence of this case study selection bias is that interviewees can refer to elements they managed well, instead of focusing on a broader set of uncertainties that might have been relevant in other contexts.

5.6. Further research possibilities

So, how do competencies and settings together lead to innovation outcomes? It is not the case that either specific uncertainty competencies or specific governance settings have led to a specific choice in the decision-making process. Rather, making a choice under uncertainty is shaped by the innovation-specific toolbox of competencies and settings which are layered and interrelated. For example, in the Heijendaal case, a lack of blueprints standards to organize the MaaS trial in combination with a lack of alignment of actors' interests and narratives led to the checking of contracts and formal agreements made. With the Sydney case, some mobility providers were not allowed to join the trial because of their lack of technical capability and different data standards. So, because of an actor's expectation (competency) about standards (setting), a specific choice was made to mitigate future uncertainties regarding the MaaS collaboration scheme. Finding broader patterns and mechanisms of competencies and governance settings, interrelated with expected futures of actors, requires more research within and beyond the transport field.

It is the question which type of governance model better suits ensuring long-term and systematic change of the transport system in a sustainable direction. Future research could execute an ex-post analysis of the Anglo-Saxon and Rhineland governance settings, to analyze the impact of each of the governance models on the further development of innovations and its role in the transition towards a sustainable transport system. Further research can also investigate the existence of different mechanisms with 'failed' innovations that structure decision-making processes under uncertainty, as well as with actors who are more uncertainty avoidant.

Developing and training higher-level uncertainty competencies in future research can be a step forward in two ways to deal with uncertainties on a governance level. Firstly, improving actors' competencies can stimulate to join innovation experiments despite big uncertainties because actors get more tools to understand uncertainty. Secondly, existing collaborations for innovations can be improved by letting actors experience how to handle uncertainty in multiple ways. By making the role of uncertainty explicit and visible in innovation processes and transitions, more sustainable innovations might pass the valley of death beyond an experimental trial phase. Regarding the second aim of this paper about understanding DMDU methodologies in practice, we see action-based research as a step forward to experiment and play with governance scenarios by focusing on collaboration forms and responsibilities. Serious game methodologies can enhance the modelling approaches that are dominant in current DMDU methodologies (Marchu et al., 2019).

6. Conclusion

Current approaches in decision-making under uncertainty tend to overlook real-word decision-making practices (Bevan, 2022; Stanton & Roelich, 2021). Comprehending the factors that influence decision-making in uncertain circumstances can aid in creating transformative change (Rauws, 2017). Therefore, we have given body to the empirical practices of uncertainty management by tracing both uncertainty competencies and governance settings in Dutch and Australian MaaS trials. We found that many uncertainties for creating a MaaS ecosystem remain unresolved. In terms of competencies, actors understood uncertainties as risks, and focused on reducing uncertainties within the scope of the individual MaaS trial through project management approaches. This response to uncertainty was reinforced by deeply institutionalized governance settings in the form of existing public-private relations, transport policies and contracts. Based on this exploratory multiple case study, we derive that mobility innovation trials can be good at resolving uncertainties on a project level, but full implementation requires (1) broader experimentation forms that include a more positive mindset towards uncertainty and (2) playing with future collaboration forms in terms of actor responsibilities and legislative configurations. Testing and experimenting with scenarios of alternative transport systems and governance forms via serious game approaches can be a fruitful way for improving uncertainty management in practice that is constructive for establishing a sustainable transition of the transport system.

CRediT authorship contribution statement

Declaration of Competing Interest

The authors declare that they do not have competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix: Overview of data sources

Case	Type	Affiliation	Date
MaaS Heijendaal	Interview	Province	12-4-2022
	Interview	Project manager	12-4-2022
	Interview	University	15-2-2022
	Interview	MaaS operator	20-4-2022
	Interview	Municipality	21-4-2022
	Document	Assignment to project manager	
	Presentation	In-between evaluation	
	Presentation	Evaluation of stakeholder conversations	
Eindhoven MaaS trial	Interview	Ministry of Infrastructure and Water Management	18-1-2023
	Interview	Municipality	12-5-2023
	Interview	Shared vehicle operator	12-5-2023
	Interview	Local businesses	01-06-2023
	Document	Project brochure	
	Document	Evaluation report	
	Document	Dutch MaaS approach	
Sydney MaaS trial	Interview	IAG MaaS-broker	01-11-2022
	Interview	University	29-09-2022
	Interview	University	07-10-2022
	Interview	iMove funder	11-10-2022
	Document	Project brochure	
	Document	Final evaluation	
Odin Pass trial	Interview	Department of Transport and Main Roads (TMR)	05-10-2022
	Interview	Department of Transport and Main Roads (TMR)	06-10-2022
	Interview	MaaS operator	07-11-2022
	Interview	Shared vehicle operator	18-11-2022
	Interview	University	05-10-2022

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