Prioritising Congestion Mitigation Agents

An Institutional Analysis of Contract Negotiations for Implementing a New Queue Management Approach in the Dutch Distribution Grid

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by

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ENEXIS GROEP

Preface

I am pleased to present this final work, which marks the end of my MSc in Complex Systems Engineering and Management at the Delft University of Technology. This thesis not only represents an academic endeavour but also reflects the invaluable support and guidance I have received throughout this journey.

I would like to extend my gratitude to Dirk Kuiken and the teams Regulering and Innovatie & Ontwikkeling at Enexis for their support and the opportunity to engage with a real-world challenge. Dirk's availability and expertise were of great help in navigating the complexities of the industry. I am grateful to my first supervisor, Dr. Ir. Rudi Hakvoort, whose sharp observations and engaging discussions enriched my understanding and approach. Rudi's assistance in facilitating my graduation project with the company was crucial and much appreciated. I am also grateful to Dr. Aad Correljé, my second supervisor and chair, who provided expert advice on research methodologies and offered different perspectives that enhanced the depth and quality of my work.

Last, my heartfelt thanks to my family and friends, whose support and motivation have been my backbone throughout this academic pursuit. Your encouragement has been a source of strength. Thank you all for your contributions to this final academic endeavour.

As a fitting reflection on our times of grid congestion, I leave you with a line from Dire Straits' "Telegraph Road", a song that accompanied me frequently throughout this journey:

"And my radio says tonight it's gonna freeze, people driving home from the factories. There's six lanes of traffic, three lanes moving slow."

Karel van Eerde

Utrecht, August, 2024

Executive Summary

The Dutch electricity grid faces significant congestion due to increased renewable energy sources and rising electrification of consumption, leading to long queues for grid connections. The ACM has introduced a queue management approach prioritising market parties based on societal value, with the highest priority given to Congestion Mitigation Agents (CMAs). CMAs are parties to which the allocation of transport capacity results in an increase in the available transport capacity. The research explores how DSOs can negotiate conditions with CMAs to ensure they increase the available transport capacity for other users. The Institutional Analysis and Development (IAD) framework is adopted to analyse the contract negotiations and to examine the interactions and outcomes of these negotiations, depending on grid congestion conditions, (financial) considerations, regulatory context and stakeholder attitudes. Data collection and analysis involved interviews with DSO and industry experts, data analysis of transport capacity usage during grid congestion and a review of regulations. The following research question is answered:

How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?

The physical and material conditions affecting the contract negotiations were analysed to find characteristics of grid congestion and CMAs. Two types of goods are exchanged between the DSO and CMA, namely transport capacity and the service congestion mitigation. Transport capacity in a non-congested grid shares characteristics with common-pool resources, but in congested areas, it takes on characteristics of private goods due to excludability. Congestion mitigation services (CMS) share properties with club goods, characterised by excludability and non-rivalry. The different types of CMAs that were distinguished are: CMA-f for feed-in congestion and CMA-c for consumption congestion. Additionally, CMAs can be new entrants in the grid or existing connections with firm transport capacity contracts. The unpredictable and localised nature of grid congestion complicates the negotiation process for CMAs. To address these physical characteristics in the outcomes of the contract negotiations, scenarios are created based on congestion severity, predictability and grid level.

The attributes of the stakeholders involved affect their behaviour in the negotiations, Part of these attributes are based on financial considerations. For DSOs, capital expenditures include network investments for grid extension and reinforcement, while operational expenditures cover maintenance, system charges, electricity losses and ancillary services. Their revenue comes from connection and transport fees. CMAs incur costs from connection fees, transport costs (fixed, energy-based and peak power charges) and operational costs specific to their business model. Revenue for CMAs primarily comes from their regular operations, with additional income from providing CMS, which is crucial for financial viability. The grid's transport cost structure charges users based on usage, potentially misaligning incentives as consumers might reduce grid stress without financial benefit, while in-feeders could increase it without incurring costs. Market parties offering flexible capacity face higher transport costs due to peak usage charges, likely increasing costs passed back to the DSO in remuneration bids. Other attributes are based on experiences with battery technology. The unpredictability of battery en-

ergy storage systems complicates DSOs' planning for grid stability and congestion mitigation. DSOs must contract more flexibility to manage potential battery behaviours, increasing costs. Timing and coordination with electricity markets add complexity and effective communication between DSOs and market parties is crucial. To assess the evaluative criteria for CMA implementation include fairness, ensuring equitable treatment of all parties; sustainability, evaluating environmental impacts; and grid stability, assessing the overall stability of the grid.

Based on the current contracts available, four variables are determined for contract negotiations between the DSO and CMAs. These variables are the terms that are negotiated in the contract. The choices include the power and duration of the Congestion Mitigation Service (CMS) provided by the CMA, the level of certainty about when congestion mitigation is required (Availability Precision), the timing between the request for congestion mitigation and its actual provision (Coordination of Activation), and the amount and duration of transport capacity the CMA receives for business operations outside congestion peaks (TCO). It's important to note that the remuneration the DSO pays for the congestion mitigation service is not among the negotiable choices but is determined by supply and demand.

Contract Negotiation

The critical action situation for managing grid congestion involves contract negotiations between the DSO and market parties (potential CMAs). These negotiations establish the conditions under which CMAs provide congestion mitigation services in exchange for priority grid connections, balancing both participants' needs within the regulatory framework. This action situation is nested within different institutional levels, analysed using Williamson's four-layer framework, ranging from the ACM code act at the institutional environment level to individual transactions and resource allocation as the contract execution.

The interactions in contract negotiations involve internal motivations, where the DSO seeks grid stability and revenue maximisation through transport costs, while market parties aim to maximise profits with minimal congestion. In terms of choice preferences, the DSO prefers more congestion mitigation, low precision and real-time coordination, while market parties favour more transport capacity to use for their own business case, high precision and early coordination. Interdependencies highlight the competition inherent in the use of transport capacity for the CMA's own operations and for providing congestion mitigation. Also, information asymmetry favouring the DSO and the DSO's risk aversion play a role in potential negotiation challenges.

The outcomes of contract negotiations are influenced by the types of market parties, supply and demand dynamics and transport costs. Existing firm contracts and new entrants require different contract formations, with existing connections often being more cost-effective CMAs. High congestion and long queues increase CMA demand and remuneration, while low congestion and short queues have the opposite effect. The structure of transport costs create discrepancies in CMA supply, with new entrants facing higher costs for feed-in congestion. Existing connections requiring no additional investment demand lower remuneration and therefore are likely represented more often as CMA as opposed to new entrants. Higher congestion duration decreases CMA supply due to deteriorating business cases and technological and financial limitations affect CMAs' ability to participate in real-time coordination, potentially excluding specific technologies.

Evaluation

The evaluation of CMAs on fairness, sustainability and grid stability reveals several issues. Fairness

concerns arise from the cost advantages of existing connections and the exclusion of certain technologies due to real-time activation constraints, potentially leading to unequal treatment among technologies. Sustainability is affected by a bias towards existing connections, limiting opportunities for integrating newer, more sustainable technologies. Grid stability is challenged by the trade-off between minimising risk and maximising CMS provision, leading to higher costs and potentially reduced CMS effectiveness. The study's limitations include a lack of empirical data, assumptions about grid congestion's dynamic nature, exclusion of certain stakeholders like CSPs and oversimplification of real-world scenarios, including the role of the TSO. Future research should explore how the DSO can optimise social welfare through the CMA implementation and how TSO-DSO coordination can be improved. Policy recommendations include simplifying existing flexibility mechanisms, allowing multiple CMAs to collaborate, reforming transport cost structures and improving information transparency to build trust and reduce unpredictability.

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Nomenclature

DSO - Distribution System Operator

ACM - Dutch Consumer and Market Authority (in Dutch: Autoriteit Consument & Markt)

RES - Renewable Energy Sources

FCFS - First come first served

CMA - Congestion Mitigation Agent (in Dutch: congestie-verzachter)

CMA-f - Congestion Mitigation Agent for mitigating feed-in congestion

CMA-c - Congestion Mitigation Agent for mitigating consumption congestion

CMS - Congestion Mitigation Service

TCO - Transport Capacity Outside of (congestion) peaks

CBC - Capacity Limiting Contract (in Dutch: capaciteitsbeperkingscontract)

1 Introduction

Climate change, a global challenge, necessitates comprehensive international cooperation and action. The Paris Agreement, along with similar international treaties, signifies a global consensus on the urgent need to significantly reduce greenhouse gas emissions and limit global warming to no more than 2 degrees Celsius above pre-industrial levels (UNFCCC, 2015). As the world rallies to meet these ambitious goals, each nation faces unique challenges in adapting their infrastructure and energy policies. The Netherlands has set its own emission reduction targets in the Dutch Klimaatakkoord, aiming to reduce greenhouse gas emissions by 55% in 2030 compared to 1990 levels ("Wijziging van de Klimaatwet", 2022). To pursue these goals, the Dutch government has set ambitious targets for RES integration consisting of 120 TWh electricity in its 2030 energy mix (Ministerie van Economische Zaken en Klimaat, 2019). However, rapid integration of RES, while critical for sustainability, worsens grid congestion issues. The Dutch association for grid operators publishes the current level of grid congestion on a daily basis, as shown in figure 1.1.

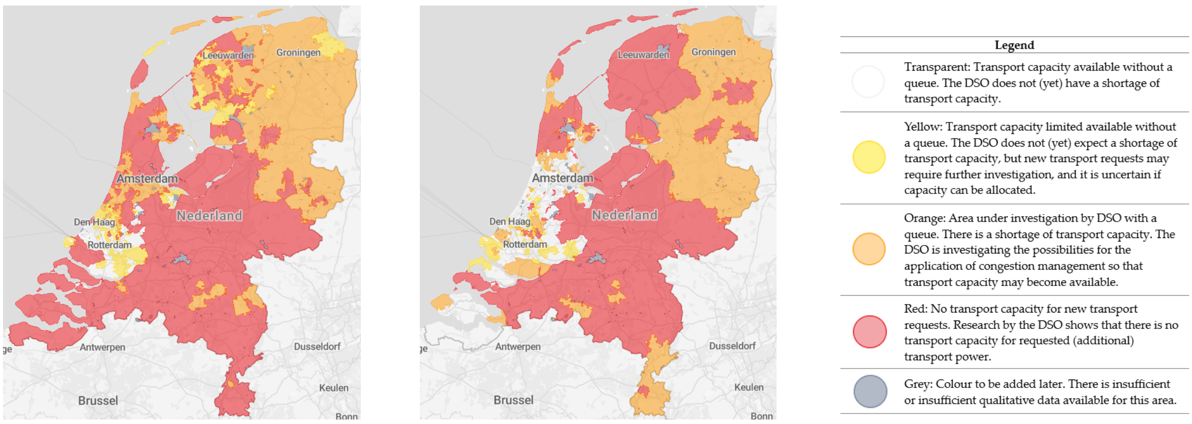

Figure 1.1: Grid congestion heatmap of the Netherlands, with the consumption congestion on the left and feed-in congestion in the middle, updated August 3, 2024, source: Netbeheer Nederland https://capaciteitskaart.netbeheernederland.nl/

The electricity grid in the Netherlands is experiencing significant congestion due to the growing integration of renewable energy sources (RES) and increasing electrification. The capacity of the current grid infrastructure is being stretched by the variable nature of RES, such as wind and solar power. Additionally, distributed energy resources, such as rooftop solar panels and small-scale battery storage, go against the centralised nature of the Dutch energy system, threatening reliability of the grid (Wolsink, 2020). Another related development due to climate change and the policy goals to shift away from fossil fuels is the electrification. The increased adoption of electric mobility and the use of electricity as the primary power source in industry increase overall electricity demand, thereby worsening the strain on the grid from the demand perspective (Damianakis et al., 2023). The increased feed-in of RES and increased demand for electricity require a higher capacity of the electricity grid. Grid reinforcements are not able to keep up due to long time horizons and issues with labour shortages and building permits due to nitrogen emissions (Laan, 2023). This grid congestion manifests most acutely in extensive queue for grid connections, shown in pressing reports and news item. The Distribution System Operator (DSO) Enexis reports that despite achieving a record in expanding the electricity grid, they cannot keep up with the growing demand (Enexis Groep, 2024). On February 21, 2024, it was announced that there are 9,400 connection requests for off-take and 10,000 in the queue for feed-in in the electricity grid across the Netherlands (Netbeheer Nederland, 2024b).

To handle these increasing queues, solutions need not be limited to physical infrastructure but can also involve adjustments to the regulatory framework, so that transport capacity can be allocated more efficiently. As of March 2024, the Dutch Consumer and Market Authority 'Autoriteit Consument & Markt' (ACM) has published several code acts consisting of measures aimed at mitigating the impact of grid congestion (ACM, 2024a). These measures range from enabling grid operators to offer non-firm transport capacity contracts and time-based transport capacity contracts to allowing the reclamation of unused transport capacity. Another innovative approach includes prioritising new connection requests based on societal importance.

Originally, grid operators managed the queues of new connections based on a 'first come, first serve' principle. While straightforward and compliant with the European non-discrimination principle, this method does not account for the broader societal impacts when critical services such as hospitals or public safety facilities are delayed in obtaining connections with the grid.

The code act, called 'prioriteringsruimte transportverzoeken' proposed by the ACM, allows the prioritisation of certain grid connection requests, specifically targeting three categories:

1. Congestion Mitigation Agent (CMA)[1]
2. Safety
3. Basic needs

1.1. Congestion Mitigation Agent

The first category receives the highest priority and is the focus of this thesis. The ACM has created the following definition for a Congestion Mitigation Agent: A party for which the grid operator determines that the allocation of transport capacity to this party results in an increase in the available transport capacity for other parties and does not result in an increase in congestion in the network of another grid operator. It is up to the DSO to implement the new queue management approach and to decide how to qualify parties for prioritisation and to negotiate under what conditions these parties can be prioritised onto the grid (ACM, 2024c).

The responsibilities of the DSO include managing grid stability and processing all connection requests,

[1] In Dutch: congestie-verzachter

as outlined in Article 16 of the electricity law (1998). The ACM has introduced the CMA as a solution for this challenge. If implemented effectively, prioritising market parties on the congested grid as CMA can assist the DSO in handling and connecting more requests without causing additional congestion. However to achieve this, it is essential that the DSO prioritises parties that are technically capable to do this. Once the technical capability of the market party to provide the congestion mitigation service (CMS) has been confirmed, the DSO and the market party must establish agreements regarding the party's behaviour within the grid. Without such conditions, the party might act in its own interest, potentially increasing congestion. After successfully negotiating the behaviour of the market party, the party will receive the grid connection it applied for initially (in the regular queue), along with the established agreements governing its behaviour (ACM, 2024c).

1.2. Research Endeavour

The question arises: how can the DSO negotiate these conditions with the market party to ensure it creates transport capacity for other parties to enter the grid? And, how can this be achieved cost-effectively while avoiding additional grid congestion for other grid operators and maintaining the DSO's own grid stability? This research aims to shed a light on this problem of negotiations between the DSO and the market party that applies to be prioritised onto the grid as a CMA. Beyond the practical interest for the DSO to better understand the negotiation process for this new form of queue management, there exists a knowledge gap in the academic field regarding alternatives to the conventional first-come, first-served approach, as discussed in Chapter 2. While various solutions for distribution grid congestion have been explored, the specific area concerning the prioritisation of grid connections remains under-examined in academic literature.

To discover how to define and implement the queue management method to prioritise connection requests, the following research question will be addressed:

How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?

1.3. Complex Systems Engineering of a Novel Queue Management Approach

Grid congestion is a complex issue within the electrical power system, resulting from the interdependencies between technical infrastructure and social institutions. The energy infrastructure can be viewed as a socio-technical system, where technical and social elements interact in mutually influential ways (Sovacool, 2006). Grid congestion in the distribution grid, for example, results from the interplay among various actors such as the ACM, DSO and grid users and technical factors like renewable energy generators and the grid itself. The evolution of these systems over time can be seen in the decentralisation of power generation and the increasing penetration of renewable energy sources, contributing significantly to current grid congestion challenges. Institutional changes within these socio-technical systems, such as the introduction of a new queue management system, represent efforts to shape and adapt to these challenges. Given the interdependencies inherent in socio-technical systems, a systems engineering approach is crucial to address grid congestion effectively. This approach ensures that newly designed institutions, such as the novel queue management approach, aligns closely with existing institutions to enhance their effectiveness (Bots, 2007). The research design employed in this thesis acknowledges this complexity and aims to integrate the diverse social and technical aspects involved.

1.4. Thesis Structure

This thesis examines contract negotiations between DSOs and future CMAs to assess their impact on managing grid congestion in the Dutch distribution grid. The structure begins with Chapter 2, which provides background on congestion management and flexibility in the Dutch distribution grid, reviews academic literature on queue management approaches and identifies knowledge gaps. It concludes with an analysis of the ACM Code Act 'prioriteringsruimte transportverzoeken', setting the foundation for the thesis. Chapter 3 outlines the methodology with the introduction of the Institutional Analysis and Development framework and the data collection and analysis methods. Chapter 4 analyses physical and material conditions through congestion data analysis, providing insights into distribution grid congestion. It explores how these conditions shape CMAs and develops scenarios that influence the negotiation process Chapter 5 explores financial considerations and stakeholder perspectives regarding the issue. This analysis examines how stakeholder attributes and operational dynamics influence negotiation outcomes and establish evaluative criteria. Chapter 6 examines the existing contracts available, setting the foundation to define the negotiation space, elements of the action situation and the rules-in-use governing DSO-CMA contract negotiations. Chapter 7 identifies how contract negotiations are positioned institutionally within the Williamson framework. It then analyses the action situation of contract negotiations to uncover the interactions and outcomes based on the findings from previous chapters. Chapter 8 evaluates these outcomes using evaluative criteria to address the main research question, discussing findings, reflecting on limitations and offering policy recommendations and future research avenues, thereby concluding the thesis.

2

Background & Literature

First, an overview of the state of the Dutch electricity grid, including congestion and congestion management practices, is provided. Next, the literature on queue management approaches used in liberalised electricity systems is examined to identify a knowledge gap. Last, the newly proposed version of the novel queue management approach focused on the Congestion Mitigation Agent is analysed in detail, forming the foundation for the subsequent analysis in this thesis.

2.1. Electricity Grid

The electricity grid exemplifies a network infrastructure characterised by monopoly properties, primarily due to high sunk costs. To foster market liberalisation and competition, the EU has passed various energy legislation to stimulate the unbundling of the energy sector, since 1996 (Brunekreeft, 2015). The EU Directive 2003/54 mandates the liberalisation European energy markets, establishing unbundling requirements for the separation of market activities. The Dutch implementation of this unbundling was initiated in multiple phases, separating grid management from commercial activities. This liberalisation of the transmission and distribution grid established TenneT as the state-owned transmission system operator (TSO) for high-voltage grids. In 2008, the process was further expanded to unbundle medium- and low-voltage grids, creating distribution system operators (DSOs) for their management and ownership (Tanrisever et al., 2015).

In Figure 2.1, the electricity system of the Netherlands is visualised, illustrating both the economic and physical layers. The physical layer includes the generation of electricity by producers in the economic layer, its transmission by the TSO TenneT, distribution by the DSO, and consumption by end-users. Small consumers receive electricity through retail channels, while large consumers obtain it directly from the market. The market comprises the EPEX SPOT power exchange, the bilateral market, the balancing mechanism, and import and export capacity allocation, the latter two being executed by the TSO.

According to Knops, De Vries & Correljé (2004), there are three levels in which rules are determined. The highest level is the law called Elektricteitswet 1998, which entails the basic rules. Second, the conditions for the electricity grid are determined in the ’netcode elektriciteit’, focused on the functioning

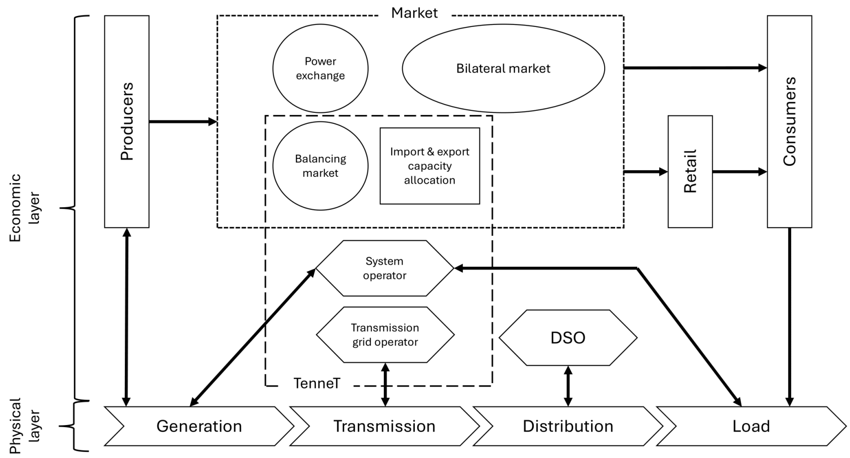

Figure 2.1: Dutch electricity system with economic and physical layer, adapted from (Knops et al., 2004)

of the grids, new connections and the transmission of electricity over the grids (ACM, 2016). Last, on an individual basis, agreements can be made within contracts between the grid operator and the user of the grid (Knops et al., 2004).

2.2. Congestion Issues and Solutions

As explained in the introduction, grid congestion has become an increasingly important issue. Grid congestion occurs when there's a risk of exceeding the grid's capacity, leading to potential current or voltage violations that can harm infrastructure and appliances (Buis, 2023). At its core, the issue involves the simultaneity factor (SF), which predicts that not all users will demand maximum power simultaneously. However, increasing peak loads and changes in power generation and consumption patterns, such as higher usage of electric vehicles and solar panels, can strain the grid beyond its designed capacity, risking congestion and necessitating careful management by grid operators to prevent outages and maintain grid stability.

Existing approaches to grid congestion can be separated into roughly two categories: Changing the grid or changing the load in the grid (Hirth & Glismann, 2018). In practice, the first approach is executed in the long term in constructing the grid capacity, while the second approach of changing the load of the system has recently been an increasing practice for DSOs. Hadush and Meeus (2018) discuss a shift from the traditional fit and forget approach—wherein transport capacity was simply allocated based on existing infrastructure without ongoing adjustments—to a more dynamic strategy where DSOs proactively manage the grid. Originally, under the fit and forget model, once transport capacity commitments were made, no further management or optimisation was conducted, assuming the grid's capabilities would remain sufficient over time. In contrast, DSOs are now exploring more active grid management strategies, primarily through congestion mitigation but also via innovative practices like flexibility solutions, to enhance grid efficiency and connect more users.

2.2.1. Congestion Management and Flexibility

There are different forms of congestion management, which can be categorised into technical or non-technical methods. The non-technical methods can be subdivided into market based and non-market based methods (Gumpu et al., 2019). One of the market based methods is congestion management based on redispatch. This is the most commonly applied version in which a generator that is upstream will be signalled by the grid operator to reduce its output (constrained-off), decreasing congestion in the grid. Simultaneously, a generator downstream will be asked to increase its output (constrained-on). The net amount of electricity produced therefore has not changed. To facilitate that these generators are constrained-on and off, a market is created that allows these generators to make offers to be constrained-on or bids to be constrained-off (Hakvoort et al., 2009; van Blijswijk & de Vries, 2012). In the Netherlands this form of redispatch has been implemented to facilitate congestion management (van Blijswijk & de Vries, 2012). The market platform, the Grid Operator Platform for Congestion Solutions (GOPACS), has been developed alongside a market organised by TenneT for large-scale connections (de Kok, 2023). GOPACS harnesses market flexibility to facilitate redispatching. Participants engage in trading by placing buy and sell orders on the existing electricity market. GOPACS evaluates these unmatched orders to determine if they can effectively alleviate congestion without introducing additional complications elsewhere in the network.

According to Beckstedde and Meeus (2023), flexibility can be sourced in two manners, namely mandatory or voluntary. Mandatory flexibility happens if net operators would set requirements for grid connections or by solely offering non-firm transport capacity. Similarly, but in voluntary manner, the user would be able to choose for a non-firm connection instead of a firm connection agreement. Another voluntary solution to source flexibility is through flexibility markets.

Recently, these forms of flexibility sourcing have been implemented in practice in the Netherlands. With the publication of several code acts by the ACM on April 18, 2024 the Dutch DSOs are able to offer non-firm transport capacity contracts and private grids are obliged to cooperate in congestion management. Additionally, the ACM is working on more possibilities to source flexibility for DSOs, such as alternative transport rights. This is where large connections are agree to use their transport capacity solely in the off-peak hours and in return they receive a discount on their grid costs (ACM, 2024a).

Other possibilities for flexibility in terms of contracts with the DSO have also been implemented recently. These are the *capacity reduction contract*[1] and *redispatch bid obligation contract*[2]. With the capacity reduction contract, if there is anticipated congestion on the electricity grid, the involved party has a standing agreement with the DSO to refrain from using a specified portion of their transport capacity, whether for feed-in or take-off. In the event of projected grid congestion, the DSO will notify the party at least one day in advance. The party is then required to confirm and comply by not utilising the agreed-upon portion of their capacity during the specified time. In terms of compensation, the party is entitled to a continuous availability fee regardless of activation and a restriction fee is paid if the capacity reduction is implemented. This ensures that grid stability is maintained without resorting to more drastic measures. (Enexis, n.d.-b). With the redispatch bid obligation contract, parties are bound to respond to potential grid congestion by offering their flexible capacity when the DSO calls for it. If a situation arises where congestion is anticipated, the DSO will issue a request through the GOPACS trading platform. Contract holders must then submit a bid based on the terms outlined in their agreement, specifying the amount of transport capacity they can provide and the time block during which adjustments will be

[1] capaciteitsbeperkingscontract als flexoplossing | Enexis Netbeheer
[2] Biedplichtcontract voor redispatch als flexoplossing | Enexis Netbeheer

made. Successful bids result in the parties adjusting their capacity at the designated times as agreed. For their participation, contract holders receive a fixed monthly availability fee, regardless of activation and a performance fee for each instance their bid is accepted and their capacity is utilised to manage congestion effectively (Enexis, n.d.-a).

2.2.2. DSO-TSO coordination

According to Hadush & Meeus (2018), grid congestion issues have made the cooperation between the TSO and DSO an increasingly important issue. First, the procurement of flexibility services might create possible mismatches between the actions of DSOs and TSOs, as these flexibility services might also be used for balancing, voltage control or congestion management (Beckstedde & Meeus, 2023; Hadush & Meeus, 2018). Second, the DSOs are no longer using the conventional fit and forget approach and design their grid capacity in different manners, through flexible contracts and congestion management in order to facilitate new grid connections (Hadush & Meeus, 2018). A consequence is that the DSO and TSO might negatively impact each other's grid when flexible resources are used. Especially closer to real-time this becomes crucial and thus the need for coordination mechanisms becomes important (Beckstedde & Meeus, 2023). Hadush and Meeus (2018) also mention the use of the 'traffic light' for coordination, in which the DSO determines the state of the grid: green signals a normal system state where available grid capacity is allocated through fit and forget or congestion pricing and there is no congestion; orange system state signals congestion and flexibility services as redispatchment of electricity to mitigate actual failure of the grid; red system state signals that redispatch capacity is either not available or is not sufficient, in this situation curtailment is the only option. Even though grid congestion is an issue on both the transmission and distribution grid, this thesis focuses on the distribution level from the perspective of the DSO. Thus, the focus is on the distribution grid, but as is explained later on, congestion issues on the transmission grid also play a role on the distribution level. Therefore, the coordination between the DSO and TSO has to be taken into account.

2.3. Queue Management Approaches

In an uncongested grid the allocation of transport capacity to connection requests is done following the first come first served principle in the Netherlands (ACM, 2024c). A study commissioned by the Swedish Energy Market Inspectorate has looked into the approach to grid connection queues in European countries and found similarities in terms of the prioritisation on the first come first served principle that is used in Germany, Great Britain, Denmark, Italy, Finland, Norway and Sweden itself (Energimarknadsinspektionen, 2020).

Similarities to the Dutch grid congestion issues and subsequent connection queues can be found internationally. UK, one of the first countries to experience congestion in the distribution grids have published a 3-point plan to deal with their long connection queue, which includes the implementation of milestones in the connection procedure to make sure that 'shovel ready' projects will be connected first; the coordination between the transmission and distribution grids are being coordinated with more transparency and cooperation; and battery storage operators will be provided with non-firm connections (Energy Networks Association, 2023). According to the study commission by the Swedish Energy Market Inspectorate, there has been one instance where the UK has proposed a different prioritisation method to prioritise flexibility providers. This approach would allow those whose connections can enable additional connections without further reinforcement to move up the queue, dependent on network confirmation that such connections would indeed alleviate network constraints, potentially facilitated by a specific contract ensuring constraint alleviation. The approach has not been found in further references or policy in the UK. Italy is the only country that has actually diverted from the regular first come first served principle using an 'open season' approach, where for a longer period of time connection applications were collected, after which they were investigated and an optimal combination of applications were contracted, focusing on efficiency, minimising costs and network interruptions (Energimarknadsinspektionen, 2020).

In academic literature, an alternative queue management system is proposed in a recent study focused on optimising the capacity allocation through the Pareto principle (Rova, 2023). This study deviates from the first come first served principle by optimising a combination of connection requests through clustering. A recent study by Pavlov (2024) examined the new queue management system implemented by the ACM, which includes the Congestion Mitigation Agent as one of its categories. This study specifically analysed the social prioritisation aspects of the system, utilising distributive justice theory to explore its implications. It must be noted that this approach assumed the social prioritisation in an early stage form which has been adjusted and improved into the definitive version as analysed in this thesis. The study identifies fairness of distribution of benefits and costs as a metric and shows that non-prioritised parties experience increasing psychological and financial uncertainty resulting from the technical impact that transport capacity is unavailable for these parties.

According to Rova (2023), the scarcity of academic literature on queue management approaches is likely due to historical conditions. Historically, grid operators have encountered minimal congestion issues, diminishing the perceived need for alternative approaches. With the increasing concerns for grid congestion nationally and internationally, there is a shift towards this area of research on how to allocate transport capacity more efficiently, as shown in different recent reports and news articles (Energimarknadsinspektionen, 2020; Energy Networks Association, 2023; Tang, 2024). The Dutch version of this is social prioritisation approach published the ACM code act 'prioriteringsruimte transportverzoeken', introducing different groups of grid users that are allowed prioritisation under different circumstances, among which the highest priority is given to CMAs (ACM, 2024c).

2.4. ACM's code act in Details

This section provides a detailed analysis of the published code act 'prioriteringsruimte transportverzoeken'. As previously noted, this regulation establishes three categories of parties eligible for prioritisation. However, this thesis focuses exclusively on the category accorded the highest priority, which is the primary subject of this section.

The ACM's introduction of a new queue management method represents an addition to the traditional first come first served principle with a prioritisation framework that addresses grid congestion through strategic allocation of transport capacity. This shift is necessitated by the growing queues for connection requests, particularly in congestion-prone areas, mandating that grid operators prioritise transport requests that significantly enhance public and societal benefits. This framework is designed to optimise the distribution of scarce transport capacity during peak times, thereby aligning with broader public and societal interests. The prioritisation process distinctly favours CMAs as the highest priority, as they can play a crucial role in enhancing transport capacity, followed by other prioritised parties before addressing the regular queue.

The following definition is translated from the ACM code act (ACM, 2024c): a CMA is a party for which the grid operator determines, based on the most up-to-date data possible from Appendix 14, first paragraph (1), that the allocation of transport capacity to this party results in an increase in the available transport capacity, as referred to in Article 9.5, fourth paragraph (2), for other parties and does not result in an increase in congestion in the grid of another grid operator. This definition refers to two sections from the *netcode elektriciteit*, namely:

1. Appendix 14, first paragraph: This refers to the data used in technical analysis for the mandatory grid congestion reports. These are reports that are published when in a certain grid area, there is a forecast that shows that grid congestion is likely to occur in the future. This is the first action that is made in the process of congestion management after the announcement that there will be likely grid congestion in this area (ACM, 2016).
2. Article 9.5, fourth paragraph: This refers to the definition of available transport capacity, which can be translated as: The available transport capacity is the part of the existing transport capacity that is not used to meet the required transport capacity and is equal to the difference between the existing transport capacity and the required transport capacity (ACM, 2016).

To qualify as a CMA, a market party must meet specific criteria through a two-step process: first, the DSO must confirm that the party aligns with the ACM's definition of a CMA; second, the party must forge contractual agreements with the grid operator to operate according to the established definition of a CMA. This thesis focuses on the second step, wherein the contract negotiations occur. These negotiations are crucial as they bind the future CMA to behaviours that actively mitigate congestion, thereby assisting the DSO in reducing grid congestion and maintaining grid stability.

Moreover, the DSO is obligated to apply prioritisation in areas affected by congestion, and a party seeking prioritisation must have already submitted a request for transport capacity. Additionally, the grid operator is required to process all prioritisation requests without a designated time limit. In situations where congestion affects multiple grid operators, a shared queue is established by both TSOs and DSOs, who then prioritise based on this queue. The grid operator might receive multiple requests for prioritisation; these are handled on a first come first served basis according to the date of the request, meaning that no prioritisation is possible within the CMA category itself. The DSO evaluates whether the CMA can create additional available transport capacity for other parties based on the flexibility offered and the technical analysis from congestion reports. If prioritisation requests for a certain area exceed 25% of the total queue, the grid operator must notify the ACM. Together, they decide whether to temporarily pause prioritisation and determine further actions. If a party granted priority as a CMA does not comply with the agreements made with the DSO or submits false documents, the transport capacity granted to that party will be revoked immediately.

In conclusion, this section has delineated the ACM's prioritisation framework for CMAs, as a shift from FCFS queue management to a strategic allocation of transport capacity in congestion areas. The roles, definitions and obligations of CMAs and DSOs are now established, providing the starting conditions for this research endeavour to discover the impact of this new queue management approach

3 Methodology

This chapter describes the research approach taken for this thesis. First, the approach is formulated as a coordination problem, the theoretical framework is introduced and subsequently the research is structured through the use of four sub-questions. Last, a detailed step-by-step explanation of the research process is given in which the data collection and analysis is explained.

3.1. Negotiation Process as a Coordination Problem

In previous chapters, the problem of grid congestion and the resulting increasing queues for grid connections were introduced. A novel queue management approach focused on prioritising CMAs was proposed as one of the solutions. This thesis focuses on implementing this different queue management approach. With the roles, definitions, and obligations of CMAs and DSOs now established, the groundwork is set for exploring the impact of this new queue management strategy.

Initially, the research approach was aimed to define a robust set of criteria to which market parties would have to adhere to be able to receive prioritisation as a CMA. However, during the first round of interviews, it became clear that there was insufficient data to support the development of robust criteria. The main reason for this is that there is no experience with a different way of handling the queue. Instead, a different approach was taken, based on other interview findings. The interviews revealed that the primary issues that were to be expected were related to the negotiation process between the DSO and potential CMAs (Interviews A, B, E). Therefore, in the starting phase of the research, the approach shifted from an optimisation problem (defining criteria) to a coordination problem (negotiation process).

This shift in focus aligns with a research approach similar to De Bruijne et al. (2011), in which the problem was identified as a wicked problem due to complexities which were visible in the opposing opinions of stakeholders. The conflicting opinions of stakeholders regarding the use of the CMA, as discussed in Chapter 5 and the broader complexity of grid congestion within the larger socio-technical system, show a similar complexity in this research. Consequently, the research approach transitioned from an optimisation problem to a coordination problem.

Following the focus on the negotiation process between the DSO and CMA, the main research question is:

How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?

3.2. Institutional Analysis and Development (IAD) Framework

To address the complexity of implementing the new role of CMA, an institutional perspective is chosen. Specifically, the IAD framework, originally developed by Elinor Ostrom for analysing the use of common-pool resources, is well-suited for this analysis (Ostrom, 1994; Polski & Ostrom, 1999). The IAD framework is also applicable to network infrastructure, such as the distribution grid, as scientific literature shows that network infrastructures share key characteristics: non-excludability of resources, rivalry in the consumption of services, and the need for system coordination (Künneke & Finger, 2009). The IAD framework allows for a systematic examination of the interactions between various actors within the electricity grid system. This framework's structured approach helps in clearly identifying and evaluating the impacts of the introduction of CMAs. Its application ensures that both the existing conditions in the system and the proposed changes are thoroughly understood and assessed, making it an ideal choice for analysing the integration of new approaches in grid management. The original IAD framework is visualised in Figure 3.1. This figure shows the whole framework itself and gives a view into the action arena itself (in green). The leftmost section lists the exogenous variables: biophysical material conditions, attributes of the community and rules-in-use (the latter are specified in Figure 3.4). It must be noted that due to the original application for ecological systems of the IAD framework such as fisheries, the term 'biophysical' is used in the figure. For network infrastructures, this is however, not applicable and instead the term 'physical and material conditions' is used in this research. This is similar to the notion from Anderies, Janssen & Schlager (2016), in which Ostrom's biophysical and material conditions was used to discover "both human-made hard and natural hard infrastructure" (p. 506). The physical and material conditions, attributes of community and rules-in-use together form the exogenous variables that influence the behaviour of participants of the action arena. The action arena is the core of the framework, because here the participants engage with each other affected by the exogenous variables. The behaviour in the action arena lead to interactions between the participants corresponding to certain outcomes of the situation. These interactions and outcomes are then evaluated using specific criteria. Together, this forms a systematic way to analyse already implemented policies through an empirical analysis by going backwards through the framework, starting with the outcomes and interactions. Or it can be used to develop or analyse new policy initiatives by going through it forwards, starting from the exogenous variables, to the make educated predictions about the interactions and outcomes of the policy (Polski & Ostrom, 1999). The latter approach is what is executed in this research.

3.3. Research Approach

The different elements that are addressed in this report are visualised per chapter in Figure 3.2. The chapter numbers are indicated in the diamond shaped object at each element in the framework. In this section, the research steps are mentioned according to this figure and structured using sub-questions. Note that after this section, a more detailed explanation of each research step, including the data collection and analysis is provided. According to Polski & Ostrom (1999), the first step in policy analysis is defining the objective. In this context, the objective is to analyse the implementation of the CMA,

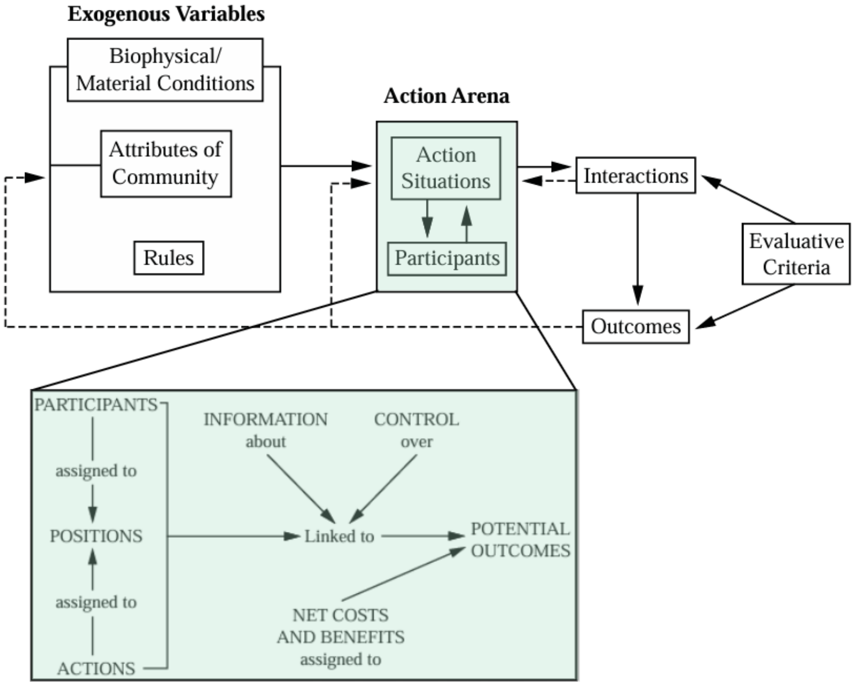

Figure 3.1: Ostrom's Institutional Analysis and Development framework with the internal elements of an action situation emphasised in green, adapted from (Ostrom, 2005)

which can be seen as the new policy initiative, through analysing the contract negotiations between the DSO and the CMA. This report is structured to systematically address the main research question: *How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?* The report is organised around four sub-questions, each corresponding to elements of the IAD framework, and their answers form the basis for understanding and evaluating the interactions and outcomes of the contract negotiations between DSOs and CMAs.

3.3.1. Chapter 4: Physical and Material Conditions

The next step involves establishing the foundation for contract negotiations by identifying the three types of exogenous variables. This part starts with the physical and material conditions, the first exogenous variable. Chapter 4 analyses the grid congestion experienced in the Dutch distribution grid to discover characteristics for CMAs. The chapter answers the following sub-question:

Sub-question 1: *What are the physical and material conditions of distribution grid congestion in the Netherlands and how do these conditions dictate characteristics for Congestion Mitigation Agents?*

3.3.2. Chapter 5: Attributes of the Community

The next step involves identifying the attributes of the community, another exogenous variable. Chapter 5 examines the attitudes and financial considerations of stakeholders, as well as how experiences with battery technology influence behaviour during contract negotiations. The evaluative criteria are based on the attributes of the problem owner, namely the DSO, and therefore discovered in this chapter as well. These evaluative criteria will be used in Chapter 8 to assess the interactions and outcomes of the negotiations. Chapter 5 answers the following sub-question:

Sub-question 2: *What are the stakeholder attributes affecting the contract negotiations and what* *evaluative criteria are needed to assess the prioritisation of Congestion Mitigation Agents?*

3.3.3. Chapter 6: Rules-in-Use and Action Situation Elements

The final exogenous variable involves examining the rules-in-use. Each of the types of rules-in-use correspond to an element of the action situation of the IAD framework. Therefore, these combiantion of rule and element are discovered simultaneously in this chapter. Chapter 6 explores the existing contracts and regulations that shape the contract negotiations, detailing how these elements interact within the action arena. The chapter answers the following sub-question:

Sub-question 3: *What rules are present in the contract negotiations between the CMA and DSO?*

3.3.4. Chapter 7: Action Situation Analysis

Chapter 7 begins by situating the action situation of contract negotiations within the Williamson framework and analysing the nestedness of these action situations. With this foundational understanding established, the chapter then explores the interactions among actors in the action arena. It addresses the following sub-question:

Sub-question 4: *How is the contract negotiation action situation positioned institutionally and what are the interactions and outcomes of the negotiation process between the DSO and potential CMA?*

3.3.5. Chapter 8: Evaluation of Interactions and Outcomes

Chapter 8 uses the evaluative criteria established in Chapter 5 to assess the interactions and outcomes of the contract negotiations. This final analysis provides an answer to the main research question by evaluating how the negotiation process influences queue management of grid congestion in the Dutch distribution grid.

3.3.6. Figure 3.2 as a Guide throughout the Report

Figure 3.2 will be presented at the start of each chapter, highlighting the specific part of the IAD framework that is analysed in that chapter. This figure serves as a visual guide to help readers understand the structure and flow of the report, ensuring clarity in the presentation of the research design and findings. What is notable in this figure is that the 'participants' element is shaded in grey. This highlights that within the contract negotiations, the participants are predetermined to be only the DSO and the market party, which is the prospective CMA.

3.4. Detailed Guide to the Research Endeavour

In this section, each step of the research process according to the IAD framework is explained in more details. Figure 3.2 provide an overview for these steps/elements of the framework. The methods for data collection and analysis are referenced throughout the steps and explained at the end of this section.

3.4.1. Establishing the foundation: Exogenous variables

In this section, an explanation is given on how the foundation for the analysis of the contract negotiation is structured according to the exogenous variables: physical and material conditions, attributes of community and rules-in-use.

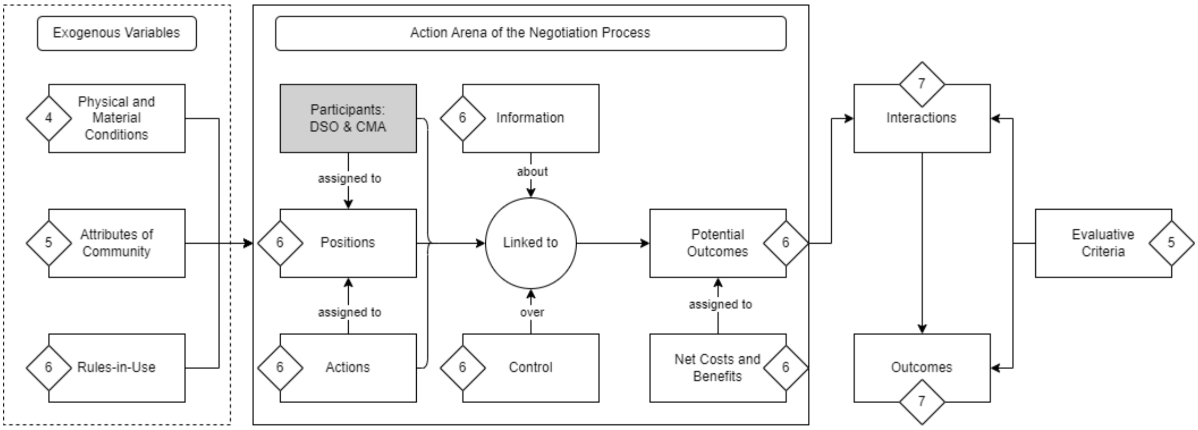

Figure 3.2: The structure of the research approach in the form of the IAD framework, with the chapter number in the diamond shaped objects.

Physical and Material Conditions - Chapter 4

The physical and material conditions encompass all physical resources related to the system being analysed. In this context, it refers to the electricity grid and energy system in the Netherlands, specifically focusing on the congestion issues within the distribution grid. These findings can all be found in Chapter 4. In this chapter, the first sub-question is answered: *What are the physical and material conditions of distribution grid congestion in the Netherlands and how do these conditions dictate characteristics for Congestion Mitigation Agents?*

The data used to answer this sub-question include congestion data to identify congestion patterns and transport capacity fluctuations over time, as well as interviews that provide information about the development of congestion and how predictions of congestion are made by the DSO. The physical and material conditions were analysed concerning the types of goods involved in contract negotiations. These goods can be classified based on two attributes from economic theory: the extent of excludability and the extent of rivalrousness, as illustrated in figure 3.3. Additionally, the physical and material conditions allowed for the distinction of CMA characteristics and the creation of scenarios. These scenarios were subsequently used to discover how different physical conditions influence the interactions and outcomes of the contract negotiations.

		Subtractability of use	
Difficulty of excluding potential beneficiaries		*Low*	*High*
	Low	Toll goods	Private goods
	High	Public goods	Common-pool resources

Figure 3.3: Types of goods, adapted from (Ostrom, 2005)

Attributes of Community - Chapter 5

The attributes of the community encompass the social and cultural contexts in which the system operates, including demographic differences, values and norms (Ostrom, 2005). Additionally, it entails the preferences and beliefs of the participants related to the actions and outcomes of the action situation (Polski & Ostrom, 1999). In this context, it includes the considerations and perceptions of the stakeholders involved in or seeking connection to the distribution grid. It is focused on deriving the preferences and the motivations of the stakeholders involved in the contract negotiations. This chapter addresses the second sub-question: *What are the stakeholder attributes affecting the contract negotiations and what evaluative criteria are needed to assess the prioritisation of Congestion Mitigation Agents?*

The main findings come from interviews about the expectations and experiences of the actors regarding contract negotiations. Additionally, the stakeholders' costs and benefits of the operations provide information on the preferences each stakeholder has in the action situation. Together these findings help to structure the actors' preferences for the outcomes of the action situation. Note that the other part of the sub-question mentioned here pertains to the evaluative criteria, which will be explained in further detail below.

Rules-in-Use - Chapter 6

According to Polski and Ostrom (1999), the rules-in-use are intrinsically linked to the internal working parts of the action situation. Therefore, in Chapter 6, the rules-in-use are defined while simultaneously identifying the different elements that constitute the action situation. The rules-in-use encompass the laws, regulations, contracts, and agreements that significantly influence the action arena (Ostrom, 2005). These rules are primarily based on the ACM code act regarding the CMA, as analysed in Chapter 2, the Dutch electricity system regulations and the currently available contracts. The findings in this chapter address the second sub-question: *What rules are present in the contract negotiations between the CMA and DSO?*

The elements of the action situation and corresponding types of rules are shown in Figure 3.4 and explained in more details here (Ostrom, 2005):

- Participants and Boundary Rules: Participants are the entities that make decisions and are linked to positions. Boundary rules stipulate who may enter or leave a position and how this is done, relating to the 'Participants' component in the action situation.
- Positions and Position Rules: Positions define the roles in which participants enter or leave, linking the action set and participants. Position rules assign these roles by linking action sets to them.
- Actions and Choice Rules: Actions are the steps participants can take within the action situation. Choice rules outline what actions must, may, or may not be taken by a participant in a given position, depending on the conditions present.
- Information and Information Rules: Information refers to what each participant knows or does not know, which is affecting the decision-making process. Information rules govern the access and authorisation of information exchange among participants.
- Control and Aggregation Rules: Control indicates the extent of control a participant has over their actions. Aggregation rules influence the degree of control participants have over their choice of actions at particular moments in the action situation.
- Costs and Benefits and Payoff Rules: Costs and benefits are the rewards or sanctions associated with certain possible outcomes of the action situation. Payoff rules define the allocation of these costs and benefits, or sanctions and rewards, resulting from actions or outcomes.
- Outcomes and Scope Rules: Outcomes are the returns from the actions made in the action situation. Scope rules delineate the spectrum of potential outcomes that may be influenced.

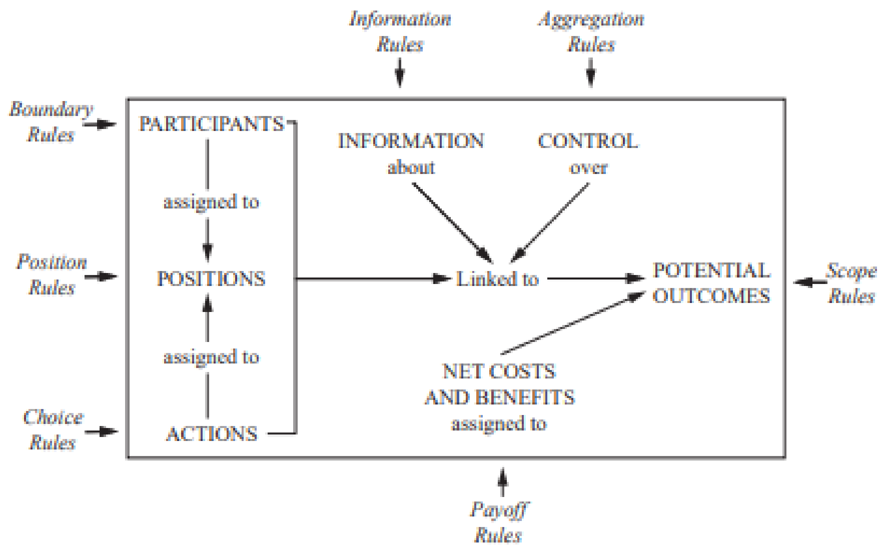

Figure 3.4: Action situation and rules as exogenous variables, adapted from (Ostrom, 2005)

3.4.2. Positioning the Action Situation

Now that the foundation of the analysis is established, the action situation itself must be specified. As explained, the interviews identified coordination problems in the implementation of the CMA. The four-layer Williamson framework was used to pinpoint critical action situations among these coordination problems and to show their nestedness at different institutional levels. This approach clarifies the inter-relation of coordination problems and their potential mutual influence (van Es, 2017). The Williamson model identifies four layers of institutions (Williamson, 1998). This framework helps to identify the levels at which the problems and institutions operate. The highest level comprises informal institutions such as norms and values. The second level encompasses the rules of the game, such as laws and regulations (e.g., EU Directives, Dutch law). The third level, likely the most critical for this analysis, pertains to contracts, which belong to the 'play of the game' institutional level. The final level is operational, where resource allocation occurs. At the start of Chapter 7, the position of the action situation is executed using the Williamson framework.

3.4.3. Inferring Interactions and Outcomes

The next step is to anticipate the interactions occurring within the action situation. These interactions shape how outcomes emerge from the action situation. As described by Ostrom (2011), in some instances, it is relatively simple to predict with certainty the interactions and thus the outcomes. However, in many situations, this is not the case. Therefore, the interactions and outcomes inferred by the institutional analysis have to be considered an assumption. This is an important consideration for this research. Nonetheless, even weaker inferences can yield significant insights into the potential workings of the policy. Specifically, if certain interactions and outcomes do not emerge, this can be an important finding in policy analysis (Ostrom, 2011).

As described by Polski & Ostrom (1999), the actions that participants take are heavily dependent on their decision-making capabilities. In this context, the following stages are identified to to systematically analyse interaction patterns:

- First, the internal motivations of each actor in light of the action situation are identified, focusing

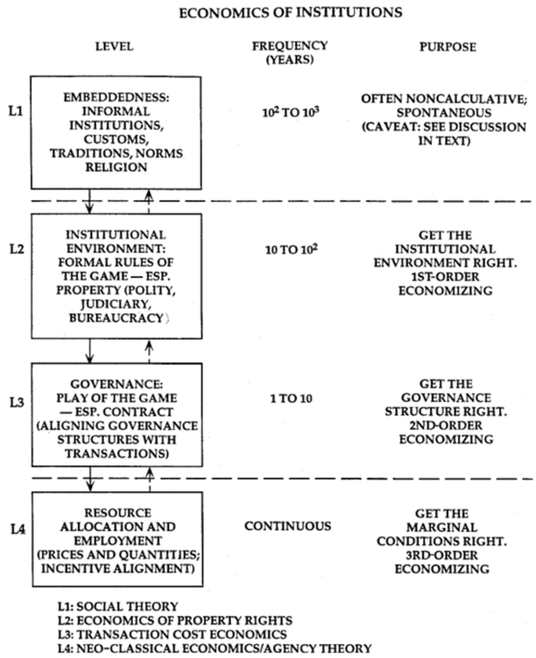

Figure 3.5: The Williamson framework with four levels of institutions, adapted from (Williamson, 1998)

on what aspects are important to the actor and what drives their decisions.

- Second, the internal considerations of the choices available to each actor are identified and compared between the participants.
- Third, the interdependencies between these choices are analysed. This stage investigates the relationships between choices, providing insights into the feasibility of certain preferences. These interdependencies are then compared with the actors' choice preferences to make inferences about participants behaviour.

These three stages provide a structured approach to inferring behaviours in contract negotiations. The inferences highlight the interactions between two actors in a single instance. Before addressing the outcomes of these interaction patterns, the effects of the scenarios defined in Chapter 4 are predicted, primarily using supply and demand principles. Using the identified interaction patterns, reasoned predictions about the likelihood of certain situations occurring can be made, resulting in different outcomes based on the characteristics, types of CMAs and scenarios.

3.4.4. Evaluating the interactions and outcomes: Evaluative Criteria

Commonly used evaluative criteria, according to Ostrom (2005), include economic efficiency, fiscal equivalence, redistribution or equity, accountability, conformance to local actors' values and sustainability. The criteria used in this analysis are provided and based on the analysis in Chapter 5. These criteria help assess the value of interactions and outcomes from the action situation (Ostrom, 2005). This final step helps structure the answer to the main research question:

How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?

The evaluative criteria are integral to the research question and are investigated in details in the analysis conducted in Chapter 5. To evaluate the performance of CMA implementation, the values of the problem owner and the reasons for prioritising CMAs are examined. The evaluation then assesses the extent to which these values are met.

3.4.5. Data Collection and Analysis

As described above, the different steps in the research include data collection and analysis. This subsection describes the data collection methods, namely interviews, congestion data analysis and desk research.

Interviews

Prior to the interviews, a submission of the research protocol was made at the Human Research Ethics Committee of the TU Delft, including a data management plan, informed consent and a risk assessment checklist to ensure the safety of the interview participants. Two rounds of interviews were conducted as part of the data collection process. The interview guides can be found in appendices A and B. The first round involved experts from the distribution system operator Enexis from different teams, that each covered a different part of the operations of the DSO that would be affected the implementation of CMAs. The goal was to conceptualise grid congestion in the distribution grid and to define criteria for the implementation of CMAs. The interviews were semi-structured, which allowed for flexibility and to pose additional questions regarding the reasoning behind the choices of the interview participants within certain criteria. This allowed the first round of interviews to also include the identification of critical areas and issues considering the process. The second round of interviews expanded to include experts from both the distribution system operator and the industry. The industry experts were found through the professional connections of the supervisor from the DSO Enexis and interview candidates from round one. The second round interviews focused on gathering insights into different perspectives of the implementation of CMAs and contract negotiations, based on potential issues that were found in the first round of interviews. This approach allowed for deeper discussions about the perspectives of the interview participants on these issues and their reasoning behind it. All interview participants are listed anonymously in table 3.1. The collected data was transcribed verbatim. The transcriptions were used to gather recurring themes, insights and correlating findings across different interviews. The analysis of the results from the first rounds interviews allowed to identify a set of issues or tensions about the implementation of CMAs. These issues were then used to structure the second round interviews and to specify the critical action situation for the IAD analysis.

Table 3.1: List of Interview Participants

Reference	Round	Company Type	Area
A	1	DSO	Asset Management
B	1	DSO	Corporate Connections
C	1	DSO	Operations
D	1	DSO	Asset Management
E	1	DSO	Corporate Connections
F	2	DSO	Innovation & Development
G	2	CSP	Management
H	2	CSP	Management

Congestion Data Analysis

This method involved gathering and analysing data from various congestion areas within the distribution system operator Enexis to identify types and patterns of congestion. The goal was to establish a comprehensive understanding of the technical aspects of grid congestion, which forms the foundation and rationale for this research. The data analysis aimed to identify congestion patterns over various time scales. The data was provided by the asset management department of Enexis and covered seven different congestion areas. It consisted of the expected transport capacity usage recorded every 15 minutes for the outlook of years 2024 to 2030. The asset management department creates its outlooks for congestion based on historical transport capacity usage, expected natural growth and anticipated future grid connections based on the queue (Interview A).

For confidentiality reasons, the specific names of the congestion areas are not disclosed. The congestion data includes the value of used transport capacity at 15-minute intervals for each year. The years analysed are future projections from 2024 to 2030. Additionally, the grid limits for these areas were retrieved from the congestion reports. The sign of the value for the limits in Table 3.2 indicates the type of congestion: a negative limit denotes the feed-in limit, while a positive value denotes the consumption limit. There is only one congestion area analysed for which there is congestion in both directions.

The analysis of the data was conducted using the Python packages pandas, numpy and matplotlib, which offer a wide range of visualisation options. Congestion was calculated by the difference between the transport capacity used and the grid limit. The focus of the analysis was to identify congestion patterns on different timescales, visualising both directions of congestion in daily, weekly, monthly and seasonal time frames. Transport capacity usage and congestion were analysed based on their duration, peaks and averages across different periods.

Table 3.2: Congestion Data Information

Congestion Area Reference	Congestion Type	Limit
A	Feed-in and consumption	-66, 74
B	Consumption	41
C	Consumption	38
D	Consumption	88
E	Feed-in	-17
F	Feed-in	-42
G	Feed-in	-42

Desk Research

The desk research focused on examining the current system and newly proposed regulations within the Dutch electricity regulatory framework. This literature review provided a understanding of the regulatory context relevant to the study and facilitated the classification of physical and material conditions. Furthermore, the desk research helped identify the rules-in-use (regulatory context), the attributes of the community and the evaluative criteria.

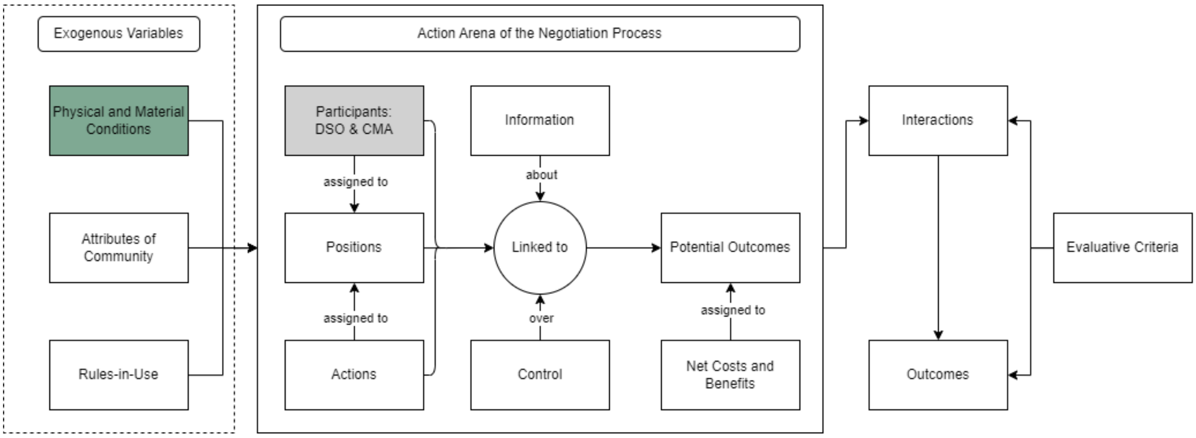

Figure 4.1: In this chapter the physical and material conditions are analysed

4

Congestion in the Distribution Grid

This chapter delves into the quantitative and qualitative aspects of grid congestion in the distribution grid. These findings are derived from desk research, data analysis and interviews, collectively forming the first exogenous variable in the IAD framework, namely the physical material conditions. This chapter collects and concludes by forming an answer to the first sub-question: *What are the physical and material conditions of distribution grid congestion in the Netherlands and how do these conditions dictate characteristics for Congestion Mitigation Agents?*

The chapter is structured as follows: First, it analyses the patterns found in the congestion data of seven different congestion areas to understand how congestion manifests in the distribution grid and the reasons behind it. Second, it defines the physical and material conditions that arise from these findings. Subsequently, it further defines the role of the CMA by identifying four types of CMA, the adjustable power characteristic and scenarios for congestion based on severity, predictability and level in the grid. Last, a chapter summary is given that summarises the main findings of this chapter.

4.1. Congestion Patterns

In Figure 4.2 and 4.3, the monthly patterns of feed-in (left) and consumption congestion (right) per hour of the day are shown for congestion area A in 2024 and 2030 respectively. The congestion value that is shown is the maximum congestion recorded and can be read using the colour scale and the size of the circle. It can be seen that feed-in congestion mainly takes place in the months February to October between 7:00 and 15:00. Consumption congestion is mostly present in the months October to March between 6:00 and 20:00. The difference between 2024 and 2030 is notable in consumption congestion, because congestion has appeared in the summer months. In feed-in congestion, the severity of the congestion has increased throughout the years, whilst the months and times of the congestion has remained quite similar between 2024 and 2030.

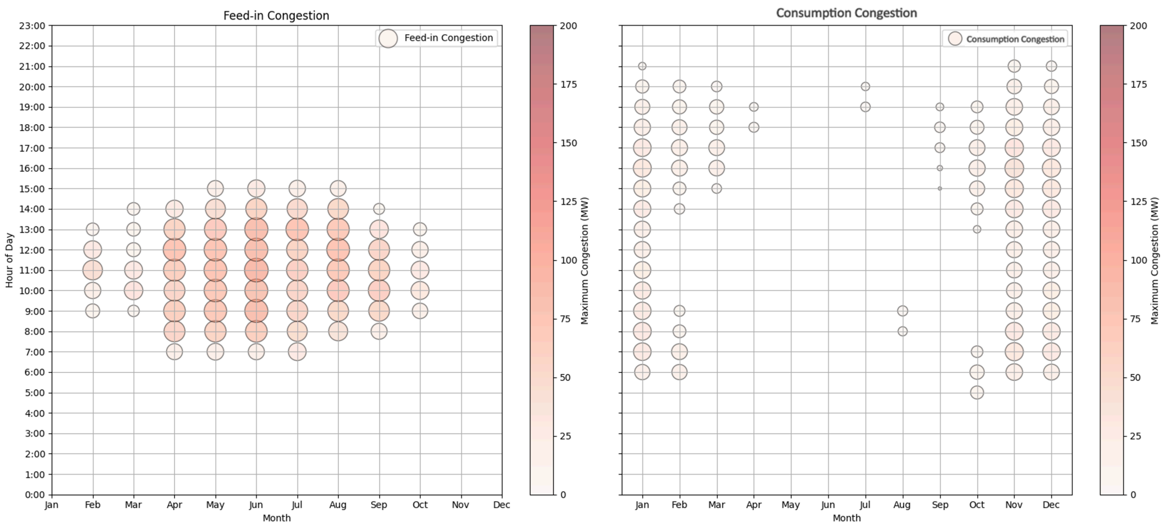

Figure 4.2: Both Types of Congestion by Month and Hour of Day for 2024 in area A

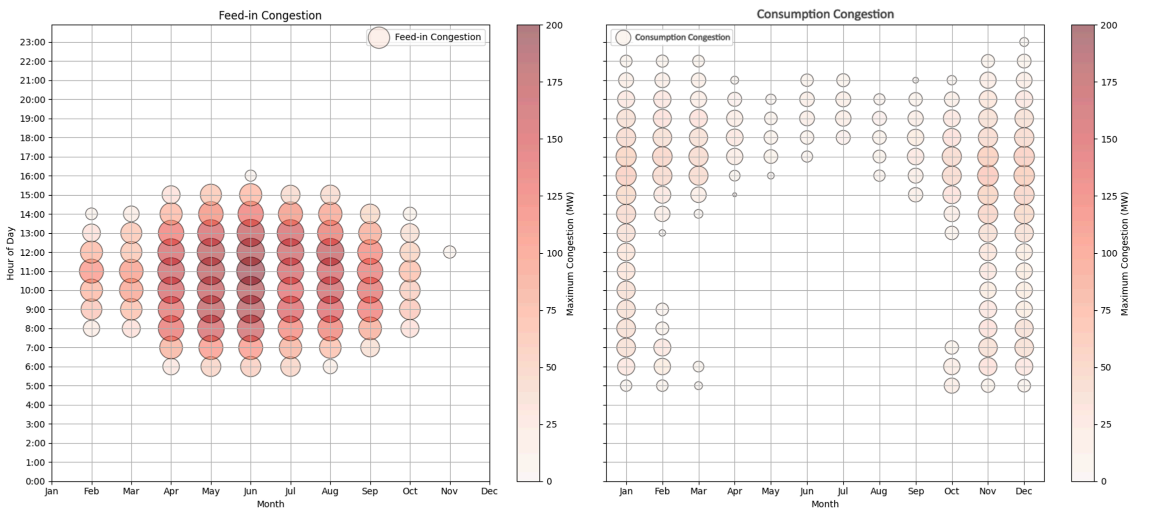

Figure 4.3: Both Types of Congestion by Month and Hour of Day for 2030 in area A

Figure 4.4, shows the accumulated congestion per day of the week that is expected in 2030 in area A. The feed-in congestion is more than twice the amount of congestion as off-take congestion. Feed-in congestion is highest on Tuesday and is notably lower on weekend days than week days. Feed-in congestion is stable around 11GWh during Mondays, Tuesdays, Wednesdays and Fridays, but lower on Thursdays and notably higher on weekend days. The other congestion areas do not experience

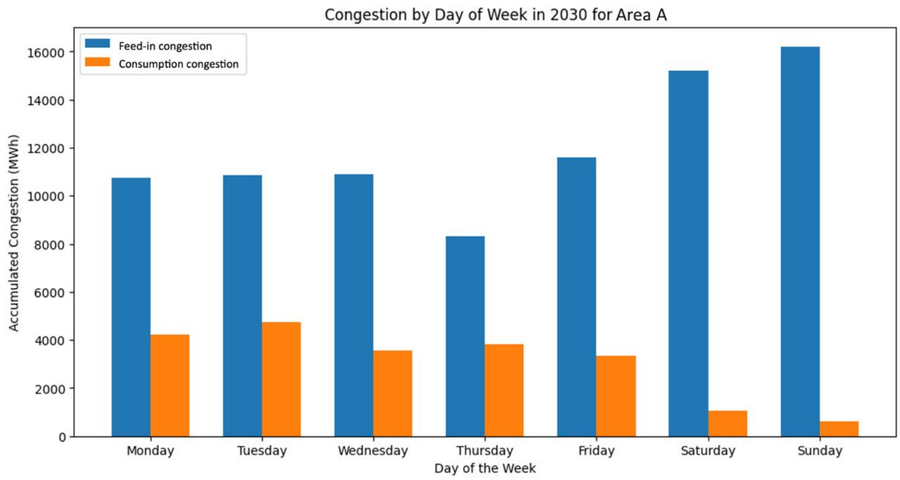

Figure 4.4: Accumulated congestion in 2030 for area A per day of the week

congestion in both directions, but only in one direction. The areas B, C and D experience consumption congestion and the areas E, F and G experience feed-in congestion. Figure 4.5 shows what values of transport capacity are predicted to occur in the different seasons in 2024 and 2030. The wider the violin, the more frequent that value is predicted. The different sides of each violin shows the values predicted in 2024 on the left and 2030 on the right side. The upper row of graphs consists of the areas that experience consumption congestion, while the lower row of graphs experience feed-in congestion. The differences per season in all graphs can be noted by the registration of higher values of transport capacity in the winter months and lower values in the summer months, corresponding to more consumption in the winter and higher feed-in in the summer. Similarly, the growth of the transport capacity between 2024 and 2030 is most notably in growth of consumption in the winter and growth of feed-in in the summer. Another notable observation is the difference in transport capacity between 2024 and 2030 across all areas, characterised by a median growth in transport capacity marked by a positive sign. This indicates an increase in consumption, even in areas experiencing feed-in congestion. These findings are consistent for area A as well. Figure 4.6 displays a similar chart for area A, showing the transport capacity per month.

Figures 4.7 and 4.8 show the frequency of congestion events for both feed-in and consumption congestion for area A in 2024 and 2030. Note that both the x-axes and y-axes do not have the same range. In general, congestion becomes more frequent and has a longer duration between 2024 and 2030 for both types of congestion. In both years, the feed-in congestion is the only form of congestion that has long periods of congestion of more than 600 minutes, whilst the off-take congestion tends to be of shorter duration. It seems that consumption congestion has increased more between 2024 and 2030 than feed-in congestion.

The growth of grid congestion in the distribution grid can be attributed to several factors. First, the transition to electrification and the increasing adoption of renewable energy sources have fundamentally altered demand and supply patterns in the grid (Interview D). Notably, different local compositions

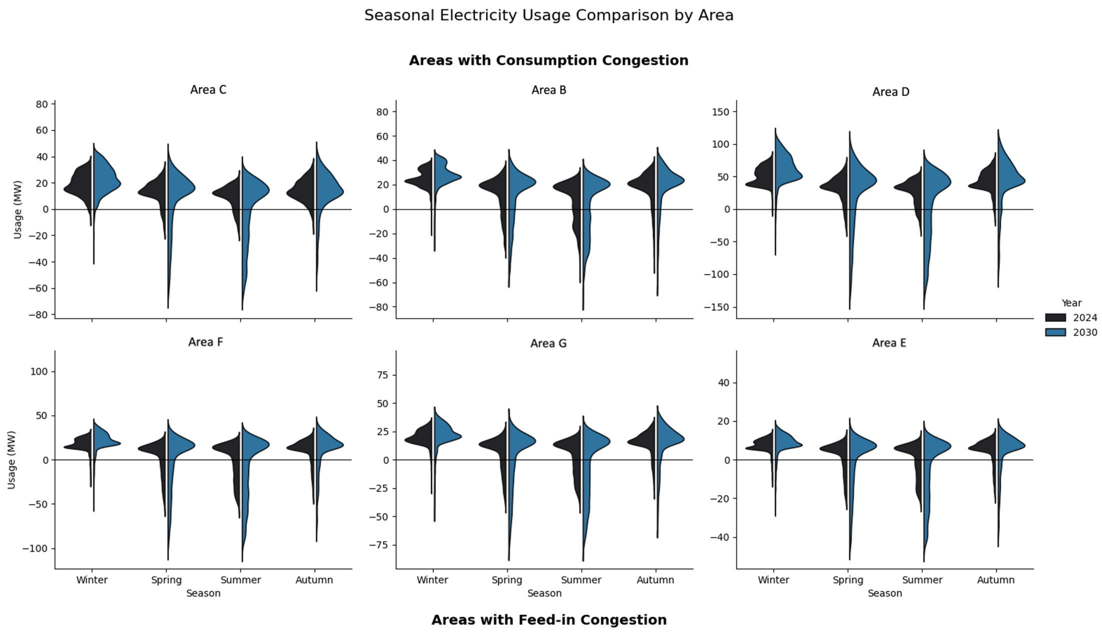

Figure 4.5: Seasonal electricity consumption and feeding-in in areas of congestion

of connections lead to varied congestion patterns; for example, rural areas may experience rapid increases in demand due to the installation of solar parks, whereas urban areas exhibit behaviour where both energy delivery and consumption rise simultaneously (Interview C). Furthermore, the infrastructure was initially tailored to specific consumption patterns, such as those of agricultural activities and not for the feed-in from renewable sources like solar parks (Interview B). Additionally, natural growth in the grid manifests in two segments: The increase in low-voltage connections driven by household adoption of electric vehicles and rooftop solar installations and the increased utilisation of existing transport capacity contracts by businesses (Interview C). The latter segment involves businesses fully using their contracted transport capacity through technologies such as electric boilers, thereby intensifying the simultaneity factor in consumption. In this context, DSOs have limited influence over these developments. Households typically operate under standardised connection sizes and businesses hold firm transport capacity contracts, which they are entitled to fully utilise as stipulated, leaving the DSO with no options to modify these arrangements if used accordingly. During the interviews, it was emphasised that there is a correlation between temperature and congestion; colder conditions invariably lead to higher energy demands (Interview A). Additionally, while congestion is undoubtedly related to energy markets, the relationship is not solely dictated by day-ahead pricing but involves a complex interplay among all energy market segments (Interview C).

4.2. Physical and Material Conditions

Here, the attributes of the physical world are examined, that form the physical and material conditions. First, the type of good being coordinated is analysed according to the classification made by (2005) and then other findings on the attributes of the physical and material world are mentioned. There are two main goods to consider: transport capacity and congestion mitigation service. Transport capacity refers to the good allocated to the CMA if they are connected to the grid under the conditions of the contractual agreements and is also the good that the CMA creates for other market parties in the queue to enter the queue. The congestion mitigation service is the other crucial good, produced by the CMA

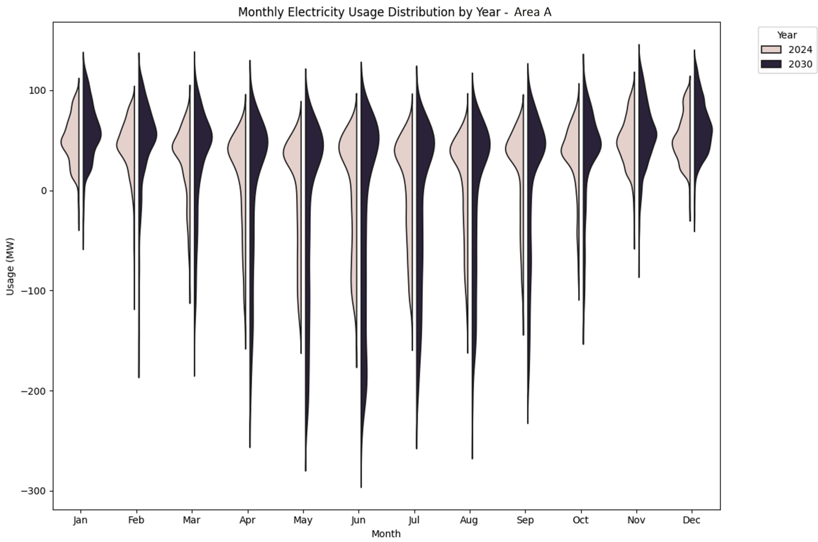

Figure 4.6: Monthly electricity consumption or feeding-in in congestion area A

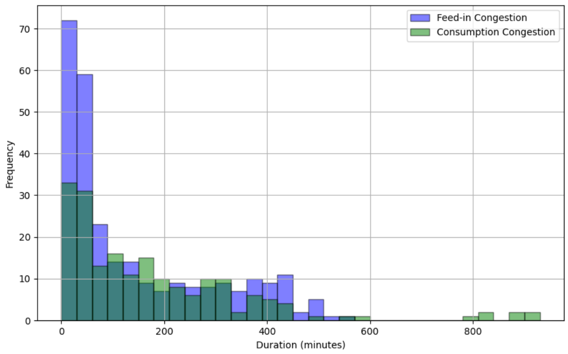

Figure 4.7: Congestion Duration Frequency for area A in 2024

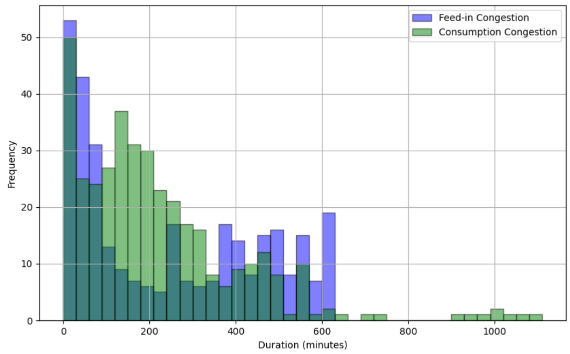

Figure 4.8: Congestion Duration Frequency for area A in 2030

and consumed by the DSO to increase transport capacity.

Transport capacity in a non-congested electricity distribution grid shares characteristics with common-pool resources (CPR) due to its characteristics of non-excludability and rivalry. Non-excludability means that it is not possible to prevent market parties from accessing the grid, because the DSO has to process and connect all users. It is rivalrous because transport capacity is limited and shared among all users. When one user draws a significant amount of power, especially during peak times, it reduces the available capacity for others, potentially leading to congestion and affecting the quality of service. However, currently not all connection requests can be processed and allocated, therefore the non-excludability characteristic does not hold anymore. Therefore, transport capacity in a congested distribution grid shares the characteristics of a private good, because it is excludable and rivalrous.

Congestion mitigation services (CMS) in the electricity distribution grid shares charactics with club goods, due to their excludability and non-rivalrous nature. Excludability means that access to provide these services can be controlled through contracts, regulatory frameworks and technological capabilities. Only entities meeting specific criteria, such as possessing the necessary infrastructure and regulatory approval, can participate in offering congestion mitigation services. Non-rivalry, on the other hand, indicates that the provision of congestion mitigation by one entity does not significantly diminish the ability of others to provide similar services. Multiple entities can offer congestion mitigation simultaneously without significantly affecting each other's effectiveness, assuming there is sufficient infrastructure and demand for such services.

Another important characteristic identified in the interviews is the unpredictable nature of grid congestion. While congestion can sometimes be predicted easily, such as during sunny or cold days when forecasts are reliable, there are occasions when it remains highly unpredictable. For instance, if a forecasted sunny day turns out to be cloudy or the other way around, this change might occur with little warning. This unpredictability poses challenges for the DSO in managing the limits of the local grid. In predictable scenarios, flexibility products can be called upon well in advance by the DSO to mitigate congestion. However, the real difficulty arises when unexpected weather changes occur shortly before real-time. This situation is further complicated by grid connections that respond intraday to these fluctuations by offering their services on the imbalance markets (Interview E). These markets are designed to stabilise the overall provision of electricity in the grid, but locally, they can cause congestion due to the unexpected use of transport capacity by parties participating in these markets. This intraday response can worsen the DSO's efforts in managing grid congestion and therefore it is important to take into account the unpredictable nature of grid congestion.

Last, an important characteristic of the distribution grid is its local nature. This means that each distribution grid covers a limited spatial area. Similar to flexibility products, this results in fewer opportunities to find suitable grid connections capable of providing congestion mitigation services (Fonteijn, 2021). Consequently, the lower supply of plausible CMAs strengthens the bargaining position of the available CMAs, leading to higher demands for remuneration of their congestion mitigation services.

4.3. Characteristics and Types of Congestion Mitigation Agents

In this section, different types of CMAs are introduced based on type of congestion and if the party already has a contract or not. Additionally, the adjustable power characteristic and the limit of transport capacity allocation to the CMA is explained.

4.3.1. CMA-c & CMA-f

This section introduces two types of CMAs: CMA-c for consumption congestion and CMA-f for feed-in congestion. CMA-c (CMA for consumption) aims to alleviate consumption congestion by enhancing transport capacity, thus enabling future participants to consume electricity from the grid. This enhancement can occur either through feeding-in electricity during instances of consumption congestion or by reducing its transport capacity utilisation under existing firm contracts. CMA-f (CMA for feeding-in) is designed to mitigate feed-in congestion by increasing transport capacity for future participants to feed electricity into the grid. This can be achieved by consuming electricity at times of feed-in congestion or by decreasing the transport capacity used, as stipulated in existing firm contracts. As depicted in simplified example situations in Figures 4.9 and 4.10, the dark blue line represents the transport capacity throughout the day without CMA intervention. Grid congestion occurs when transport capacity exceeds the grid's limit (black line). In these scenarios, the CMA intervenes to mitigate congestion, thereby creating additional available transport capacity, illustrated by the difference between the new transport capacity (light blue line) and the grid limit (black line). This additional capacity, marked by the green bar, enables new grid connections for businesses awaiting firm transport capacity. The dashed blue line shows the activity of the CMA, where a negative value indicates electricity being fed into the grid by CMA-c and a positive value indicates the reverse for CMA-f. Please note that these examples are highly simplified, ignoring safety margins of the DSO and assuming that only one CMA is contracted that consumes or produces a steady flow of electricity, while in reality it might be optimised to match the required transport capacity more precisely. This differentiation made between the two types of CMAs is technology-neutral. The idea of technology-neutral is characterised by a degree of controllable capacity that is utilised to create firm transport capacity for new grid connections or the expansion of existing ones, depending on the queue in the specific grid area. The differentiation between the two types of CMAs is technology-neutral. The concept of being technology-neutral is defined by the use of a controllable capacity to 'create' firm transport capacity for the queue.

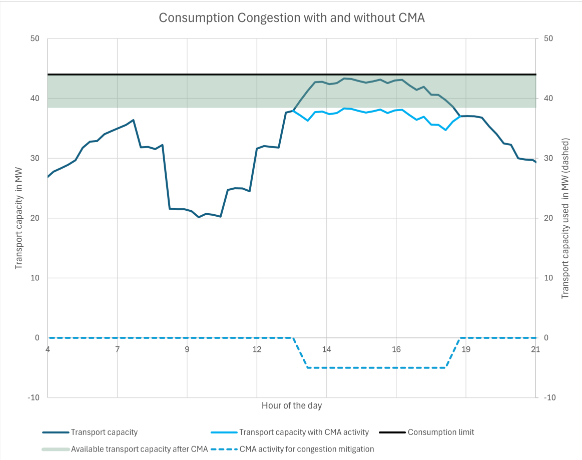

Figure 4.9: CMA-c feeding-in electricity during consumption congestion

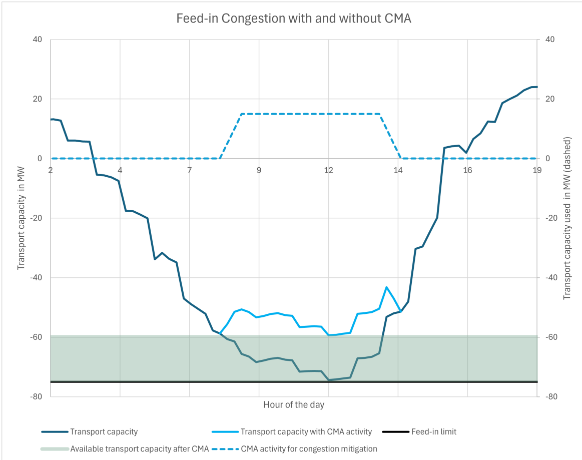

Figure 4.10: CMA-f consuming electricity during feed-in congestion

4.3.2. New entrant & existing firm contract

In a different manner, two other types of CMAs can be distinguished: new entrants that require a new grid connection and existing participants with firm transport capacity contracts. New entrants can only act as CMAs if they are capable of feeding in or consuming electricity in the opposite direction of the congestion. This straightforward approach requires the CMA to manage their electricity usage in a way that alleviates the congestion during peak times. For instance, during consumption congestion, a suitable technology would be one that can feed in energy and during feed-in congestion, a technology that can consume energy. For market participants with existing firm transport capacity contracts, there is an additional possibility. These users can also act as CMAs by limiting their own firm capacity during congestion periods. This method is logical if they seek to secure extra transport capacity outside of peak congestion times. By voluntarily reducing their firm capacity during congestion, they free up additional transport capacity, thereby helping to mitigate the congestion. Figure 4.11 illustrates this distinction: A new entrant acts as a CMA by adjusting its power usage during times of congestion between 13:00 and 19:00, while an existing connection limits its firm transport capacity to provide the necessary flexibility between 6:00 and 8:30.

To conclude from this distinction between types: a new entrant is constrained by its ability to mitigate congestion during peak times in a single direction. For instance, a new solar park cannot effectively act as a CMA because it can only feed in energy during sunny periods, which often coincide with peak congestion. On the other hand, an existing connection with firm transport capacity can adjust its usage more in both directions to alleviate congestion, providing greater flexibility and responsiveness to grid

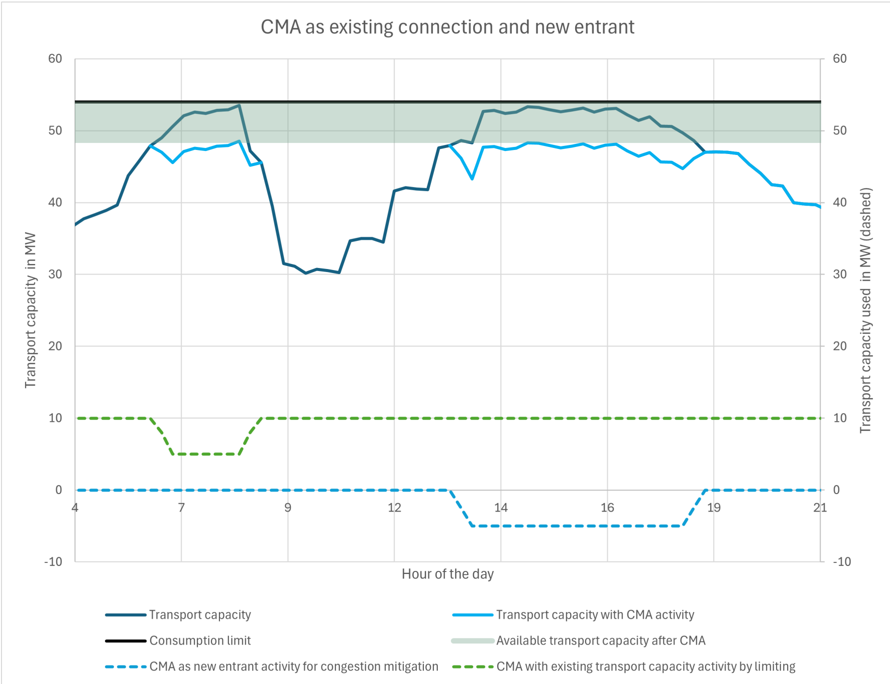

Figure 4.11: An existing connection with firm transport capacity (left) and a new entrant (right) actively mitigating congestion as CMA

demands.

4.3.3. Adjustable Power Characteristic

In this section, the characteristic of a CMA is introduced: adjustable power. This characteristic is an intrinsic characteristic for any technology utilised in congestion management and is inherently technology-neutral, meaning it applies universally across different types of assets. In the interviews, various technologies were mentioned as being particularly effective for taking on the role of CMA. Among these, batteries were frequently mentioned due to their ability to quickly respond to grid demands. However, they come with limitations regarding charging and discharging cycles and timing constraints. Batteries possess a specific depth of discharge that must be managed carefully to maintain their longevity and efficiency. Other proposed technologies include e-boilers, Combined Heat and Power (CHP) systems, data centres and electrolysers. These technologies are considered viable options as long as they are controllable and operate under appropriate contractual agreements. What these technologies have in common is their degree of adjustable power, which is the most critical characteristic for a suitable CMA. Adjustable power allows these assets to modulate their output or consumption in response to grid needs, thereby providing the necessary flexibility to alleviate congestion effectively.

4.3.4. Balance of Transport Capacity Allocation Outside of Congestion (TCO)

The allocation of transport capacity to a Congestion Mitigation Agent (CMA) outside of congestion peaks depends on the total transport capacity of the grid, and is therefore limited. This limitation is illustrated in Figure 4.12, where on the left, a smaller CMA requires no limiting in this example, and on the right, a larger CMA requires limiting (indicated by the grey area). The black line is the transport capacity levels in the grid throughout time, and the dotted line is the transport capacity levels after the implementation of the CMA. Here, the CMA is assumed to be able to consume and feed-in electricity. The green area represents the transport capacity that the CMA has received to use for its own operations and it is assumed this is used for 100%, therefore the transport capacity after the CMA integration is lower than before. The purple area is when the CMA must assist the DSO in mitigating congestion, effectively increasing the transport capacity levels. In this example, the total transport capacity is 50 MW. If a CMA is allocated 20 MW of transport capacity outside of congestion peaks (TCO), it can only fully utilise the 20 MW for a limited time because the grid load is likely to exceed 30 MW (50-20) when there are no congestion peaks. During these times, the CMA must also be limited (as indicated by the grey area). In contrast, with a 5 MW allocation of transport capacity, the instances where the grid load permits the full use of 5 MW TCO occur more frequently, thus necessitating less frequent limitations. Therefore, the higher the TCO relative to the grid's total transport capacity, the less often a CMA can fully utilise its allocated capacity outside of congestion peaks, leading to more frequent limitations. In this thesis, such limitations are assumed to be part of the Congestion Mitigation Services (CMS) provided by the CMA, due to the restriction on freely using their allocated transport capacity.

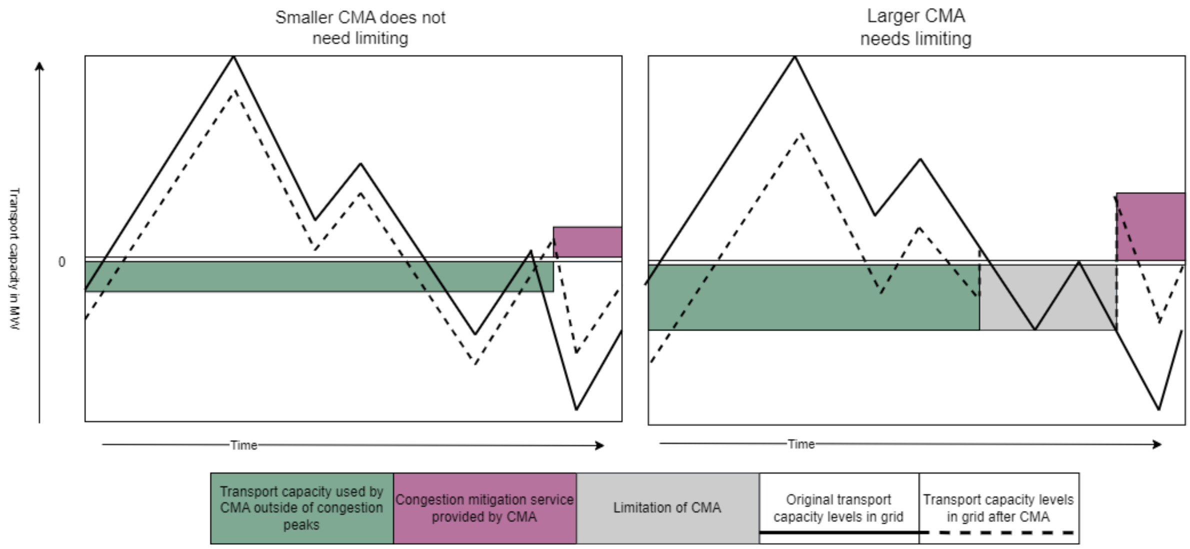

Figure 4.12: Limiting of CMAs is necessary outside of congestion peaks. The larger the CMA's transport capacity, the more limiting is necessary

4.4. Scenarios

These scenarios will be utilised in the analysis of contract negotiations between the DSO and market parties aspiring to act as CMAs to highlight how physical fluctuations in the grid influence the interactions and outcomes of these negotiations.

As discussed in the previous section, the distribution grid experiences variations in congestion predictability and severity, as seen in the physical and material conditions and congestion data analysis. Another characteristic of the distribution grid is its localised nature. Each level of the grid covers a distinct geographical region, with varying sizes of areas covered by different levels within the distribution grid.

These variations in the physical conditions of the grid and its congestion patterns necessitate a flexible approach to the behaviour of CMAs. Therefore, understanding these fluctuations is important during contract negotiations, where terms governing CMA behaviour are established.

To address the fluctuations in physical conditions, several scenarios are proposed. One scenario is based on congestion severity, where severe congestion—characterised by prolonged durations and deeper congestion levels—requires CMAs with greater power capabilities, while mild congestion, marked by shorter durations and shallower levels, demands less power from CMAs. Another scenario hinges on congestion predictability, distinguishing between unpredictable congestion, where congestion is volatile due to unforeseen variations in renewable energy sources and consumption, and predictable congestion, which features less volatility as renewable energy sources and consumption patterns can be anticipated with greater certainty. A third scenario focuses on the grid level, differentiating between a high-level grid, which covers a larger area and connects more grid users, increasing the likelihood of identifying a suitable CMA, and a low-level grid, which encompasses a smaller area with fewer grid users, presenting challenges in finding an appropriate CMA.

These scenarios will be utilised in analysing contract negotiations between the DSO and future CMAs, highlighting how physical fluctuations in the grid influence the interactions and outcomes of these negotiations.

4.5. Chapter Summary

In this chapter, the physical material conditions of the distribution grid congestion are examined. It was found that two types of goods that are important for the contract negotiations to implement CMAs are transport capacity and the service of congestion mitigation. Transport capacity in a non-congested grid shares characteristics with common-pool resources, but in congested areas, it takes on characteristics of private goods due to excludability. Congestion mitigation service shares properties with club goods, characterised by excludability and non-rivalry. A differentiation is made within the CMA based on the type of congestion they mitigate: CMA-f for feed-in congestion and CMA-c for consumption congestion. Also, CMAs can be new entrants or existing connections with firm transport capacity contracts. The congestion data analysis showed that distribution grid congestion can be unpredictable in timing and severity. Therefore scenarios are created, based on congestion severity and predictability. Another scenario is created to analyse the influence of different levels in the grid. These scenarios help to understand interactions and outcomes influenced by physical fluctuations in the grid.

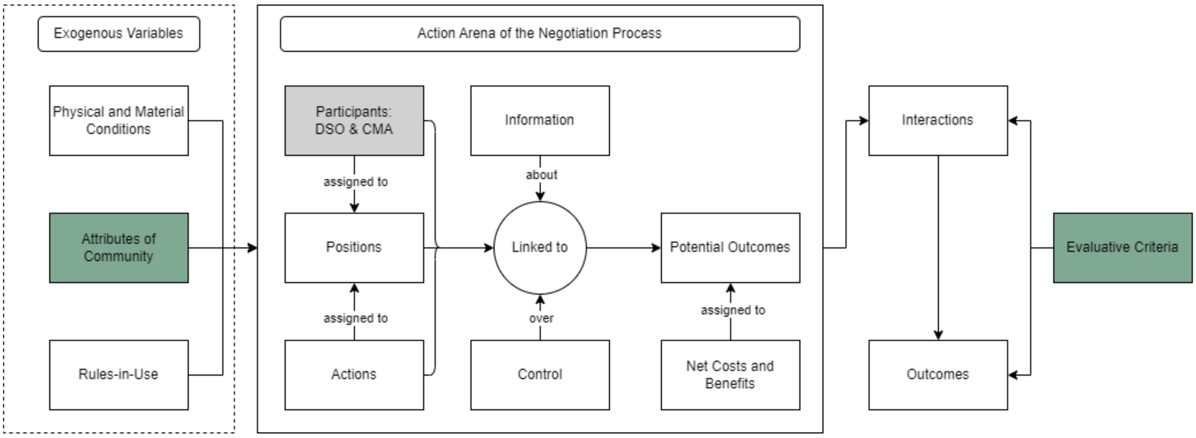

Figure 5.1: This chapter elaborates on the attributes of community and evaluative criteria

5

Stakeholder Attributes and Evaluative Criteria

This chapter is aimed at collecting and analysing the data necessary to answer the third sub-question: *What are the stakeholder attributes affecting the contract negotiations and what evaluative criteria are needed to assess the prioritisation of Congestion Mitigation Agents?*

First, the attitudes of the stakeholders DSO, market parties and the local community are explained. Second, an analysis of the cost-benefit considerations of the DSO and market party is presented. Next, the use of battery storage technology is given to illustrate the operational dynamics and timing interactions between the DSO and grid users. Last, a chapter summary is given that summarises the main findings of this chapter.

5.1. Attitude of Stakeholders

This section synthesizers the perspectives and expectations of the participants, namely the the DSO and market parties. Additionally, it analyses the local community, which is impacted by grid congestion in their area.

5.1.1. DSO

DSOs value grid stability as it is fundamental to their mandate of preventing blackouts. The increasing RES in the system complicates their operations, directly impacting grid stability. As monopolistic owners of the infrastructure, DSOs operate under strict regulation and oversight by the ACM. This is necessary because DSOs operate as distinct, for-profit companies. However, given their ownership by local and regional provinces, their operations can be influenced by the local community. They must expand the network, connecting all requests and through that generate revenue from the associated grid fees (Solat et al., 2023). In its turn, the ACM regulates how efficiently DSOs can manage the grid to curtail their potential revenue (ACM, 2012). The responsibilities that drive the DSO are articulated in Article 16, 23 and 24 of the electricity law (1998), which mandates that DSOs: operate and maintain the networks they manage; ensure the safety and reliability of the networks and the transport of electricity across them in the most effective manner; construct, repair, renew, or expand the networks, considering sustainable electricity measures, energy conservation and demand management or decentralised electricity production to mitigate the need for replacement or increased production capacity; and provide third parties with a network connection.

Interviews indicate that DSOs tend to be risk-averse and therefore putting a high importance on a predictable and stable grid (Interview F, G, H). Additionally, DSOs are prohibited from generation and trading electricity, further delineating their operational constraints (Solat et al., 2023). During interviews it was mentioned that a more facilitating attitude by DSOs could foster innovative congestion mitigation solutions that would be advantageous for both market parties and the DSO (Interview H). Currently, DSOs primarily support a variety of pilot projects; however, it is suggested that their efforts might yield greater benefits if they were more receptive to market-driven solutions, provided these are pursued under conditions that ensure shared responsibility.

5.1.2. Market Parties

Market parties emphasise the necessity of a long-term vision in regulatory frameworks to build sustainable business models, particularly stressing the need for revenue certainty as discussed earlier (Interview G). Their dependency on stable regulatory environments underpins their investment strategies in technologies and practices aimed at congestion mitigation. Market parties are inherently profit-driven and represent a heterogeneous group with varied business models. As elaborated in Chapter 4, these entities can be categorised based on their grid interaction (consumption or feeding-in) and market status (existing firms with contracts or new entrants). This diversity influences their operational tactics and their engagement in congestion mitigation efforts.

5.1.3. Local community

The local community of the congestion area is also a stakeholder due to the inherent local characteristics of the distribution grid, which primarily serves area-specific businesses and households. Although the community does not participate in the contractual discussions directly, the implications of their interests are significant when considering the deployment of CMAs. It is essential to comprehend both the scale of the distribution grid and the roles of associated governmental entities. Municipalities and provinces, acting as shareholders of the DSO, are integral to this. Their stakes in the DSO potentially shape the operator's strategies and priorities (Vanhove, 2023). Their interests may also steer the DSO's agenda (Wijk, 2019). The DSO, influenced by its shareholders who represent the local community, is likely to focus on maximising transport capacity to enhance overall welfare. Therefore, this analysis that the involvement of local governments as shareholders is expected to drive the DSO towards increasing grid connections, thereby boosting local welfare. This dynamic reinforces the community's significant impact on the DSO's operational strategies and the strategic implementation of CMAs.

5.2. Financial Considerations

This section examines the costs and benefits for the DSO and potential future CMAs in relation to their operations. It also provides an analysis of how transport costs are structured. These financial considerations are fundamental to the decisions made by participants during contract negotiations.

5.2.1. Costs and Benefits

According to van Werven & Scheepers (2005), the DSO's capital expenditure (CapEx) involves network investments for grid extension and reinforcement, such as power lines and transformers. Operational expenditure (OpEx) encompasses network maintenance, use of system charges paid to the TSO, payments for electricity losses in the grid and ancillary services. In this thesis, flexibility services, such as congestion mitigation, are considered part of ancillary services. The benefits for DSOs primarily come from connection fees and transport fees. Connection fees are the income received from establishing new grid connections. Transport fees are derived from the transport of electricity, including charges for additional grid connections and transport costs (van Werven & Scheepers, 2005).

The capital expenditure for a CMA includes the connection fee paid to the DSO for establishing the grid connection. Operational expenditure includes transportation costs, which consist of three main components: A fixed fee, an energy-based fee (unit: euro/kW/year) and a charge based on peak power per month (unit: euro/kWmax/month) (Enexis, 2024; Fonteijn, 2021). Transport costs will be analysed in more details in the next section. Additionally, CMAs have costs related to their regular business operations, which vary depending on their specific business model. As explained in chapter 4, there is a variety of technologies that can take on the role of a CMA, leading to a wide variety of businesses with different business cases. Similarly, the benefits for CMAs are largely dependent on their usual business operations. Therefore, the primary revenue stream for a CMA is based on the extent to which they can operate their original business model. However, this business model is likely to be influenced by the availability of transport capacity. A low availability of transport capacity may lead to a lower output of the original business, thereby reducing the revenue stream from business operations. However, the unique revenue stream for a CMA, distinct from other grid connections, stems from the remuneration received for providing congestion mitigation services. This remuneration is an important aspect of this analysis and will be explained in more detail in this chapter.

Given the frequent mention of batteries as suitable technology to act as CMAs during the interviews, this business model is elaborated on using the example of a stand-alone battery. The costs for a battery include investment costs as the CapEx and operational costs (OpEx) such as maintenance and the cost of electricity required to operate the battery (Weterings, 2010).

The revenue for batteries comes from arbitrage on electricity prices in day-ahead, intraday markets and imbalance trading (Nolten et al., 2017). Future contracts markets are not considered in this analysis due to their longer time periods of at least one month. Batteries also generate revenue from providing ancillary services like primary reserve (FCR), secondary reserve (aFRR) and tertiary reserve (mFRR)

(Nolten et al., 2017). These revenue streams are based on markets and services for the TSO. At the distribution grid level, batteries can earn revenue from congestion management through redispatching on the GOPACS platform. Or receive a discount on their transport costs through capacity limiting (CBC). These contracts with the DSO allow the battery to provide congestion mitigation services.

As mentioned in the interviews, batteries improve their business case by stacking multiple revenue streams (Interview G). These revenue streams have different time frames, allowing the battery to optimise its capacity across various markets and increase its overall revenue.

Table 5.1: Expenditures and Revenues of a DSO and CMA

Category	DSO	CMA
CapEx	Grid investments	Connection fee
OpEx	Grid maintenance; UoS charges to TSO; Electricity losses; ancillary services	Transport fee
Revenue	Connection fee; Transport fee	Business operations enabled by transport capacity; Congestion Mitigation Service

5.2.2. Transport Costs in More Detail

The structure of transport costs is governed by the principle of 'kostenveroorzakingsprincipe,' which means that grid users should pay proportionally to the extent they utilise the grid (ACM, 2020). According to the ACM, users pay based on the degree of transport capacity they consume. However, those who decrease the grid's transport capacity usage by feeding electricity into the grid alleviate grid stress and are thus exempt from these costs. As stipulated during interview H, this approach primarily charges consumers for transportation, while infeeders are not charged these costs, creating a potentially oversimplified application of the principle. It fails to consider scenarios where infeeders might increase grid stress or consumers might alleviate it, particularly during periods of high renewable energy production. This discrepancy highlights a fundamental misalignment between the principle's intent—to charge users based on the stress they place on the grid—and its implementation, where consumers may pay despite reducing grid stress and in-feeders might not pay even though they could be contributing to it.

Additionally, interviews with market parties reveal that there are disincentives for offering generators as flexible capacity to the DSO (Interview H). Market parties face higher transportation costs as they must pay for both the total electricity used and the peak capacity, as stipulated in the 'kW contract' and 'kW max' components of their contracts. Consequently, offering capacity to the DSO, which often results in high electricity and peak usage, leads to increased transport costs for the market party. While these costs are typically passed back to the DSO in the form of higher prices for flexibility, this reveals an intrinsic mismatch in the allocation of costs and benefits when contracting for flexible power and transport costs.

To address these issues, discussions with market parties suggest a potential reconfiguration of transportation costs towards time-based tariff structures, particularly time-of-use tariffs (Interview H). Under such a system, transport costs would be higher during peak periods when the grid is under more stress and lower during off-peak times (Fonteijn, 2021). This approach more accurately reflects the actual stress placed on the grid and aligns costs more closely with usage patterns, potentially addressing the current discrepancies in cost allocation.

5.3. Remuneration for the CMA

During the interviews, the topic of remuneration was frequently discussed, revealing various perspectives from the DSO and market parties that could serve as CMAs. As mentioned earlier, the ACM has set a financial limit for the costs of congestion management at 1.02 euros per MWh of the total electricity that can be transported with the available transport capacity in the congestion area during the designated period. The interview participants of the DSO all referred to this financial limit as a potential limit for determining the remuneration that the CMA receives.

External market parties emphasised the need for revenue certainty to ensure the feasibility and financing of CMAs (Interviews G, H). They suggested that remuneration should align with the overall revenue of the CMA's business model. One proposed method was to determine compensation based on the percentage of time a system is constrained. This would be calculated proportionally: for each hour the system is limited, a corresponding compensation agreement would be in place, similar to determining the value of an option. For example, if a battery generates a certain amount of revenue, this can be calculated on a per-megawatt-per-hour basis and for each constrained hour, the appropriate compensation would be provided. The most critical point for market parties is having certainty in terms of availability and pricing to ensure a positive business case and secure financing. The terms must be 'bankable,' meaning the availability and prices need to be established beforehand to guarantee financial viability (Interview G).

Assuming from the interview insights regarding remuneration, there is no consensus on how to approach this for CMA implementation. Therefore, the choice was made that in this thesis the remuneration is not part of the choices of the contract negotiations, but mere a sum of the terms negotiated and affected by the supply of market parties that apply as CMA or demand for CMAs by the DSO. This is explained in further details in Chapter 6.

5.3.1. Operational Dynamics - An Example with Battery Technology

This section delves into how the unpredictability of battery technology influences the operational dynamics between the DSO and battery market participants. This example serves as an experience for shaping interactions during contract negotiations.

A notable challenge identified in interviews with DSO and market party participants is the unpredictability introduced by battery technology in the grid (Interview C, E, G, H). Specifically, the DSO must consider the potential behaviours of batteries, which could range widely without operational restrictions. For instance, a 5MW battery could either consume or feed in 5MW, significantly complicating the DSO's planning for grid stability and congestion mitigation strategies (Interview E). This unpredictability necessitates that the DSO prepares by contracting more flexibility, creating more costs. In the interviews this was mentioned by both the DSO participants and the market parties as a subject that was frequently addressed in discussions between these stakeholders.

The complexity of managing battery unpredictability is worsened by the timing of battery operations. For instance, if a battery's capacity is not called upon for congestion mitigation services, it could potentially contribute to congestion, though typically it should remain neutral in such instances due to common practice of net neutral connection of batteries, unless the congestion peak is unexpected (Interview H). The synchronisation of battery operations with the different electricity markets mentioned earlier also adds to the complexity.

The complexity also shows in the communication between the DSO and market parties. Market parties require advance notice to prepare for demand spikes, but predictability issues make it challenging for the DSO to provide timely alerts. This leads to a critical point where the operational agreements need to be as specific as possible to allow market parties to build robust business cases. However, this specificity introduces risks for the DSO, especially if high availability demands from the DSO constrain the market parties' ability to profit, thus potentially driving up the prices they charge for congestion mitigation services.

This example explains the dynamics that might occur between the DSO and market parties, as identified in the interviews and it will help to predict the interdependencies between the DSO and market parties (as CMAs).

5.4. Evaluative Criteria

The DSO can be seen as the problem owner in the implementation of the ACM code act, which encompasses the prioritisation of CMAs, as the DSO is responsible for the queue management itself. As the owner of the network infrastructure, the DSO is tasked with deciding who receives grid connections and under which conditions, guided by principles of fairness and non-discrimination. Additionally, their obligations under Article 16, 23 and 24 of the electricity law mandate the management of the grid, ensuring its stability and overseeing its expansion while connecting all users. These responsibilities necessitate integrating sustainable energy generation, energy conservation and accommodating electricity demand and decentralised generation. Given these roles and responsibilities, the evaluative criteria for assessing the implementation of the CMA are:

- **Fairness**: This criterion assesses the DSO's adherence to equitable treatment among grid users and market participants, ensuring that no entity is unduly favoured or disadvantaged. Additionally, the notion of cost allocation is included in this criterion.
- **Sustainability**: This evaluates the environmental impact of the CMAs' implementation, particularly the influence on climate change. An increase in contracts favouring high-polluting technologies would be viewed negatively under this criterion.
- **Grid Stability**: This measures the impact of CMA implementation on the overall stability of the electricity grid, an essential factor in maintaining reliable energy supply and accommodating future growth and integration of renewable energy sources.

5.5. Chapter Summary

DSOs prioritise grid stability to prevent blackouts, a core aspect of their mandate. As monopolistic infrastructure owners, DSOs operate under strict ACM regulation. DSOs aim to optimise earnings through network expansion and generating revenue from grid fees. However, because they are owned by local and regional governments, their operations are influenced by factors beyond just earnings optimisation. DSOs tend to be risk-averse, valuing a predictable and stable grid. Market parties emphasise the need for a long-term regulatory vision to build sustainable business models and ensure revenue certainty. Their investment strategies in congestion mitigation rely on stable regulatory environments. As profit-driven entities, market parties have diverse business models, influencing their demands for grid interaction (consumption or feeding-in).

The stakeholders behaviour is affected by their financial considerations. For DSOs, capital expenditures include network investments for grid extension and reinforcement, while operational expenditures cover maintenance, system charges, electricity losses and ancillary services like congestion mitigation. Their revenue comes from connection and transport fees. CMAs incur costs from connection fees, transport costs (fixed, energy-based and peak power charges) and operational costs specific to their business model. Revenue for CMAs primarily comes from their regular operations, with additional income from providing CMS, which is crucial for financial viability. The grid's transport cost structure charges users based on usage, potentially misaligning incentives as consumers might reduce grid stress without financial benefit, while in-feeders could increase it without incurring costs. Market parties offering flexible capacity face higher transport costs due to peak usage charges, likely increasing costs passed back to the DSO in remuneration bids.

The unpredictability of battery technology is given as an example for the interactions between DSO and a market party operating a battery energy storage system. It complicates DSOs' planning for grid stability and congestion mitigation. In some instances, DSOs must contract more flexibility to manage potential battery behaviours, increasing costs. Timing and coordination with electricity markets add complexity and effective communication between DSOs and market parties is crucial. Specific operational agreements are needed to allow market parties to build robust business cases, balancing the DSO's need for grid stability with market parties' profitability.

The evaluative criteria that are used to assess the interactions and outcomes of the negotiation process are: fairness, assessing the treatment of parties involved and equitable cost allocation; sustainability, evaluating environmental impacts; and grid stability, assessing the overall stability of the electricity grid.

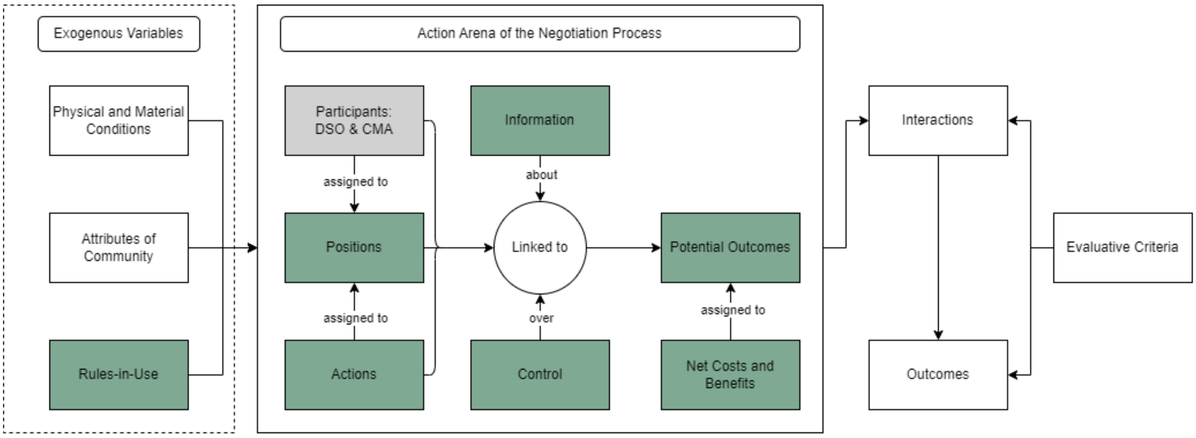

Figure 6.1: In this chapter the following parts are identified: rules-in-use and the corresponding elements of the action situation

6

Contracts, Rules-in-Use and the Elements of the Action Situation

This chapter addresses the data collection and analysis required to answer the second sub-question: *What rules are present in the contract negotiations between the CMA and DSO?* Initially, the currently available contracts are explained to establish the starting conditions for discussing each element of the action situation. Subsequently, the applicable rules-in-use for each element are identified and analysed. Last, a chapter summary is given that summarises the main findings of this chapter.

6.1. Contracts

This section examines the role of different types of contracts and their operational implications for CMAs.

6.1.1. Diversity of Contracts

Contracts in the Dutch grid can be broadly categorised into firm and non-firm types. Contracts in general can be either for consumption or for feeding-in. This means that a solar park only requires a contract for transport capacity for feeding-in, while a factory only requires a consumption contract. A battery, that wants to charge and discharge onto the grid, needs both. Firm contracts guarantee a specific transport capacity, allowing consistent grid feeding or consumption. Non-firm contracts (NFAs), on the other hand, provide flexibility without guaranteed capacity, which is beneficial during congestion as they allow dynamic grid management for the DSO. However, for market parties this is a downside, as was found in during the interviews, the original format of the NFA does not create enough certainty for developers for the financing of battery projects (Interview G). An updated version of the NFA is currently under development, which allows the DSO to give out non-firm capacity for specific time frames (ACM, 2024b). This would increase the certainty for the financing of battery projects as they can base it on the provided time frames (Oortmann, 2024). However, there is currently no experience with it and because these recent developments that are not definitive yet, the option of NFAs are not taken into account in this analysis.

A specific variant, the 'capaciteitsbeperkingscontract' (CBC, English: capacity limiting contract), is an addition to firm contracts by allowing users to voluntarily reduce their transport rights. This helps the grid operator manage congestion more predictably, avoiding the need for last-minute redispatch, which can be costly and complex. Another advantages of this contract type for the DSO is that under CBC arrangements, the DSO must notify the involved party at least a day in advance about anticipated congestion. The party must then confirm and comply by not utilising the agreed-upon portion of their capacity during the specified time (ACM, 2022). According to the ACM, the CBC offers several benefits to market parties: Remuneration for participating in the CBC offers advantages over the bid obligation contract. These include better alignment with specific business models, the absence of a need for knowledge of electricity markets due to no interaction with them, and flexible execution frequencies, such as a maximum number of times per year or seasonal agreements. Additionally, CBCs can be signed also in grids that do not currently experience congestion (ACM, 2022). The CBC contract exhibits several critical characteristics that influence both the terms of the agreement and the remuneration required by the market party. According to the ACM (2022), it is determined by:

- Activity on the connection: The economic value of the electricity is influenced by the business operations which determine how they consume or feed in electricity.
- Duration of capacity limitation: The cost associated with the duration of capacity limitations varies, which depends on the specific circumstances of the connected party.
- Frequency of capacity limitation: The pricing of each activation may be influenced by the historical and anticipated frequency of such events. Regular activations could potentially alter the cost dynamics.
- Notice period for activation of capacity limitation: Costs can escalate if the CBC allows for variability and the grid operator imposes capacity limitations at short notice, requiring rapid adjustments by the connected party.
- Time between different activations: Costs may also come from the intervals between activations, affecting the overall financial burden on the connected entity.

As these elements are important for the design of CBC contracts, they can also provide valuable components for the contract negotiations between the DSO and a future CMA.

The Bid Obligation Contract (biedplichtcontract) involves an obligation to bid for providing flexible power capacity when the grid operator requires it through the GOPACS trading platform. Contract holders must submit a bid specifying the regulatory capacity they can provide and the time block during which adjustments will be made. If the bid is accepted by the DSO, participants must adjust their power usage or generation to prevent grid overload. The financial incentives for this contract include fixed monthly compensation and a payment per accepted bid (Enexis, n.d.-a). The bid obligation contract adds a layer of responsiveness by allowing intraday adjustments, making it a responsive tool for managing unexpected congestion. The execution of the bid obligation contract also has technical implications, as the DSO has to contract another market party to increase or decrease its used transport capacity to balance the overall load on the grid, which can be costly (ACM, 2022).

Table 6.1: Requirements set out in CBC and requirements for each bid for the bid obligation for redispatch, from appendix 11 and 12 of the Dutch netcode elektriciteit

Capacity Limiting Contract (CBC)	**Bid Obligation Contract for Redispatch (for each bid)**
Maximum transport capacity	Transport capacity in MW per period
Limitation: permanent or dynamic	The direction of the transport capacity delivered
	The duration (in amounts of periods)
	The minimum amount of power that should be called upon
Price (Remuneration) in euro per MW: fixed and determined in contract	Price (Remuneration) in euro per MW: Depending on price determination of supply and demand + availability fee + need to contract other market party outside of congestion area
Contract period	
Location of connection (EAN-code)	

6.1.2. Differences Between Contracts

Table 6.1 shows the difference between the CBC and bid obligation contract. The remuneration structure for these contracts also differs. For the CBC, the price is determined bilaterally, with a fixed agreement on the compensation paid by the DSO to the market party. This provides a stable and predictable income stream. For the bid obligation contract, the price is determined through supply and demand on the GOPACS market. This introduces market dynamics into the price setting. Although, it was found in interviews that a price cap can be negotiated bilaterally, offering some level of security for the DSO to not have exceptionally high costs (Interview F). The remuneration for the bid obligation contract includes both a fixed monthly compensation for availability and a payment per accepted bid, balancing stability with performance-based incentives. The timing of these contracts significantly impacts their operational implications. The CBC requires day-ahead or bilaterally agreed notifications, providing more predictability and allowing better operational planning. In contrast, the bid obligation contract operates on an intraday basis, where bids are made and accepted within the same day, adding a level of flexibility but also increasing the risk for the market party due to the shorter notice period. A key difference is that the capacity limitation under CBC occurs before the day-ahead market closes and before forecast data submission, ensuring that congestion is resolved by the time connected parties declare their planned grid inputs or withdrawals to the grid operator. This is beneficial for the grid operator as no further action is needed to manage congestion (ACM, 2022). In summary, the contracts available differ mainly in terms of timing and financial structure. The CBC offers day-ahead or bilaterally agreed predictability with stable, bilaterally determined remuneration. In contrast, the bid obligation contract offers intraday flexibility with market-determined pricing, though a price cap can be negotiated. These differences impact the risk and operational planning for market parties.

6.1.3. Batteries Connected 'Grid Neutral'

It is already common practice to connect batteries ’grid neutral’ (in Dutch: netneutraal), to avoid worsening congestion (Interview F). This means that during times of anticipated congestion, the battery’s connection is limited to prevent it from increasing congestion. To achieve this, the battery signs a CBC in addition to the firm transport capacity agreement, ensuring it does not use the grid when congestion is expected. According to interviews, these agreements are made for the long term, with the periods during which the battery is limited being agreed upon for the upcoming years, providing predictability for the battery’s operations.

6.2. Rules and Corresponding IAD Element

In this section, all the elements of the action situation (as shown in Figure 6.1) and the corresponding rules-in-use to those elements are mentioned.

6.2.1. Participants and Boundary Rules

Two participants are involved: the DSO and the market party (potential CMA). The DSO is responsible for managing grid congestion and facilitating new grid connections. The market party is the entity capable of providing congestion mitigation services and is in exchange for this service prioritised in the queue and provided transport capacity under certain conditions.

The boundary rules determine who may enter or leave a position and how this process occurs. For the DSO, depending on the negotiations with the market party, its position changes if an agreement is reached and a contract is signed. In such a case, the DSO assumes the role of the buyer of the congestion mitigation service. For the market party, entering the position of a CMA involves a two-step process managed by the DSO. This process includes a technical check to verify the market party’s ability to mitigate congestion and successful negotiation on the CMS to be delivered to the DSO. This procedure is outlined by the ACM in the code act ’prioriteringsruimte transportverzoeken’, as mentioned in Chapter 2. Since this action situation occurs after the initial technical check, the primary entry rule for this phase is that the market party must demonstrate technical capability to offer CMS. This capability can be achieved either by limiting its existing firm transport capacity or by feeding-in or consuming electricity in the opposite direction of the expected congestion, as discussed in Chapter 4. The successful negotiation of the CMS that the market party will deliver to the DSO ultimately determines if the market party enters the position of CMA. By signing a contract for CMS, the CMA assumes the role of a seller of CMS to the DSO.

6.2.2. Positions and Position Rules

Positions define the roles in which participants enter or leave, linking the action set and participants. Position rules assign these roles by linking action sets to them. The position for the DSO is straightforward, because it manages grid operations, ensuring stability and efficiency, and facilitates the integration of new grid connections. For the market party, two types can be distinguished. They can be either a party with an existing grid connection and firm transport capacity or a new entrant to the grid. They differ in the choices they can make in the contract negotiations: Existing grid participants with firm contracts can apply for additional transport capacity as CMAs by agreeing to restrict their use of the original firm transport capacity at specific times. New grid connections, however, must actively feed-in or consume electricity in the opposite direction of the congestion to qualify as CMAs.

6.2.3. Actions and Choice Rules

The actions in the negotiation process correspond to the choices that the DSO and CMA can make in their efforts to agree upon the details in the contract. The choices are based on the readily available contracts, discussed earlier in this chapter. These are the choices that lead to the agreement between the DSO and potential CMA and form the actions in the action situation of contract negotiations between the DSO and the market party. The choices are:

- **Congestion Mitigation Service (CMS)**: The service of consumption or feeding-in electricity executed by the CMA to ensure that there there is available transport capacity that the DSO can provide for other market parties awaiting firm transport capacity. This service consists of the power and the total duration that the CMA delivers. This includes any limitations that the CMA has while using the transport capacity it gets in return, explained in last choice in this section.
- **Availability Precision**: This is about the level of precision of CMA availability. The choices are to what extent the CMA is able to know when and how many times it must help to mitigate congestion. This ranges from low to high. Low is when the CMA must be available all the time to possibly be activated to mitigate congestion. High is when in the contract it is exactly determined when the CMA needs to assist the DSO in increasing available transport capacity.
- **Coordination of Activation**: This is time between the moment when the DSO notifies the CMA that it must assist in congestion mitigation at a specific moment and the actual moment of delivery. This ranges from early to late. Early is when there is a lot of time between the activation and the actual moment of congestion. Late is when there is little time remaining between the activation and congestion peak, thus the activation is very close to-real time.
- **Transport capacity outside of congestion peaks (TCO):** This is the amount of transport capacity that the CMA receives to use for its own business operations. This consists of the amount of power and duration of the transport capacity. The power and duration can be restricted during certain moments, due to expected congestion. It must be noted that this limitation is then part of the service of congestion mitigation, because the CMA cannot freely use the transport capacity.

Remuneration is not part of the actions, but subject to supply and demand

Remuneration could also be seen as a choice in the negotiation space, however in this analysis it is assumed it is not an action in the action situation itself. This is because remuneration is expected to be a variable that depends on the choices made in the contract, not as a choice on its own. If there are multiple market parties applying as a CMA that all make equal choices but ask different prices for remuneration, the DSO will always have to pick the lowest. Therefore, the remuneration will be handled from a perspective of supply and demand. For example, if all of a sudden existing connections are excluded to apply as CMA, the supply of market parties that can apply as CMA decreases and if it is assumed that the demand for CMAs stays equal, the market parties that are still eligible to apply as CMA have a better bargaining position and therefore the remuneration is likely to be higher.

Choice Rules

The rules that govern the actions in the action situation are choice rules. Choice rules outline what actions must, may or may not be taken by a participant in a given position, depending on the prevailing conditions and linked to the 'Actions' component in the action situation. A choice rule that is addressed in the ACM code act limits the DSO in its choices for future CMAs. The DSO cannot choose the CMA based on its technology. Additionally, the DSO has to be non-discriminatory in its choices (ACM, 2024c).

6.2.4. Control and Aggregation Rules

It is assumed that both the DSO and the potential CMA have full control over their actions during contract negotiations. They are not restricted in their choices or actions during this process. Similarly, there are no explicit rules limiting the extent of choices available to the DSO and market parties during the negotiations. However, it should be noted that depending on the agreements and the contract signed during this action situation, the execution phase is likely to be heavily governed by aggregation rules. This is however, a different action situation and not part of the scope of this analysis.

6.2.5. Information and Information Rules

In this section, the information available to the participants and the rules associated with it are discussed. Information refers to what each participant knows or does not know, which is affecting the decision-making process. Information rules govern the access and authorisation of information exchange among participants.

Information exchange between the DSO and market parties is strictly regulated to ensure both transparency and confidentiality, which are important for maintaining privacy and fair competition on the distribution grid. Under Appendix 14 of the netcode elektriciteit (2016), the DSO must publish details about network connections, usage, and transport capacity as part of the congestion research reports. However, the release of this information is carefully managed to safeguard confidential data. Additionally, any information that could provide a commercial advantage is shared in a way that ensures all parties have equal access, preventing any distortion of the competitive environment. The general rule, set out in Article 79 of the electricity law, is that the DSO publishes all information that contributes to effective competition and efficient market operation.

The DSO has comprehensive access to both historical and current data on grid congestion and user details, which enables informed decision-making regarding grid management and congestion mitigation strategies. In contrast, the market party's access to information is more limited, restricted to publicly available congestion reports and a general status overview provided by the congestion map[1]. This data provides an overview of current and anticipated congestion but lacks the detailed, day-to-day granularity.

6.2.6. Costs/Benefits and Payoff Rules

Costs and benefits are the rewards or sanctions associated with certain possible outcomes of the action situation. Payoff rules define the allocation of these costs and benefits, or sanctions and rewards,

[1] https://capaciteitskaart.netbeheernederland.nl/

resulting from actions or outcomes. In the contract negotiations the following costs and benefits are negotiated: The CMA receives transport capacity outside of the moments when it must assist the DSO with congestion mitigation. In return for providing the mitigation service, the CMA receives remuneration. The DSO provides the transport capacity and remuneration. In exchange, the DSO receives flexibility from the CMA, which allows the DSO to offer new firm transport capacity to market parties in the queue. Additionally, the DSO incurs the transport costs associated with the transport capacity used by the CMA.

6.2.7. Outcomes and Scope Rules

Outcomes are the returns from the actions made in the action situation. They include the agreements on the behaviour of the CMA with the DSO and thus the details of the contract that is signed. Scope rules delineate the spectrum of potential outcomes that may be influenced. The ACM code act stipulates certain rules that must be present in the outcome of the contract negotiations (ACM, 2024c). These include:

- The allocation of transport capacity to the CMA must result in an increase in the available transport capacity for other parties.
- The allocation of transport capacity to the CMA must not result in an increase in congestion in the grid of another grid operator.

6.3. Chapter Summary

To summarise this chapter, an overview of the components of the IAD framework that were examined is provided. While the elements of the action situation and the rules-in-use were analysed in pairs within the chapter, they are presented separately in this summary. The specific elements of the action situation are detailed in Table 6.2 and the rules-in-use are shown in Table 6.3.

Table 6.2: Elements of the Contract Negotiations Action Situation

Participants	DSO	Market Party (Existing Connection)	Market Party (New Entrant)
Positions	Acts as the grid operator	Possesses an existing firm transport capacity contract	Represents a new entrant to the grid
Actions (negotiation space)	The following choices are made: Amount of CMS provided; Precision in availability of transport capacity; Coordination of activation timing; Amount of OTC available outside of congestion peaks		
Control	Both participants exercise full control over choices within the negotiation process.		
Information	Has complete information on grid congestion historically and detailed forecasts of future transport capacity	Access to limited information: General data on congestion via congestion reports and an overview of current congestion status via the congestion map.	
Costs and Benefits	Provides transport capacity and compensation for CMS; benefits from CMS and revenue from additional transport costs	Offers CMS and bears additional transport costs; receives OTC outside of congestion peaks and compensation	
Outcomes	Agreements finalised regarding the operation of the CMA in the distribution grid to facilitate congestion mitigation		

Table 6.3: Rules Governing the Relationship Between DSO and Market Parties (CMA)

Rule Type	DSO	Market Party (Existing Connection)	Market Party (New Entrant)
Position Rule	Acts as the grid operator	Able to restrict usage of original transport capacity and actively provide mitigation in opposite direction.	Can only actively feed-in or consume electricity in the opposite direction of congestion.
Boundary Rule	Entry rule: Agreements and contract signing turns DSO into the buyer of flexibility.	Entry rule: Passes technical check and is deemed capable of providing congestion mitigation. Upon agreement and contract, becomes CMA and flexibility seller to DSO.	
Choice Rule	Must choose CMA non-discriminatory, not based on technology.	-	-
Aggregation Rule	Participants are not restricted by rules in their actions.		
Information Rule	Prohibited from sharing individual user data.	-	-
Payoff Rule	No defined payoff rules for the contract negotiations.		
Scope Rule	Allocations must increase available transport capacity and not worsen congestion in another grid.		

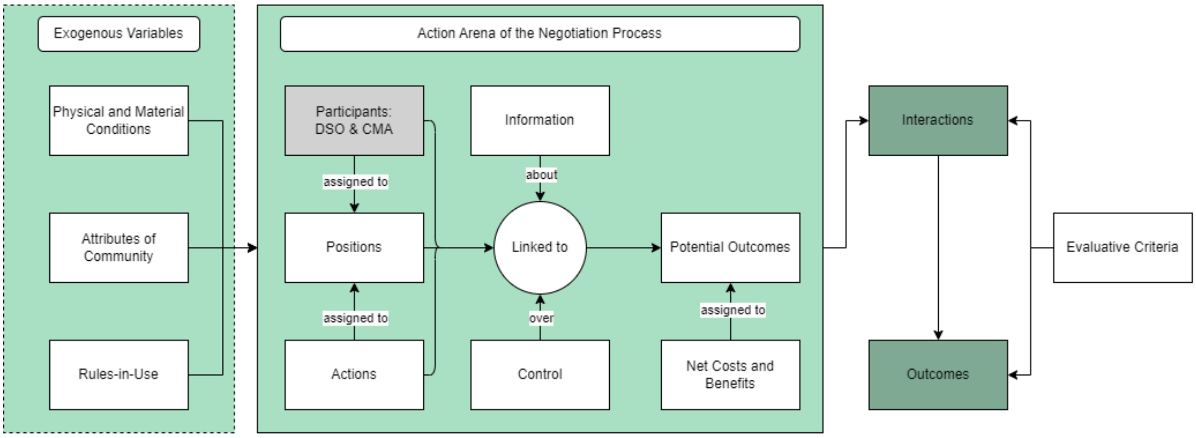

Figure 7.1: In this chapter the interactions and outcomes are determined, using the findings for the exogenous variables and action arena.

7

Analysis: Interactions and Outcomes

This chapter is structured into two main sections: The first specifies the critical action situation, and the second analyses the interactions and outcomes arising from the negotiation process between the DSO and potential CMA. These steps together address the final sub-question: *How is the contract negotiation action situation positioned institutionally and what are the interactions and outcomes of the negotiation process?*

7.1. From Coordination Problems to Critical Action Situations

In this section, the action situations around the CMA implementation are analysed using the four-layer model of Williamson to determine their nestedness and institutional alignment, concluding with the critical action situation of contract negotiations. The main coordination problem for a new queue management approach is balancing the need for CMAs to receive priority access to transport capacity with the DSO's requirement for substantial congestion mitigation services at a fair price. The action situations are positioned in the four-layer model of Williamson (1998), as shown in Figure 7.2. At level 2, the institutional environment where rules and regulations are determined, the ACM code act is located, with more specifically the category of CMAs. At level 3, further details of the execution of this code act is found, including the technical check and the contract negotiation of CMAs itself. To further analyse the contract negotiations, this section examines the execution of the contract and the subsequent transactions enabled by its signing. These include priority access and transport capacity outside of congestion peaks granted to the CMA, as well as the transaction between the DSO and the first party in the queue who receives firm transport capacity as a result of the agreement between the CMA and the DSO. This all takes place on level 4, which is where the individual transactions take place and the resources are thus allocated. The levels can influence each other; for example, if the current contracts available might not fit the needs for prioritisation of CMAs: the rules for the current contract are embedded in the second level and thus limit the possibilities for the contract negotiations in level 2. Therefore it is important that the institutions in these levels are aligned. In figure 7.2, the nestedness of the action situations within the institutional layers can be seen, in which the lines represent relationships between the action situations and arrows indicate the order of certain action situations. The critical action situation is the contract negotiations between the DSO and market party for prioritisation, which is the action situation that follows from the code act determination and allows for the execution of CMS and subsequently creates available transport capacity for market parties awaiting a connection in the queue.

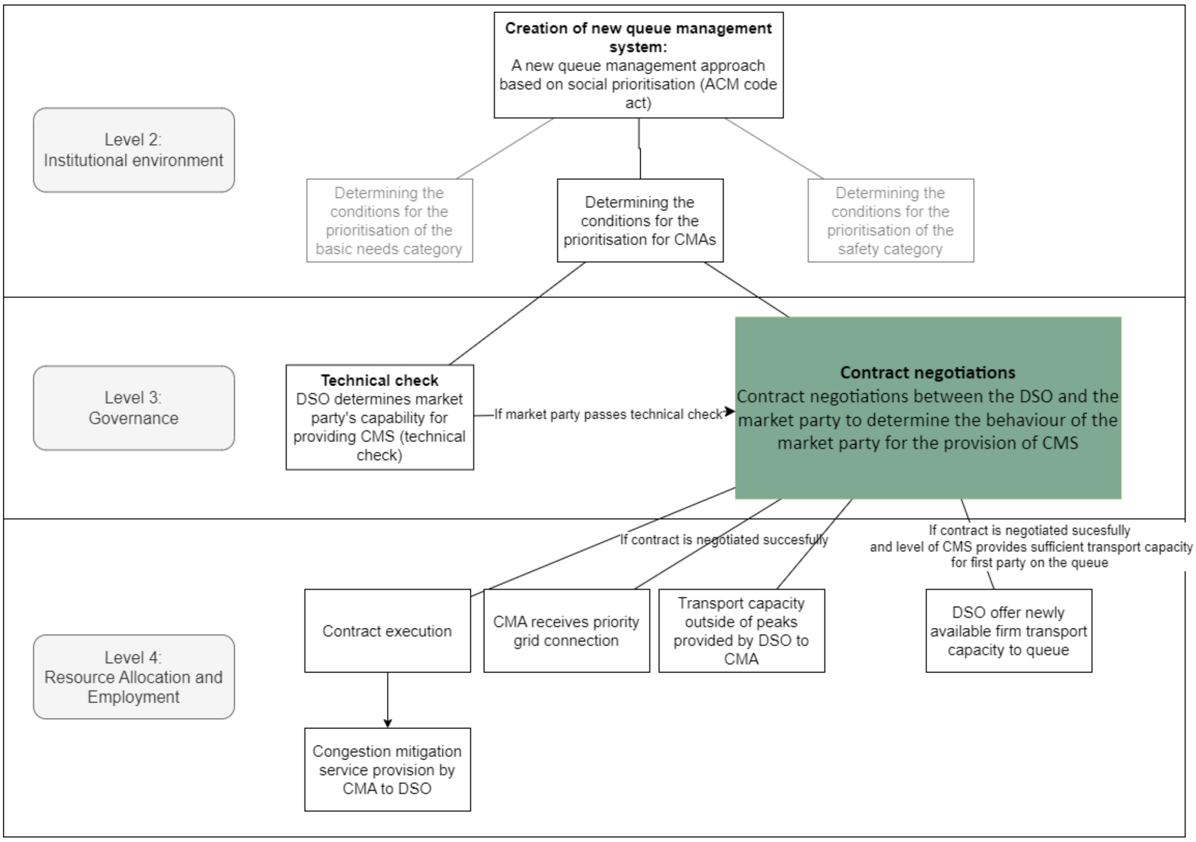

Figure 7.2: Nestedness of action situation in the four-layer model of Williamson (1998)

7.2. Interactions - Internal Motivations

This section explores the internal motivations of the DSO and the market party in context of contract negotiations. The internal motivations are critical as they reveal the underlying factor of risk as a shared problem.

7.2.1. DSO: Stability and Revenue, Risk Limitation

The primary motivation for the DSO is to ensure grid stability while maximising revenue potential through transport costs. The DSO seeks to facilitate users in the queue by securing firm transport capacity, necessitating the engagement of CMA services. The DSO aims to optimise the behaviour of the CMA, by controlling the activation and availability of the CMA to manage congestion. This control is vital as the DSO's financial remuneration for the mitigation service is assumed to be related with the risk associated with maintaining grid stability, because more risks taken by the DSO will likely lead to lower willingness to pay for remuneration.

7.2.2. Market Party: Profit-Driven Objectives

Conversely, the market party's goals are predominantly profit-oriented, focusing on maximising revenue from their business models that leverage additional transport capacity. This might necessitate an initial investment by the market party to capitalise on the transport capacity they receive outside of congestion peaks. The market party seeks to minimise the costs associated with providing flexibility for congestion mitigation, assuming that the remuneration received is typically less than the revenue generated from their primary business operations. The remuneration bid for the market party also includes a risk premium. The risk for the market party is based on the certainty of leveraging the received transport capacity outside of the congestion periods in which they need to assist in congestion mitigation. This in turn depends on the coordination of activation and the precision to which the market party knows that they need to be available.

7.2.3. The value of Priority Access and Investments

The grid congestion that is seen nowadays creates a significant barrier to entry for new market parties or existing connections wanting to expand. This is reflected in the queues for grid connections. Priority access as a CMA has the potential to accelerate market entry for new participants, enabling them to initiate their primary business activities and generate revenue more rapidly. This prioritised market entry is particularly advantageous for business models highly dependent on timely grid access, such as battery operations that rely on arbitrage opportunities in electricity markets, because a late entry means that the market is likely to be more saturated, decreasing the profitability of the battery (Martins & Miles, 2021; Saulny et al., 2017). Therefore the question arises how this priority access might be monetised. Can it be seen as an asset for the CMA in the negotiation? Here, the assumption is made that this should not be reflected in the considerations for contract negotiations. This has to do with the wide variability of conditions present which makes it complex to quantify. Additionally, on the other side, the CMA is likely to make a substantial investment to apply as CMA as well. Given these variations, both priority access and the investment necessary to apply as CMA are not included as a factor in this analysis.

7.3. Interactions - Considerations & Choice Preferences

From these internal motivations, the base preferences of both actors for each variables are derived. The variables in which a choice needs to be made during the contract negotiations are:

- The amount of congestion mitigation service provided from CMA to DSO
- Transport capacity for CMA outside of congestion mitigation service (TCO)
- Availability precision: The precision that the CMA is aware on when it must provide congestion

mitigation

- Coordination of activation: The amount of time between the request/activation of the CMA to support in congestion mitigation and the actual congestion.

An overview of the choice preferences for both participants is given in Table 7.1.

7.3.1. Congestion Mitigation Service and the Transport Capacity outside of congestion peaks

The amount of flexibility provided by the CMA and the transport capacity that the CMA can use outside of this service can not be executed at the same time. Transport capacity is made up out of a certain amount power and duration. These quantities share restrictions a priori: During the provision of CMS, the CMA cannot benefit from the transport capacity it has received. This is because both these variables share the quantity of time as both have to be executed by the CMA, which is not possible simultaneously. Therefore there is a limit to the duration of CMS and the duration of transport capacity that can be allocated to the CMA.

A different restriction is present in the quantity of power. Logically, there are technical limitations to the amount of power that the CMA can provide or consume, limiting the power for CMS provision and transport capacity outside of CMS.

As mentioned in the internal considerations of the actors, the DSO benefits from a higher amount of CMS. For the market party it depends on the remuneration it receives for the CMS. But since this is likely to be lower than the revenue it can receive from its own business case and the fact that the mitigation service and the transport capacity outside of this service share the time dimension, the market party prefers lower provision of mitigation service and more transport capacity.

7.3.2. Availability Precision

The effects of the availability precision and risk associated for both actors are visualised as a theoretical concept in Figure 7.3. It represents the risk from low to high on the y-axes for the DSO (solid line) and the CMA (dotted line). On the x-axis, the availability precision is shown from low precision on the left to high precision on the right. Low precision means that the CMA needs to be available most of the time for a possible activation to provide congestion mitigation. High precision means that the CMA well-aware of when it must be available to provide congestion mitigation service. The situations corresponding to A, B and C are explained in more details here: Situation A is the first extreme in which the CMA would always be available to support the DSO in congestion mitigation. This would be very low risk for the DSO as they always have the CMA as an option to activate throughout the year. However, this would have a large impact on the business case of the CMA and therefore it would increase the risk for the CMA, leading to a high risk premium demanded by the CMA. Situation B corresponds to a moderate availability precision. The DSO and CMA both are exposed to a moderate amount of risk. Situation C is on the other extreme there is a pre-determined dates and times that are agreed between the CMA and DSO when the CMA must support in congestion mitigation. This would increase the risk for the DSO due to unpredictable nature of the congestion and thus they would be at risk when there is congestion during the moments that are not pre-determined. Therefore, the preference of the DSO in the contract negotiations is to aim for as low precision as possible, while the CMA prefers highly precise availability.

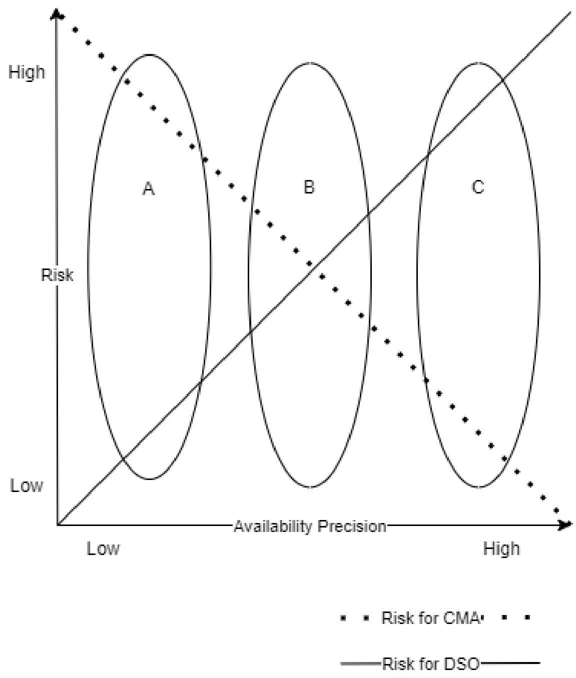

Figure 7.3: Availability Precision and Risks associated for DSO and CMA

7.3.3. Coordination of Activation

A similar concept can be found for the coordination of activation and the associated risks for the DSO and CMA, visualised in Figure 7.4. The x-axis represents the time between the activation of the CMA and the actual real-time congestion. The y-axis represents the risk experienced by the DSO (solid line) and the CMA (dotted line). For the DSO, risk increases when the activation to support in congestion mitigation is made earlier. This is because after the activation is triggered, there is a lot of time between in which unpredictability could affect the actual need for the congestion mitigation. For the CMA this is the opposite, because if they would know early when they are activated, they have more time to optimise these limitations in their business model. If they would know late, close to real-time, they would not be able to prepare. There are also technology specific limitations to take into account, because certain technology might not be able to ramp up or down in their electricity usage quick enough to adjust close to real-time. Another example of technology specific limitations would be that a battery would not have the correct level of stored electricity to handle the activation if it is very close to real-time (e.g. battery is empty when it needs to feed-in electricity as CMS, or full when it needs to consume as CMS). Thus, the preference of the DSO would be to make agreements that the activation for congestion mitigation happens close to real-time, while the CMA might not be able to facilitate that due to technology specific limitations and themselves prefer the coordination of activation as early as possible.

7.3.4. Overview of Choice Preferences

Table 7.1 is an overview of the sections above and shows the preferences of both actors in the contract negotiations.

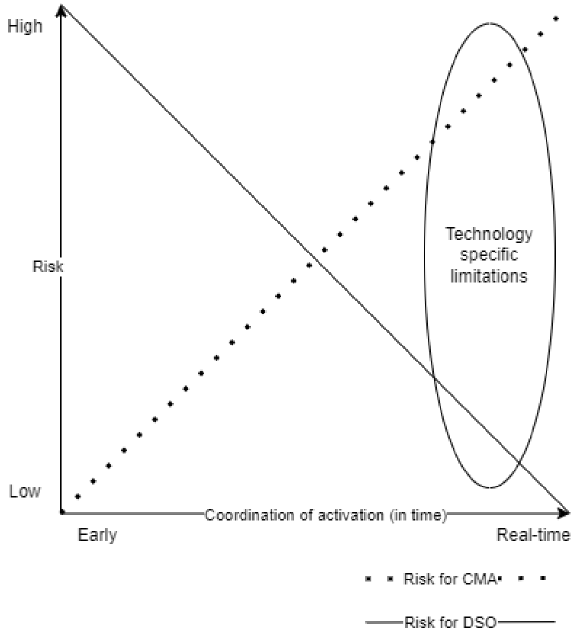

Figure 7.4: Coordination of Activation and Risk associated for DSO and CMA

Table 7.1: Choice Preferences of the DSO and Market Party

Parameter	DSO	Market Party
CMS	High demand	Low offer[1]
TCO	No preference	High demand
Availability Precision	Low	High
Coordination for Activation	Late[2]	Early

7.4. Interactions - Interdependencies

In this section the restrictions that occur in the choice preferences are discussed. The relations between the choices are explained and other parts of the IAD variables are included.

7.4.1. Competition on Time and Duration and Technical Limitations

In Chapter 4, it was established that the service for congestion mitigation shares characteristics with club goods, being excludable and non-rivalrous, whereas transport capacity in a congested grid with a queue shares properties with private goods, marked by both excludability and rivalrousness. The contract negotiations facilitate a transaction where this club good is exchanged for a private good. The market party supports the DSO in congestion mitigation and in exchange it receives transport capacity outside of the congestion peaks. The critical aspect of this exchange is the concurrent dimension of time; when a CMA is engaged in supporting in congestion mitigation, it is restricted from using the transport capacity for its own use. Moreover, the technical capabilities of the CMA significantly influence the volume of transport capacity it can use.

To visualise this, a simplified situation is created. Figure 7.5 shows the transport capacity duration curve, which is similar to a load duration curve, showing the duration in hours for the transport capacity used throughout the year. The figure shows the transport capacity used on the y-axis and the duration

[1] Low offer depends on remuneration, likely below usual business revenue.
[2] Technology specific limitations might exist close to real-time.

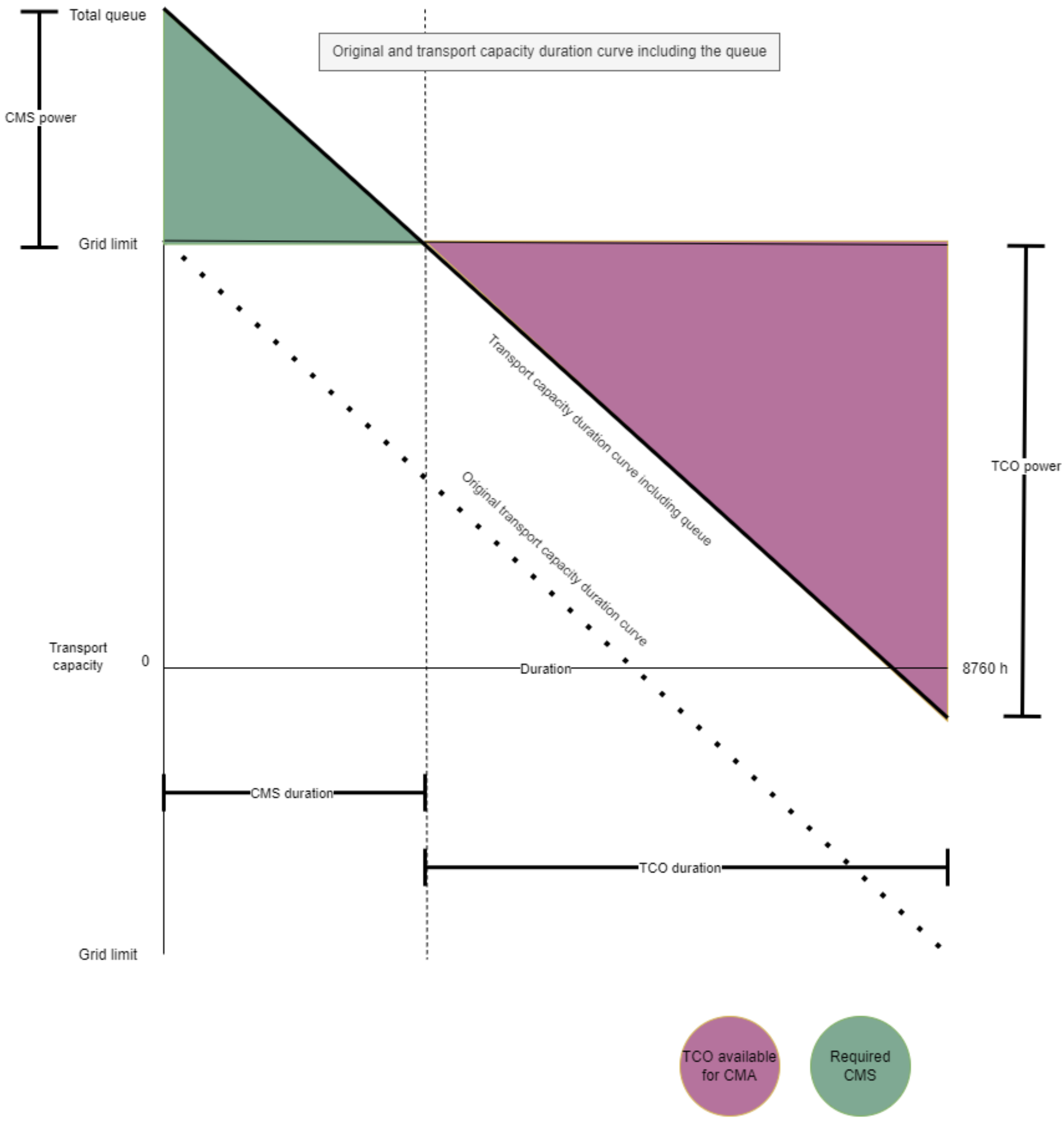

Figure 7.5: Transport capacity duration curves with a the optimal CMA

in hours on the x-axis and includes two transport capacity duration curves. The dotted curve represents the original curve, namely the transport capacity used of all grid users. The curve with the regular line represents the transport capacity duration curve if all market parties awaiting a grid connection in the queue were given a firm capacity. The grid limit represents the maximum used transport capacity that the grid can technically facilitate. The green area is thus the total amount of congestion that occurs when the whole queue is connected. This is equal to the amount of congestion mitigation (CMS) that the perfect CMA would need to provide in opposite direction. This can be seen as the goal of the DSO to achieve in contract negotiations with market parties. Because, with this perfect CMA, the whole queue can receive its firm transport capacity. Then, the rest of the year, the CMA would be able to use the rest of the transport capacity available (TCO, the purple area) to use for its own business, if it is willing and capable to use it.

In practice, this perfect CMA is very unlikely. This is because the CMA would have to at least, be able to provide or consume electricity equal to the grid limit and the total amount of firm capacity in the queue. Additionally, the CMA would need to be able to provide a high level of power for longer periods of time (not equal to the CMS duration in the graph), which is also not likely. From a market party point of view, the purple area is where it can create revenue from its own business operations. Additionally, it will receive a remuneration for the CMS it provided for the total green area. The market party might be limited in the maximum power it can deliver because of its technical capacity, therefore limiting revenue from the remuneration for the mitigation service and its own business case outside of these congestion peaks. This transport capacity duration curve shows the relationship between the duration of congestion mitigation service (CMS) provided and the duration of transport capacity used for its own business case (TCO). If the DSO would want to connect more users to the grid from the queue and thus require more CMS, the duration of CMS would shift to the right and therefore lower the time available for the CMA to create revenue from the TCO.

7.4.2. Information Asymmetry & Conflicting interests

The following can be said from the preferences and interdependencies discussed so far. The market party wants maximise its revenue and for this it needs a high amount of transport capacity to use for its own business case. Assuming a certain technical limitation in terms power, this aim to maximise transport capacity competes directly with the duration of congestion mitigation service that the market party must provide. On the other side of the negotiation table, the DSO aims to gain as much support from the CMA as possible. This can then be converted in firm transport capacity for market parties in the queue. This competition for transport capacity can be seen as a conflict of interest. Another conflict of interest that exists for both parties is the aim for decreasing one's own risk. The DSO wants to minimise risk from unpredictable congestion through close to real-time coordination of activation and a low precision of availability of the future CMA. While the market party wants the opposite, namely an early coordination of activation and a low availability precision.

These two conflicts exist in a situation where both parties have the same amount of information on the conditions of the congestion and the required amount of mitigation needed. This is, however, not the case in the current action situation, because there is an information asymmetry between the DSO and market party. This information asymmetry is most present in the knowledge of the DSO about the specific grid area. The DSO has information on the type and behaviour of users in the grid, which allows them to get a detailed overview of grid congestion expectations. These grid expectations also include knowledge about the market parties that are awaiting a grid connection. The information rules described, forbids the DSO from sharing any information about specific users and thus this information cannot be shared and the only source of information currently present for the market parties in this are the congestion reports and the capacity map, giving an indication of the queue aggregated over different grid levels and areas (Netbeheer Nederland, 2024a).

Therefore, the DSO has an advantage in the negotiation over the market parties due to their information and therefore is likely to better assess the risks associated with the choices in the contract negotiations than the market party with limited information. The market party cannot have the same information about the consequences for each choice that they are supposed to make and therefore are not able to assess their risk in the same way as the DSO. This undermines their outlook on certainty. Specifically, they are unknown of the the conditions present in the grid and what the consequences of this are for all choices to be made in the contract negotiations, leading to less accommodating choices. This information asymmetry therefore lead to a sub-optimal contract negotiation, because the market party tends to be less accommodating due to the higher levels of risk they face.

7.4.3. Risk-averse DSO

In Chapter 5, it was noted that the DSO is risk-averse due to its obligation to ensure grid stability. The DSO therefore naturally has a tendency to overestimate risk, which leads to less accommodating choices in contract negotiations. In general, this risk aversion results in fewer successful negotiations and thus fewer CMAs, which in turn limits the ability of other market parties to receive a grid connection. This raises the question whether this risk aversion creates an internal conflict for the DSO, as its obligation to ensure grid stability and its obligation to process grid connections are at odds. This issue is rooted in the DSO's sole responsibility for maintaining a stable grid and its societal role and corresponding interests. A potential solution for the DSO to limit risk and successfully contract CMAs is to increase the remuneration offered. This would likely lead to a better business case for the market party, allowing them to accept a higher level of risk due to less precise availability and closer to real-time coordination of the activation for congestion mitigation.

7.5. Exogenous Effects on Interactions

This section examines the exogenous factors affecting contract negotiations, focusing on the severity and predictability of congestion and the grid level's impact on supply and demand dynamics.

Severity of Congestion

The severity of congestion directly influences the demand for congestion mitigation. In scenarios of severe congestion, there is an elevated demand for mitigation by a CMA in terms of power, resulting in fewer CMAs that meet the necessary technical capabilities. The remaining market parties that meet these technical capabilities can subsequently demand a higher remuneration. Additionally, congestion with longer duration diminishes the available transport capacity that CMAs can use for their own business case. This limits the opportunities for CMAs to capitalise on the transport capacity they receive. This reduced availability heightens the remuneration as the supply of capable CMAs decreases and bids per CMA increase.

Predictability of Congestion

The predictability of congestion significantly affects the coordination strategies between the DSO and market parties. In conditions or areas where congestion can be predicted precisely, the DSO is more likely to accept contract terms with early coordination of activation and precise availability schedules.

This predictability reduces the risk for market parties, subsequently lowering the necessary remuneration. Conversely, unpredictable congestion necessitates closer to real-time coordination and less precise availability. This increases the risks for market parties, resulting in higher remuneration bids.

Level in the Grid

The level of the grid at which a CMA operates influences its potential supply and the geographical scope of its impact. Higher levels in the grid cover larger areas, enhancing the possibilities for market parties to connect to the grid and, in turn, increasing the supply of CMAs and driving down the price of remuneration. Conversely, lower levels of the grid are characterised by a reduced scope, which limits the number of feasible CMAs, thereby elevating the remuneration due to the decreased supply.

7.6. Outcomes

Concluding from the interactions that are present in the contract negotiations, the DSO and market party compete on different choices: The DSO aims for more congestion mitigation service from the market party, while the market party wants the opposite, namely more transport capacity to be used for its own business case. These are mutually exclusive goods and thus a consensus must be made. For the coordination of the congestion mitigation, the market party wants a very precise availability and early coordination of activation to lower its risk. In contrast, the DSO wants to decrease its risk through very broad (less precise) availability and late coordination of activation. Additionally complexity is increased by a high variation in congestion areas, types of business cases and operational limitations of the market parties. This creates conflicting interests that do not allow for a single optimal outcome. However, these interactions lead to different possible outcomes that are explained in this section.

7.6.1. Contract Formations

The variety in types of market parties affect what formations of contracts are needed. The following factors influence these contract formations.

When determining the contract, a distinction must be made between a party with an existing firm contract that wishes to limit its firm transport capacity and a new entrant or an existing firm contract that wishes to use transport capacity for both consumption and feeding-in. The first version, applicable only to an existing connection (type A), serves as the base case because it requires only a contract limiting transport capacity. The second version adds to the base case by requiring a contract for providing transport capacity in the opposite direction. Thus, contracts must be established in two directions: a transport capacity contract with limitations during agreed (expected congestion) periods and a transport capacity contract in the opposite direction with an obligation to deliver during these periods. This applies to both an existing connection (type B) and a new entrant (type C). Similar to the distinction made in Chapter 4, Figure 7.6 illustrates the formation of contracts for the different types of CMA. In the figure, the three types are shown in each a distinct graph. The green area is the transport capacity that is already owned from an existing contract or received to use for the market parties own business case. The grey area shows the moments of congestion, in which the market party must assist in congestion mitigation through limiting its own transport capacity. The purple area is the active form of congestion mitigation by consuming or producing electricity in the opposite direction of the congestion. The reason for not incorporating the other available contract, namely the bid obligation, is that it does not offer the option for limitation. Additionally, during this contract negotiation, the focus is mostly on longer time frames than those provided by the bid obligation contract. The bid obligation contract only offers oppor-

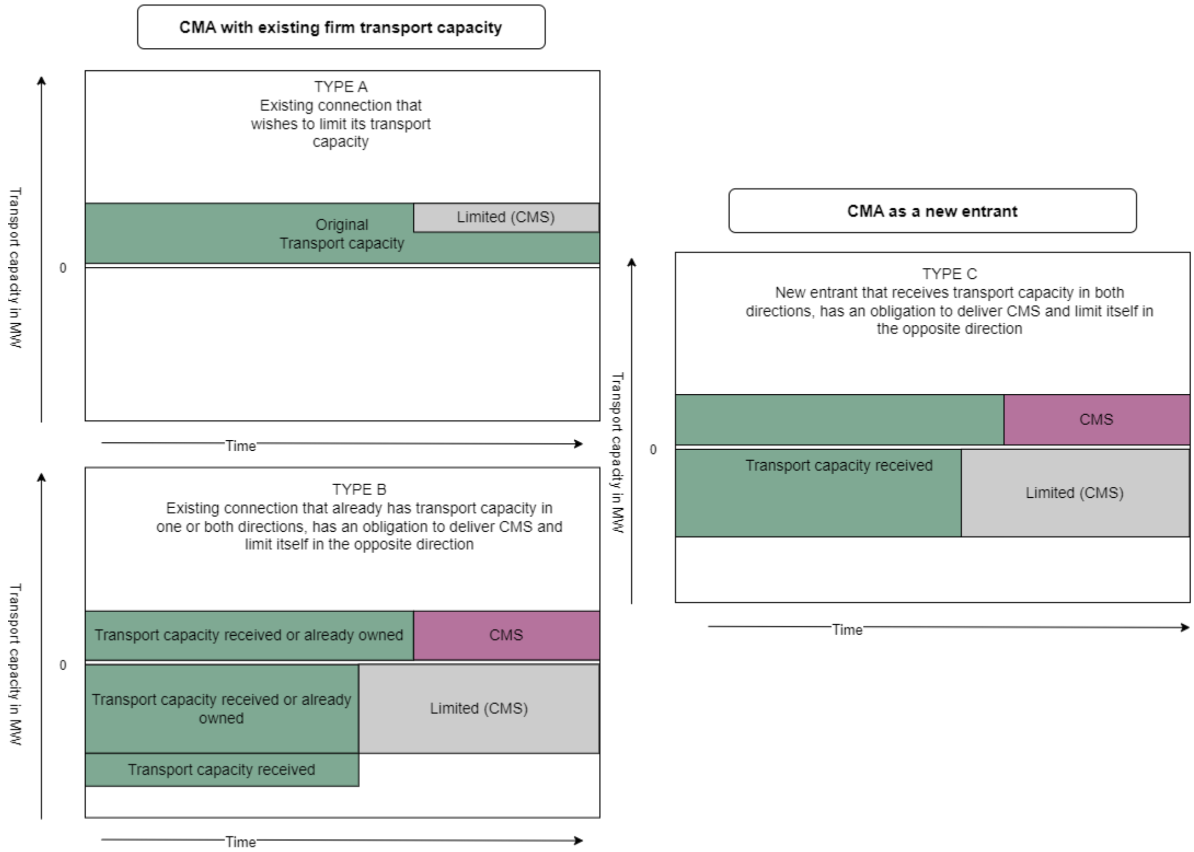

Figure 7.6: Contract formation for different types of CMA

tunities for close to real-time contracts, making it potentially suitable for those purposes, which is only a slight portion of the scope that is taken in this analysis.

7.6.2. Supply of CMAs and Remuneration

The remuneration level is primarily dependent on supply and demand dynamics. For instance, when there is high expected congestion and a long queue for grid connections, the demand for CMAs increases. This scenario lowers the DSO's bargaining power, likely resulting in higher remuneration for the CMA. Conversely, when there is lower expected congestion and a short queue, the demand for CMAs decreases, enhancing the DSO's bargaining power and likely leading to lower remuneration. The local nature of the distribution grid means there is a limited supply of potential CMAs, increasing their bargaining power. As a result, the remuneration price tends to be higher due to the scarcity of suitable CMAs. These supply and demand dynamics help to make conclusions about the amount of market parties that will apply as CMA.

Transport costs: a discrepancy in CMA supply

In general, the DSO wants as much congestion mitigation provided by the CMA as necessary depending on the expected congestion and the queue present. In the way transport costs are structured, the DSO would want to demand even more support from CMA-f as a new entrant specifically. This is because for this specific type the DSO would receive transport costs for the service that the CMA-f and new entrant delivers to the DSO, because for decreasing congestion it consumes electricity. For the CMA-c with an existing firm contract the same but opposite happens. While providing congestion mitigation, this specific type limits its transport capacity, effectively lowering its transport costs that has to be paid to the DSO. In exact the same (but opposite) cases, the difference in transport costs would be higher for the first situation with the new entrant CMA-f, because it would need to pay both an increased kW-max and kW-contract, while the second case only has to lower its payments by the kW-contract, because the kW-max was already registered higher, because it is lowering its consumption. For both cases it is however not possible to determine exactly what these extra costs are *ex ante*, because it depends on the activation of the mitigation service if it is paid, which depends on the availability precision to which is agreed for the activation of the service. In terms of supply and demand dynamics, the new entrant CMA-f would thus be less frequently be represented as a CMA for feed-in congestion due to the higher transport costs and thus the market parties applying to provide mitigation for feed-in congestion are likely to be existing connections. For consumption congestion this happens in the opposite direction: market parties that have an existing connection pay lower transport costs and thus there is a higher supply of this type, leading to more existing connections as CMA-c.

Existing connections requiring no investment

Existing connections that keep their regular business model, but are capable of adjusting consumption/feeding-in and are able to be limited temporarily are a good candidate as CMA. If no additional investment is necessary, they will demand a lower remuneration. Overall this will lead to a higher representation of these types of CMAs due to their lower remuneration demand.

More congestion leads to a lower supply of CMAs

From a supply and demand perspective, the higher total duration of mitigation service that must be provided by the CMA, the less supply of CMAs will exist. Because a higher duration of congestion is equal to a smaller duration available for the CMA's own business operations, leading to a deterioration of the CMAs business case. The underlying assumption here is that there one CMA must provide all the CMS equal to the congestion mitigation needed to free up a certain quantity of firm transport capacity. Therefore, if congestion is higher (than average) there will be more congestion peaks that need mitigating by a single CMA in order to free up the same amount of firm transport capacity. Therefore, the more congestion, the less likely a market party might be able to provide this amount of mitigation. Consequently, the supply of CMAs decreases, while essentially the demand for CMA has increased, because there is more congestion.

Technological and financial limitations

As seen in the choice preferences, the DSO prefers late coordination for activation, which is very close to real-time. This preference decreases the risk for DSOs concerning unpredictable grid congestion, allowing them to use the CMA as a source of flexibility. However, certain CMAs might not be able to provide this due to technological limitations, such as slow ramp-up or ramp-down times, preventing them from quickly responding to activations from the DSO. Additionally, financial limitations exist for technologies dependent on the intraday and imbalance market for most of their revenue. If the DSO's coordination for activation is close to real-time, these technologies cannot act on the intraday and imbalance market, restricting their revenue. This issue, particularly relevant for storage technology, suggests that the likelihood of these technologies accepting these contract negotiations is low.

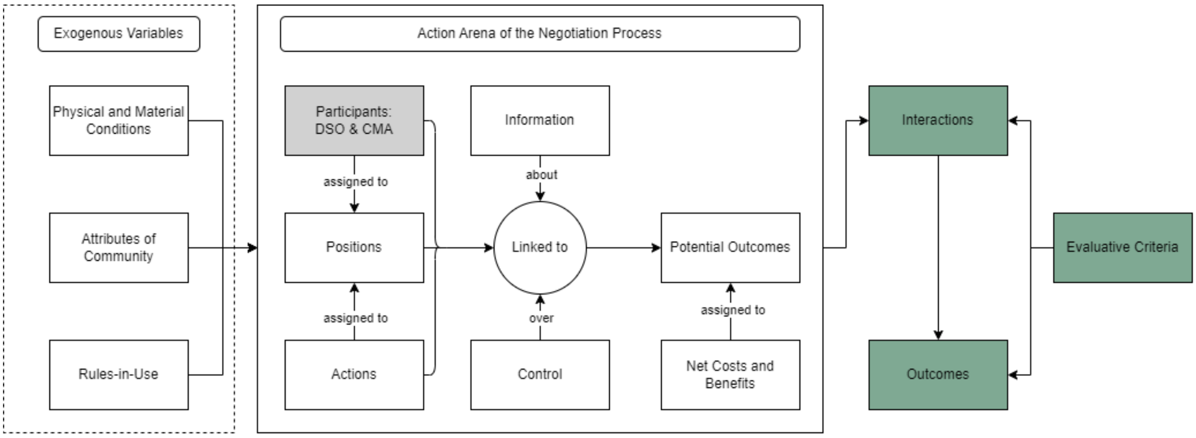

Figure 8.1: This chapter concludes by using the evaluative criteria to assess the interactions and outcomes of the negotiation process

8

Discussion & Conclusion

8.1. Introduction

This chapter synthesises the findings from previous analyses to address the main research question: *How does the negotiation process between the DSO and potential CMAs influence queue management of grid congestion in the Dutch distribution grid?*

Initially, it summaries the answers to the sub-questions presented in the preceding chapters. Subsequently, the interactions and outcomes of the contract negotiations are assessed using the evaluative criteria of fairness, sustainability and grid stability. Finally, the chapter discusses the limitations of this research, reflects on the research endeavour, and offers suggestions for future research and policy recommendations.

8.2. Recap of Sub-Questions

This section provides a summary of the answers to the sub-questions posed in each chapter, linking them to the overarching theme of the thesis.

8.2.1. Physical and Material Conditions of Distribution Grid Congestion

Sub-question 1: *What are the physical and material conditions of distribution grid congestion in the Netherlands and how do these conditions dictate characteristics for Congestion Mitigation Agents?*

Congestion in the distribution grid is inherently unpredictable, often influenced by sudden weather changes and unexpected (market) activities, posing grid management challenges. The classification of goods show that transport capacity shares characteristics as a common-pool resource in non-congested scenarios, and that of a private good when congested due to its limited, excludable nature. The service of congestion mitigation shares characteristics with club goods, characterised by controlled access and non-rivalry. Other physical and material conditions, such as the local nature of the grid and variations in consumption and feeding-in patterns, necessitate a flexible approach to the management of congestion. CMAs are designed to create additional transport capacity and therefore facilitate firm contracts for other market participants, necessary for meeting the growing demand for grid connections. They are characterised by their adjustable power capability. The differentiation of CMAs has been defined into four types, namely CMA for consumption congestion (CMA-c), for feed-in congestion (CMA-f) and based on if they already have a current contract in the grid (an existing connection or a new entrant). The scenarios developed for severe and mild congestion, along with predictable and unpredictable congestion patterns, are created to address the fluctuating conditions of grid congestion. Furthermore, the scenarios based on grid levels show the challenges and opportunities in finding suitable CMAs, reflecting the local nature of grid operations. These scenarios help to highlight the exogenous effects on the contract negotiations between the DSO and market parties, ensuring that the agreements reflect the nuanced understanding of physical fluctuations in the grid and grid congestion.

8.2.2. Stakeholder Attributes

Sub-question 2: *What are the stakeholder attributes affecting the contract negotiations and what evaluative criteria are needed to assess the prioritisation of Congestion Mitigation Agents?*

The interplay between the DSO's regulated monopoly and market parties' profit-driven motives shapes the grid congestion mitigation ecosystem. The DSO priorities grid stability and risk aversion, constrained by regulations and the need to connect new users and generate revenue. However, the local community, as DSO stakeholders, influences the DSO's strategies to maximise transport capacity and enhance local welfare. Market parties seek stable regulatory environments to support their business models and investment strategies. The participants are driven by financial considerations. From this perspective, the DSO incurs capital expenditures in grid infrastructure and operational expenses in maintenance and ancillary services. These expenses are balanced by revenues from connection and transport fees. CMAs face expenses related to connection fees and operational costs tied to their specific business models, with revenues originating primarily from their core business activities and additional remuneration for providing congestion mitigation services. The unpredictability introduced by technologies like batteries complicates grid management operations, as their behaviour can be unpredictable, posing a risk to grid stability. This necessitates clear agreements about the timing of contract execution.

In the context of implementing the CMA initiative, the evaluative criteria deemed crucial are:

- Fairness: Ensures equitable treatment of all grid users and market participants, including the fair allocation of costs and benefits.
- Sustainability: Evaluates the environmental impact of CMA implementation.

- Grid Stability: Assesses the impact of CMA implementation on the overall stability of the grid.

8.2.3. Regulatory Impact

Sub-question 3: *What rules are present in the contract negotiations between the CMA and DSO?*

Regarding the regulatory environment, various contracts are available, such as the Capacity Limiting Contract (CBC) and the Bid Obligation Contract, each with distinct timing and remuneration structures. CBC offers more predictability with fixed compensation, whereas the Bid Obligation Contract allows for flexibility but includes market-driven pricing, which introduces a degree of financial risk. The negotiation space for these contracts includes defining the terms of the Congestion Mitigation Service (CMS), the precision of CMA availability, the coordination of activation times and the transport capacity allocated to the CMA outside congestion peaks. These elements are crucial as they directly affect the operational effectiveness and financial outcomes of the engagements.

Important rules-in-use influencing the contract negotiations are:

- Boundary Rules: Entry into a contract signifies the DSO becoming the buyer of the congestion mitigation service, while the market party, assuming it passes the technical capability check before the negotiations, becomes a CMA and seller of the congestion mitigation service.
- Choice Rules: The selection of a CMA by the DSO must be non-discriminatory and cannot be based on the technology used by the potential CMA.
- Information Rules: The DSO is restricted from sharing information that could reveal data specific to individual grid users.
- Scope Rules: The agreements ensure that the allocation of transport capacity to a CMA enhances the overall capacity available to others and does not increase congestion elsewhere in the grid.

8.2.4. Institutional Analysis

An overview of the institutional analysis focusing on the institutional alignment, interactions and outcomes of the contract negotiations action situation, answering to the fourth and final sub-question: *How is the contract negotiation action situation positioned institutionally and what are the interactions and outcomes of this negotiation?*

In the Williamson framework for institutional analysis, the contract negotiation action situation between the DSO and market parties (future CMAs) is positioned at the governance level. This level focuses on the operational and contractual frameworks that govern day-to-day transactions and the longer-term relationships, which allows for establishing a way of coordinating regular exchanges between DSO and CMA.

The interactions are characterised by an interplay of competing priorities and challenges, central to which is the negotiation over the duration of CMS and TCO. The DSO typically seeks broad availability in CMS terms to maintain flexibility for real-time grid management, preferring general precision to adjust based on grid conditions. CMAs, however, push for highly precise availability terms to minimise operational disruptions. Furthermore, while the DSO benefits from late activation of the migigation service for better handling unpredictable congestion, CMAs, constrained by specific technological limits, favour early activation to synchronise with their operational frameworks.

Outcomes of these negotiations are influenced by several critical factors:

- Severity and Predictability of Congestion: High congestion severity increases demand for CMS, raising remuneration bids due to the scarcity of CMAs with adequate capacity. Conversely, predictable congestion allows for better planning and lower costs, facilitating more efficient CMS deployment.
- Grid Level Impact: The operational level of CMAs on the grid influences supply dynamics. Higher grid levels expand the potential CMA pool, reducing remuneration rates, whereas lower levels limit CMA availability, increasing costs.
- Transport Cost Structure: The structure of transport costs significantly impacts negotiation outcomes. Existing connections, typically incurring lower transport costs, often submit lower remuneration bids, resulting in more successful negotiations compared to new entrants who face higher costs and hence need for higher remuneration to cover their financial risks.
- Information asymmetry: The DSO's access to detailed grid and congestion data provides them with an advantage in assessing risks and potential needs, an advantage not shared by CMAs who operate with less information, increasing their risks and thus ask for higher remuneration.
- Technology-specific Limitations, such as the ability to quickly adjust power outputs and financial dependencies on market timings affect CMAs' capacity to meet DSO demands for real-time CMS activation.

8.3. Evaluation

This section uses the evaluative criteria of fairness, sustainability and grid stability to assess how CMAs have restructured the management of grid congestion to answer the main research question. Additionally, the institutional alignment of the contract negotiations is discussed.

8.3.1. Fairness

The evaluation of CMAs reveals several critical issues concerning the allocation of transport costs and the fairness in operational dynamics within the grid. A significant fairness issue arises from the discrepancy in transport costs between CMAs as existing connections and CMAs as new entrants. Existing connections benefit from lower transport costs since they can reduce existing transport costs by providing congestion mitigation. This creates an unfair advantage for existing connections, disadvantaging new entrants who must bear higher costs. Moreover, certain choices in the activation of CMAs may lead to discrimination among technologies. Specifically, close to real-time coordination of activation excludes technologies that are limited in providing service if activated close to real-time. These limitations may be due to inherent technological constraints or because real-time activation negatively impacts their business model, particularly those reliant on imbalance trading. Consequently, these technologies may be rendered unfeasible for CMA participation, leading to an inequitable technology landscape.

8.3.2. Sustainability

This subsection evaluates the prioritisation of certain technologies by the current CMA framework and their long-term sustainability implications. The sustainability impacts of CMAs reveal several technological and investment biases that favour existing connections. Existing connections are more likely to become CMAs due to the lower transport costs they incur and the reduced need for new investments. This results in a bias towards maintaining the status quo, which could lead to a missed potential for increased sustainability if newer entrants offer more sustainable solutions. Additionally, the choices made in contract negotiations influence the number of parties in the queue that can receive transport capacity. However, the sustainability characteristics of these parties remain uncertain, as every queue is different and the implementation of CMAs does not affect the order of non-prioritised parties. Therefore, no definitive conclusions can be drawn about the sustainability impacts of parties remaining in the queue.

8.3.3. Grid Stability

The balance between grid stability and the effectiveness of CMAs reveals a potential conflict. The DSO's goal of grid stability might suppress the effectiveness of CMAs due to the trade-off between minimising risk and maximising the mitigation of congestion. The interaction identified indicates that minimising risk for the DSO involves ensuring high availability and precise coordination of congestion mitigation service, which typically results in higher remuneration bids from market parties. While this approach increases the likely stability of the grid by giving the DSO more control over CMAs, it also leads to higher costs. Limited resources mean that higher remuneration costs could reduce the overall amount of mitigation the DSO can achieve. Consequently, while grid stability might be maximised, it could lead to lower congestion mitigation, sustaining the status quo of grid congestion and keeping grid stability at risk. The effect of more congestion mitigation on grid stability remains unclear. While more mitigation provided should theoretically reduce congestion and enhance grid stability, it also increases the complexity of grid management for the DSO, requiring more coordination during times of congestion. Proper coordination of congestion mitigation could indeed lead to less congestion and improved stability, but this dynamic warrants further investigation and is addressed in future research.

8.3.4. Institutional Alignment

Contract negotiations are situated at level 3 of the four-layer model of Williamson(1998), within the institutional environment where the rules of the game are created. To ensure the effectiveness of CMAs, issues such as the transport costs structure must be addressed. The model helps tackle these issues by highlighting the need for broader changes at higher institutional levels, particularly within the institutional environment. For CMAs to succeed, other institutions must be aligned with this new queue management approach. As analysed, other institutional factors currently limit the effectiveness of CMAs, with the transport costs structure being the most notable. To maximise the effectiveness of CMAs, the transport costs structure must be aligned with CMA objectives. Implementing time-of-use pricing for transport costs could potentially reduce grid congestion. This approach should apply to both consumption and feeding-in of electricity. Such a structure would result in low costs for CMAs that provide congestion mitigation by feeding electricity in the opposite direction during peak times. It would also lower costs for existing connections that limit their electricity usage to mitigate congestion. Institutional alignment, therefore, is crucial for addressing the transport costs structure and ensuring the successful implementation of CMAs. By aligning transport costs with CMA goals, better incentives are given to CMAs to provide congestion mitigation service for lower remuneration and at the same time other grid users are steered to using electricity at different moments.

8.4. Limitations of Research

This section identifies key limitations encountered during the study. The primary methodological limitation of this research is the lack of empirical data. This limitation means that some of the interactions and outcomes discussed are based on calculated predictions of how the DSO and CMA will approach the contract negotiations, instead of experiences from past negotiations. Additionally, the inherently dynamic nature of grid congestion is challenging to encapsulate fully and therefore major assumptions were made for the analysis. Another limitation is the exclusion of certain stakeholders, such as Congestion Service Providers (CSPs), who have distinct focuses and roles and are likely to provide coordination for the coordination of congestion mitigation. Financially, CSPs aim to take margins on transactions, which can influence solutions negatively. However, operationally it can have a positive influence, as they are often knowledgeable about technical options and effective communication strategies for congestion mitigation (Interview G, H). Their exclusion from the analysis simplifies the action situation but overlooks their potential impact. Furthermore, the scenarios analysed were based on a static view of congestion, which does not account for the highly dynamic nature of grid congestion. An example of an assumption of this static view is the way how the implementation of CMA was simplified based on the congestion area, allowing to assume that a CMA can be placed anywhere in the congestion area, but in reality there are more restrictions to this and the issue of congestion in one part of the congestion area might not be the same issue in the other part of the same congestion area. Additionally, the study assumes that market parties have the technical capabilities to assess associated risks, which might not always be the case due to a wide variety of types of businesses, with different levels of expertise. The analysis focused solely on the DSO and market parties (CMAs), simplifying the complexity of real-world situations. The role of the TSO in cases of transmission grid congestion was excluded due to the complex interplay involved, which itself constitutes a separate action situation of the coordination between the TSO and DSO on the impact of CMA implementations on other grid areas. In this study it was simply assumed as part of the rules-in-use and not impacting the contract negotiations, however in reality it is. This point warrants further investigation and is addressed for future research. Last, the study did not account for the element of trust in negotiations between the DSO and market parties. Trust, especially built through successful negotiations in earlier instances, could significantly improve outcomes but was not considered in this analysis (Walker & Ostrom, 2009).

8.5. Methodological Reflection

Reflecting on this research endeavour, the methodology employed offers several notable strengths that have facilitated a good understanding of the new queue management approach. Employing a coordination perspective allowed for detailed analysis of various aspects involved in policy implementation such as the impact of physical conditions, the operational rules, and the considerations of stakeholders. Unlike a model-based approach, this methodology offers a ”glass box” visibility of the impacts and outcomes, making all elements and assumptions clearly identifiable. The qualitative nature of this research provides flexibility, allowing for the adaptation of assumptions in response to evolving regulatory and technological contexts in the future. Additionally, the flexibility of this approach is advantageous for future research, as it allows for modifications, such as the inclusion of new participants, without the need to completely overhaul the existing framework.

However, a limitation of this approach, compared to a model-based and optimisation-focused methodology, is the challenge in quantifying the effects observed from the implementation of CMAs. Furthermore, the institutional perspective adopted here introduces a higher level of subjectivity and room for interpretation, which might be more more reliable in an optimisation-based approach.

After reflection, the methodology adopted in this thesis, prior to the implementation of the actual implementation of CMAs appears to be well-suited for the circumstances. The reason for this is that in the early stages of policy development, actual rules and processes are either non-existent or subject to rapid changes. The chosen analytical approach provided the necessary adaptability to accommodate these fluctuations. From the author's perspective, there has been significant development in the implementation of this queue management approach over the last 6-12 months. The adoption of the coordination perspective and the IAD framework facilitated timely adjustments to these changes, resulting in a complete and up-to-date analysis.

8.6. Future Research

This section provides suggestions for extending the research to address the identified gaps and explore new dimensions. As mentioned in the evaluation, the current DSO strategy focuses on maximising transport capacity to serve the queue. However, this approach might not lead to a net profit for the DSO, as it could drastically increase remuneration bids if even the most severe peaks need to be mitigated. An alternative strategy proposed during an interview suggests focusing on net positive profit from transport costs by the CMA (Interview F). For this strategy, the revenue from the transport costs of the capacity used by the CMA would need to exceed the remuneration paid, allowing the DSO to earn money while providing additional transport capacity. For example, a factory would negotiate a contract with the DSO as a CMA, in which the factory receives transport capacity but needs to assist the DSO with handling daily feed-in congestion and in return receives remuneration. The DSO receives in its turn transport costs from the factory because it uses the transport capacity. The idea proposed here is that the amount of transport costs that the DSO receives by prioritising this CMA is higher than the remuneration the DSO pays. This approach could enhance social welfare, but its impact on the queue and overall welfare from the additional transport capacity remains unclear. Future research should explore the optimal strategy for the DSO in terms of social welfare with the inclusion of CMAs. Another area for future research involves the coordination between the TSO and DSOs, which represents an interesting action situation. Effective coordination is important for managing congestion and ensuring grid stability. Interviews and literature review reveal significant challenges, such as inadequate communication channels and sub optimal methods of congestion analysis (Interview E) (Hadush & Meeus, 2018). Furthermore, coordination issues are also evident within the DSOs, particularly among teams responsible for different grid levels (Interview C). Congestion does not merely affect the specific grid level where it occurs but also impacts other levels; hence, when a grid connection is established, communication with teams across various grid levels is necessary. Research into enhancing TSO-DSO coordination, and integrating these efforts with contract negotiations, could provide essential insights into more effective grid management.

Another important area for future research is the coordination between the TSO and DSO as a relevant action situation. Effective coordination is essential for managing congestion and ensuring grid stability. Interviews and literature highlight issues related to the lack of communication channels and the current methods of congestion analysis (Interview E) (Hadush & Meeus, 2018). Also internally within the DSO these coordination issues seem to exist between teams of grid levels (Interview C). Congestion in the grid does not only influence the grid on that specific level, but also impacts other grid levels, therefore when a grid connection is made, it must be communicated with teams of other grid levels as well. Investigating how TSO-DSO coordination can be improved and integrated with contract negotiations would provide valuable insights into enhancing grid management.

8.7. Policy Recommendations

Based on the study's findings, the following policy recommendations are offered for policymakers, regulatory bodies and the DSO to improve the implementation and effectiveness of CMAs.

- Simplification: The implementation of CMAs essentially is a way of contracting flexible capacity to reduce congestion. Policymakers should treat it as such, avoiding the addition of new unnecessary regulations. Simplifying and clarifying existing mechanisms will prevent unnecessary complexity and make it easier for institutional alignment, improving the overall effectiveness of flexibility for congestion mitigation.
- Combining CMAs: An outcome is that increased congestion leads to a reduced supply of CMAs. As congestion grows over the years and more peaks need to be mitigated by a single CMA, it becomes less favourable for a CMA to provide these services. Consequently, the supply of CMAs decreases while demand likely increases, resulting in a weaker negotiating position and higher remuneration demands. This issue can be addressed by allowing multiple CMAs to collaboratively provide the congestion mitigation service, by taking turns.
- Transport Cost Structures: The current transport cost structure can disincentives CMAs from addressing feed-in congestion. Reforming these costs to better reflect the true costs and benefits of CMAs will encourage more market parties for applying as CMA and allowing for a fairer price for remuneration.
- Information Transparency: The uncertainty and risk faced by market parties partially stem from information asymmetry. Establishing mechanisms for more transparent information sharing can build trust and reduce unpredictability. A multi-step process that gradually increases information exchange can help market parties and DSOs gain mutual confidence for the contract negotiations. At the same time this decreases the risk of breach of confidentiality because further in the process it is likely that only serious market parties will remain in the process.

8.8. Conclusion

To answer the main research question, the implementation of CMAs significantly influence queue management of grid congestion in the Dutch distribution grid. This can be seen in impacts on fairness, sustainability and grid stability. Fairness issues arise as existing connections benefit from lower transport costs for providing congestion mitigation, disadvantaging new entrants who face higher costs. The demands for close to real-time activation coordination may exclude certain technologies, which can be seen as unfair. Additionally, limited supply of CMAs due to the local nature of the distribution grid make it difficult to find a fair price for remuneration. Sustainability is affected as the transport costs structure favours existing connections, sustaining the current technology landscape and missing opportunities to integrate newer, more sustainable technologies. Regarding grid stability, the DSO's risk aversion requires high availability and precise coordination for the activation of mitigation during contract negotiations, resulting in higher remuneration costs for CMAs. While this enhances grid control, it raises costs, potentially reducing overall congestion mitigation and sustaining grid congestion. Overall, contract negotiations are complex due to the variety of interdependencies involved, among which the balance between actually providing congestion mitigation and the transport capacity that the CMA receives in return is particularly critical. It is hard to standardise the contract negotiations, due to the conditions present in each specific congestion area. Therefore, further investigation based on empirical data is required, coming available after the implementation of the CMAs in October 2024.

References

ACM. (2012). *Regulering regionale netbeheerder elektriciteit | acm.nl* [Accessed: 2024-06-22]. https://www.acm.nl/nl/publicaties/publicatie/11249/Regulering-regionale-netbeheerder-elektriciteit

ACM. (2016). *Netcode elektriciteit | acm.nl* [Accessed: 2024-05-09]. https://www.acm.nl/nl/publicaties/publicatie/14381/Netcode-Elektriciteit

ACM. (2020). *Transporttarieven en elektriciteitsopslag* [Accessed: 2024-06-22]. https://www.acm.nl/system/files/documents/transporttarieven-en-elektriciteitsopslag.pdf

ACM. (2022). *Vragen en antwoorden – congestiemanagement en het capaciteitsbeperkingscontract* [Accessed: 2024-06-22]. https://www.acm.nl/system/files/documents/q-en-a-over-congestiemanagement-en-capaciteitsbeperkingsconctract.pdf

ACM. (2024a). *Acm presenteert pakket aan maatregelen tegen netcongestie | acm.nl* [Accessed: 2024-05-09]. https://www.acm.nl/nl/publicaties/acm-presenteert-pakket-aan-maatregelen-tegen-netcongestie

ACM. (2024b). *Ontwerp codebesluit alternatieve transportrechten* [Accessed: 2024-06-22]. https://www.acm.nl/system/files/documents/ontwerpbesluit-alternatieve-transportrechten.pdf

ACM. (2024c). *Staatscourant 2024, 12928 | overheid.nl > officiële bekendmakingen* [Accessed: 2024-05-06]. https://zoek.officielebekendmakingen.nl/stcrt-2024-12928.html

Anderies, J. M., Janssen, M. A., & Schlager, E. (2016). Institutions and the performance of coupled infrastructure systems. *International Journal of the Commons*, *10*(2), 495–516.

Beckstedde, E., & Meeus, L. (2023). From “fit and forget” to “flex or regret” in distribution grids: Dealing with congestion in european distribution grids. *IEEE Power and Energy Magazine*, *21*(4), 45–52.

Bots, P. W. (2007). Design in socio-technical system development: Three angles in a common framework. *Journal of Design Research*, *5*(3), 382–396.

Brunekreeft, G. (2015). Network unbundling and flawed coordination: Experience from the electricity sector. *Utilities Policy*, *34*, 11–18. https://doi.org/10.1016/j.jup.2015.03.003

Buis, G. (2023). Applying game-theory to evaluateincentives for cooperative behaviour between households within the distribution grid [Accessed: 2024-03-23]. https://essay.utwente.nl/97278/1/Buis_MA_Engineering_Technology.pdf

Damianakis, N., Mouli, G. R. C., Bauer, P., & Yu, Y. (2023). Assessing the grid impact of electric vehicles, heat pumps & pv generation in dutch lv distribution grids. *Applied Energy*, *352*, 121878. https://doi.org/https://doi.org/10.1016/j.apenergy.2023.121878

de Bruijne, M., Steenhuisen, B., Correljé, A., ten Heuvelhof, E., & de Vries, L. (2011). How to design a new gas bid price ladder? exploring market design issues in the new dutch gas balancing regime. *Competition and Regulation in Network Industries*, *12*(1), 83–97.

de Kok, A. (2023). Matching algorithm with efficient market-based redispatch bid structures and the change in co2 emission caused by redispatch.

Elektriciteitswet 1998 - bwbr0009755 [Accessed: 2024-06-27]. (1998). https://wetten.overheid.nl/BWBR0009755/2024-01-01

Energimarknadsinspektionen. (2020). *International principles for the prioritisation of grid connections* (Accessed: 2024-03-23). https://www.ei.se/download/18.5f8cc396177db5159bd9cb5/1615305623815/THEMA-Consulting-group-International-Principles-for-the-Prioritisation-of-Grid-Connections.pdf

Energy Networks Association. (2023). *Improving and accelerating customer connections- our immediate action plan* (Accessed: 2024-03-23). https://cdn.prgloo.com/media/35e96278bc7040f08ed7103df86c23e4.pdf

Enexis. (n.d.-a). *Biedplichtcontract voor redispatch als flexoplossing | enexis netbeheer* [Accessed: 2024-05-09]. https://www.enexis.nl/zakelijk/netcapaciteit/congestie/congestiemanagement/congestiemanagementcontracten/biedplichtcontract-voor-redispatch

Enexis. (n.d.-b). *Capaciteitsbeperkingscontract als flexoplossing | enexis netbeheer* [Accessed: 2024-05-09]. https://www.enexis.nl/zakelijk/netcapaciteit/congestie/congestiemanagement/congestiemanagementcontracten/capaciteitsbeperkingscontract

Enexis. (2024). *Periodieke aansluit- en transporttarieven elektriciteit* [Accessed: 2024-06-22]. https://www.enexis.nl/zakelijk/aansluitingen/tarieven/tariefbladen

Enexis Groep. (2024). *Recorduitbreiding elektriciteitsnet niet voldoende om groeiende vraag bij te benen - enexis* [Accessed: 2024-03-23]. https://www.enexisgroep.nl/nieuws/recorduitbreiding-elektriciteitsnet-niet-voldoende-om-groeiende-vraag-bij-te-benen/

Fonteijn, R. (2021). Utilising flexibility in distribution system operation: Theory and practice.

Gumpu, S., Pamulaparthy, B., & Sharma, A. (2019). Review of congestion management methods from conventional to smart grid scenario. *International Journal of Emerging Electric Power Systems*, *20*(3), 20180265.

Hadush, S. Y., & Meeus, L. (2018). Dso-tso cooperation issues and solutions for distribution grid congestion management. *Energy policy*, *120*, 610–621.

Hakvoort, R., Harris, D., Meeuwsen, J., & Hesmondhalgh, S. (2009). A system for congestion management in the netherlands. *D-Cision/The Brattle Group, Zwolle*.

Hirth, L., & Glismann, S. (2018). Congestion management: From physics to regulatory instruments.

Knops, H. P. A., De Vries, L., & Correlje, A. F. (2004). *Energiekeuze (s) belicht, beleidskeuzes voor de inrichting van de elektriciteits-en gassector in nederland* (Accessed: 2024-05-09). Wetenschappelijk Instituut van het CDA.

Künneke, R., & Finger, M. (2009). The governance of infrastructures as common pool resources.

Laan, J. (2023). *Electricity grid congestion and application of a novel tariff in the netherlands* [Master's thesis, University of Twente].

Martins, J., & Miles, J. (2021). A techno-economic assessment of battery business models in the uk electricity market. *Energy Policy*, *148*, 111938.

Ministerie van Economische Zaken en Klimaat. (2019). *Klimaatakkoord hoofdstuk elektriciteit* [Accessed: 2024-03-23]. https://www.klimaatakkoord.nl/elektriciteit/documenten/publicaties/2019/06/28/klimaatakkoord-hoofdstuk-elektriciteit

Netbeheer Nederland. (2024a). *Capaciteitskaart elektriciteitsnet* [Accessed: 2024-06-27]. https://capaciteitskaart.netbeheernederland.nl/

Netbeheer Nederland. (2024b). *Wachtlijsten nemen toe | netbeheer nederland* [Accessed: 2024-05-06]. https://www.netbeheernederland.nl/artikelen/nieuws/wachtlijsten-nemen-toe

Nolten, J., Drissen, S., Geldtmeijer, I. D., Morren, J., & Slootweg, J. (2017). Smart integration of battery storage. *TU Eindhoven*.

Oortmann, P. (2024). *Acm opent de deur voor non-firm ato's (nfa 1.0) - energy storage nl* [Accessed: 2024-06-22]. https://www.energystoragenl.nl/acm-opent-de-deur-voor-non-firm-atos-nfa-1-0/

Ostrom, E. (1994). *Neither market nor state: Governance of common-pool resources in the twenty-first century* (Vol. 2). International Food Policy Research Institute Washington, DC.

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton university press.

Ostrom, E. (2011). Background on the institutional analysis and development framework. *Policy studies journal*, *39*(1), 7–27.

Pavlov, M. (2024). Social prioritization for the energy grid: Energy justice evaluation and impact analysis.

Polski, M. M., & Ostrom, E. (1999). An institutional framework for policy analysis and design. *Elinor Ostrom and the Bloomington School of political economy: A framework for policy analysis*, 13–47.

Rova, T. N. (2023). Optimal capacity connection queue management for tsos and dsos.

Saulny, N., et al. (2017). *Operation and profitability of batteries in electricity reserve markets* [Master's thesis].

Solat, S., Aminifar, F., & Shayanfar, H. (2023). Changing the regulations for regulating the changes: From distribution system operator (dso) to electricity distribution stakeholders' organization (edso). *Energy & Environment*, *34*(4), 830–854.

Sovacool, B. K. (2006). The power production paradox: Revealing the socio-technical impediments to distributed generation technologies.

Tang, A. (2024). *Eu grid action plan will help renewables, but urgent action needed on excessive connection queues | windeurope* [Accessed: 2024-06-29]. https://windeurope.org/newsroom/press-releases/eu-grid-action-plan-will-help-renewables-but-urgent-action-needed-on-excessive-connection-queues/

Tanrisever, F., Derinkuyu, K., & Jongen, G. (2015). Organization and functioning of liberalized electricity markets: An overview of the dutch market. *Renewable and Sustainable Energy Reviews*, *51*, 1363–1374.

UNFCCC. (2015). *Paris agreement to the united nations framework convention on climate change* (Accessed: 2024-03-23).

van Blijswijk, M. J., & de Vries, L. J. (2012). Evaluating congestion management in the dutch electricity transmission grid. *Energy policy*, *51*, 916–926.

van Es, W. (2017). An institutional analysis framework to close the regional water cycle.

Vanhove, S. (2023). The electricity distribution system operator in a world of active customers. a legal laboratory analysis under eu, belgian and dutch law.

van Werven, M. J., & Scheepers, M. J. (2005). The changing role of energy suppliers and distribution system operators in the deployment of distributed generation in liberalised electricity markets. *Energy research Centre of the Netherlands*.

Walker, J., & Ostrom, E. (2009). Trust and reciprocity as foundations for cooperation. *Whom can we trust*, *91124*.

Weterings, R. (2010). Battery storage systems: An exploratory business model research for high power battery storage applications in the netherlands.

Wijk, B. (2019). *Stakeholder involvement in the energy transition-a grid company's perspective* [Master's thesis, University of Twente].

Wijziging van de klimaatwet [(implementatie Europese klimaatwet), Accessed: 2024-03-23]. (2022). https://zoek.officielebekendmakingen.nl/kst-36169-2.pdf

Williamson, O. E. (1998). Transaction cost economics: How it works; where it is headed. *De economist*, *146*, 23–58.

Wolsink, M. (2020). Distributed energy systems as common goods: Socio-political acceptance of renewables in intelligent microgrids. *Renewable and Sustainable Energy Reviews*, *127*, 109841. https://doi.org/10.1016/j.rser.2020.109841

A

Interview Guide - Round 1

Introduction

- Informed Consent: Show the informed consent form, ask for agreement, and request signature afterward.
- Recording: With your permission, I would like to record this interview for accurate transcription and analysis. Is that okay with you?

Introductory Questions

- What is your role at Enexis?
- How involved are you with the ACM Codebesluit on societal prioritization?

Part 1: Characteristics of Grid Congestion

- What are the main causes of grid congestion?
- Can you describe the different compositions of connections in a congestion area? (e.g., urban areas, rural areas with solar/wind parks, industrial zones)
- What congestion patterns do you expect for each type of composition?
- When do you expect the most help is needed from a party that assists in congestion mitigation?
- Considering the growth expectations of grid congestion, when do you anticipate the most problems on the grid?
- What are the underlying reasons for this?

Part 2: Design Parameters

Involvement with ACM Codebesluit

- To what extent are you involved with the ACM Codebesluit on congestion mitigators?
- How do you envision this in practice?

Definition and Goals

- According to ACM, assigning transport capacity to this party should lead to an increase in available transport capacity for other parties and not increase congestion in another grid operator's network. When is a congestion mitigator considered successful?

Design Variables

- Duration of mitigation
- Power used for mitigation
- Frequency of congestion mitigation: daily, weekly, etc.
- Scalability of mitigation over the long term as congestion worsens
- Response time: minimum time needed for the congestion mitigator to be deployed
- Potential to cause congestion in another direction
- Impact on other grids: congestion on the high-voltage network The purpose of this list is to identify variables/parameters that play a role in mitigating grid congestion. What must a congestion mitigator meet to mitigate peaks?

Research Goal

- The objective of the research is to design a framework to assess the extent to which a party can serve as a congestion mitigator for us.
- Review the list, ask for additions.
- Request prioritization of this list to determine the most critical requirements for a congestion mitigator.
- Emphasis on: How significant is this variable?

Key Design Variables

- Review the most critical variables. Make a selection in these design variables. Why?
  - Degree of congestion mitigation: a percentage or a minimum value? How much? Why?
  - Frequency of congestion mitigation: daily, weekly, etc.? Why?
  - Flexibility of the congestion mitigator to address growing congestion. Should it grow with a percentage of congestion increase?
  - Compensation costs: fixed amount or a discount on transport costs?
  - Response time: establish a fixed value? One month in advance? How significant is this?

Implementation of a Congestion Mitigator: Net Operator's Stance on Prioritizing Congestion Mitigators

- Active (e.g., tender process) or passive (congestion mitigator approaching us)?
- How do you view the determination of the price the net operator pays for the congestion mitigation service?
- Percentage of mitigation compared to transport capacity: discount by that percentage
- Purchasing the service: price per MWh
- Financial limit

- Steering of the congestion mitigator: signal from the net operator or information on expected congestion for anticipatory action?
- What type of contract between the congestion mitigator and the net operator is appropriate? Why?
- Other potential solutions to the congestion mitigation problem for the net operator, such as curtailment. How do you decide whether to contract a congestion mitigator or use curtailment?

B

Interview Guide - Round 2

Introduction

- Confidentiality: Your responses will be kept confidential, and any information you provide will be anonymised in the research report.
- Recording: With your permission, I would like to record this interview for accurate transcription and analysis. Is that okay with you?

Introductory questions

- What is your role at [...]?
- How involved are you with the ACM Codebesluit on congestion mitigation, specifically focusing on the Congestion Mitigation Agent (CMA)?

ACM Codebesluit on Congestion Mitigation

- What do you see as the main goal of implementing congestion mitigators?
- What should these mitigators achieve?
- How do you envision the implementation of this concept in practice?
- What problems do you foresee in implementing this concept?
- Follow-up: Can you provide an example of a potential problem?

Dilemmas Validation of Known Dilemmas

- CMA Receiving Transport Capacity vs Priority: One dilemma identified is that CMAs must receive transport capacity while also providing services to the DSO. What are your thoughts on this?
- How do we balance the extent of mitigation with the priority given?
- Non-Discriminatory Access: Ensuring non-discriminatory and fair access to network capacity for both existing and new customers is crucial. Do you agree with this dilemma? Why or why not?
- Can you provide a scenario involving existing and new solar parks?

- Legal Vulnerability: More criteria might lead to more lawsuits against the DSO because they are not specified in the netcode. How do you perceive this issue?
- How should we address this?
- Predictability vs. Flexibility: Balancing predictability versus flexibility is another dilemma. How do you see this affecting the implementation?
- For instance, consider a battery profile that reserves a lot of space and is flexible in switching. If they are active in other markets, they need earlier notification to remain flexible.
- Scalability vs. Specificity: The trade-off between scalability and specificity is challenging. What are your thoughts on this?
- A scalable solution ensures that congestion mitigators can be applied widely across various regions. However, each region might have specific causes and patterns of congestion that require tailored approaches.

Gathering Additional Dilemmas

- Do you agree with the dilemmas identified above? Why or why not?
- What other dilemmas do you think exist in the context of implementing CMAs?

Contract Negotiations

- Congestion Mitigation Actions vs Priority and Pricing
- How do you view the trade-off between congestion mitigation actions for the DSO and priority for the CMA?
- How do you envision these negotiations? What would be the requirements from an industry party's perspective?
- When does the congestion mitigator agree?

Preferred Contract Types

- Regarding the types of contracts currently available, what would be the preference for a market party? (e.g., firm with CBC, bid obligation contract, non-firm, time-block bound)
- DSO's Role in Prioritizing CMAs

Active vs Passive Stance

- What should be the stance of the DSO in prioritizing CMAs: active (e.g., tender process) or passive (CMA approaching the DSO)?
- Follow-up: Can you provide an example of how either approach might work in practice?

Scalability vs Specificity

- Given the dilemma of scalability versus specificity, how do you think the process should be designed to find the most effective CMAs? (e.g., considering different congestion types and areas)
- Follow-up: How should the DSO approach areas with varying types of congestion?

Predictability

- How should coordination with other market timings be handled to ensure predictability in the implementation of CMAs?

- Follow-up: What specific measures can be taken to synchronize the timing with other markets?

Comparison with Current Situation (FCFS)

Current FCFS Process

- How does the current first-come, first-serve (FCFS) process work in practice within your organisation?
- Follow-up: What are the strengths and weaknesses of the current FCFS approach?

Comparison with Proposed Approach

- How do you think the proposed prioritisation approach compares to the current FCFS system?
- Follow-up: What benefits or drawbacks do you see in the new approach?