Sustainability in Subcontractor and Supplier Selection

Qualitative research on the effectiveness of environmental EMAT criteria on achieving sustainability in the selection of subcontractors and suppliers in the Dutch infrastructure sector

Master's Thesis

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Preface

My time as a student at the University of Technology in Delft comes to an end after 6 years with this thesis. The research into sustainable EMAT tendering and the selection of subcontractors gave me a new insight into this topic. I could not have done this without the help of others.

First of all, I would like to thank my committee. *Marcel* thank you for your enthusiasm, interest in the topic, and constructive feedback.
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Secondly, I would like to thank Heijmans for the opportunity they gave me to conduct my research at their company. I would like to thank my company supervisor *Rene* for the constructive feedback and also the help with practical matters such as interviews and the facilitation of the documentation research. I would also like to thank my colleagues at Heijmans for their interest in and feedback on my thesis.

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Enjoy Reading!

Aloysius Herman van Slingerland

Delft, March 2023

Executive summary

The rapidly growing infrastructure sector has a detrimental effect on climate change. The infrastructure sector is responsible for approximately 10% of worldwide emissions (United Nations Environment Programme, 2020). Furthermore, it is responsible for a significant share of timber consumption, solid waste generation, raw materials, energy consumption, and global water use (Durdyev et al., 2018; United Nations Environment Programme, 2022).

Many developments have taken place to implement sustainability in the construction sector worldwide. In the past years, sustainability became more important in the procurement of infrastructure projects. One of the ways to implement sustainability in infrastructure projects is by award criteria in the tender phase of the project (Lenferink et al., 2013; Santen, 2020). These award criteria are called EMAT criteria, which stands for Economically Most Advantageous Tender. In this way, the client or procurer can determine the added value of the quality per contractor. So, the EMAT criteria is a way of tendering through the best quality/price ratio.

Not only the contractor is tendered by the client, but also the subcontractors and suppliers of the project are selected by the contractor. Selecting a suitable subcontractor and supplier will considerably improve the professional services capabilities of the main contractor (Chen et al., 2020). Approximately 80 – 90 percent of large infrastructure projects are subcontracted (Ramalingam, 2020). This means that to have a transition towards a sustainable sector, the subcontractors and suppliers must help too.

Although all spheres of sustainability were taken into account in this research (such as the environmental and social sustainability in the EMAT criteria), the focus of this research was on environmental sustainability. The results, therefore, concentrated on environmental sustainability since they are the most prominent included in EMAT and are most likely to create an impact on the selection of subcontractors and suppliers.
Secondly, only the contractors' perspective is included, as they are the ones in charge of selecting sub-contractors and suppliers.

This master thesis fills the missing link in the literature for the procurement of infrastructure projects with sustainability and the impact on subcontractor and supplier selection. Furthermore, a missing link in the literature is filled when it comes to the distinguishment of different sustainability EMAT criteria in infrastructure tenders

This research, therefore, aims to generate insight into how the EMAT criteria influence the selection of subcontractors and suppliers in such a way that the most (environmentally) sustainable party is selected. In this research the following question was answered:

> *How does sustainable bidding (through EMAT criteria) in infrastructure projects affect contractors' selection of subcontractors and suppliers?*

A qualitative research design was used to answer this question based on a literature review, document research, and multiple case study. The literature review was divided into three subjects. The first subject was a review of the EMAT criteria literature, the second of the selection criteria for subcontractors and suppliers, and the third of trade-offs between the selection criteria. The multiple case study was performed with three different infrastructure cases. In every case, three people involved with the tender of these cases were interviewed. The nine interviews were coded and analyzed with the Atlas.ti tool.

The first literature review (combined with the document research) found that there were 26 different EMAT criteria used by the clients (mostly municipalities) in the Netherlands. From these 26 EMAT criteria, 11 dealt with environmental sustainability, 2 with social sustainability, and the other 13 criteria were put in a miscellaneous category. In the miscellaneous category criteria such as planning, accessibility, or risk management can be found.
The second literature review found 8 different categories of selection criteria for subcontractors and suppliers: cost, experience, level of technology, quality, relationship, safety, sustainability, and time. Based on criteria in these categories contractors select their subcontractors and suppliers for a project.
The third literature review found that the trade-off between cost and sustainability is very important for a contractor when selecting subcontractors and suppliers. Furthermore, it was found that the cost is the most important selection criterion for subcontractors and suppliers. Lastly, it was found that there are multiple ways to measure the sustainability of an infrastructure project: Electrical vehicles or equipment, Economic Cost Indicator (ECI), Life Cycle Analysis (LCA), Dubotool, or CO2 equivalent.

The analysis of the case study found that safety is not a selection criterion on the project level but a pre-selection criterion for subcontractors and suppliers. For the preselection of subcontractors and suppliers, the safety requirements that are needed are the 'Veiligheid, Gezondheid en Milue' (VCA) certification, 'Generieke Poort Instructie' (GPI), and 'Veiligheid in Aanbestedingen' (VIA). Furthermore, a new selection criterion was added to the categories: distance. This was very important in all of the cases. The distance was an important selection criterion for subcontractors and suppliers since it deals with the delivery time, the cost, and the sustainability of the project.
Moreover, the results show that the EMAT criteria influenced the selection of subcontractors and suppliers, especially when it comes to sustainability. The EMAT criteria are an incentive for the contractor to look at the sustainability level and development of the subcontractors and suppliers. When the client asks for sustainability in the tender through EMAT criteria, the contractor will use sustainability as one of the selection criteria for subcontractors and suppliers. Moreover, the importance of the EMAT criteria (read the percentage of deduction of the tender bid) influence the trade-offs between the selection criteria as well. When the deduction for sustainability in the EMAT criteria is higher, the more important the sustainability selection criteria will be in the trade-offs for subcontractors and suppliers.
Another important result from the case study is that both the client and the contractor are responsible when it comes to the transition to a more sustainable infrastructure sector and more sustainable subcontractors and suppliers. The client sets the boundaries and rules for the tenders through the EMAT criteria and provides therefore an incentive for the contractors to look into sustainability. The contractor is responsible for the development and investment of sustainable solutions in cooperation with the subcontractors and suppliers.

A framework was made as a guideline for the contractors and clients in the infrastructure sector, which can be seen in figure 1. The framework is the combined result of the literature study and the case study which explains the selection process of subcontractors and suppliers for an infrastructure tender and the way that EMAT criteria influence this selection, especially when it comes to (environmental) sustainability.

The framework is an overall stepwise selection process for subcontractors and suppliers connected to the currently applied sustainability EMAT criteria. Furthermore, the framework can be used as a guideline for the inclusion of sustainability in the selection of subcontractors and suppliers and the influence the contractor and client have on this process. For example,

the contractor has an overview of the possible EMAT criteria and the influence of these EMAT criteria on the selection criteria for subcontractors and suppliers. Furthermore, the framework shows how to measure sustainability, which can be used in the trade-offs between subcontractors and suppliers. The trade-offs are project specific and will therefore be different for every different tender.

It is recommended to the client and the contractor to have dialogue sessions with each other about the measurement of the sustainable EMAT criteria and the responsibility for the monitoring of this. Making clear how sustainability is measured and what is needed to monitor it, will stimulate the contractors, subcontractors, and suppliers of the infrastructure sector to be more sustainable in the future.
Furthermore, the use of equally weighted sustainable EMAT criteria makes it easier for the contractor to select the most sustainable subcontractor or supplier.
A final recommendation towards the clients of infrastructure projects is that sustainability should be part of EMAT, or part of all present and future contracts in general if we are to achieve sustainability goals for the infrastructure sector, but mostly for the ambitious goals in the Netherlands.

The main recommendation for future academic research is to take the clients, subcontractors, and suppliers' perspectives, into account when looking into the influence of EMAT criteria on the implementation of sustainability in the selection of subcontractors and suppliers..
Furthermore, the differentiation between the influence of different environmental EMAT criteria can be interesting to look into.
Lastly, it would be interesting to perform this study with other contractor companies and more cases to see whether the same results can be found and whether a generalization of the results can be made.

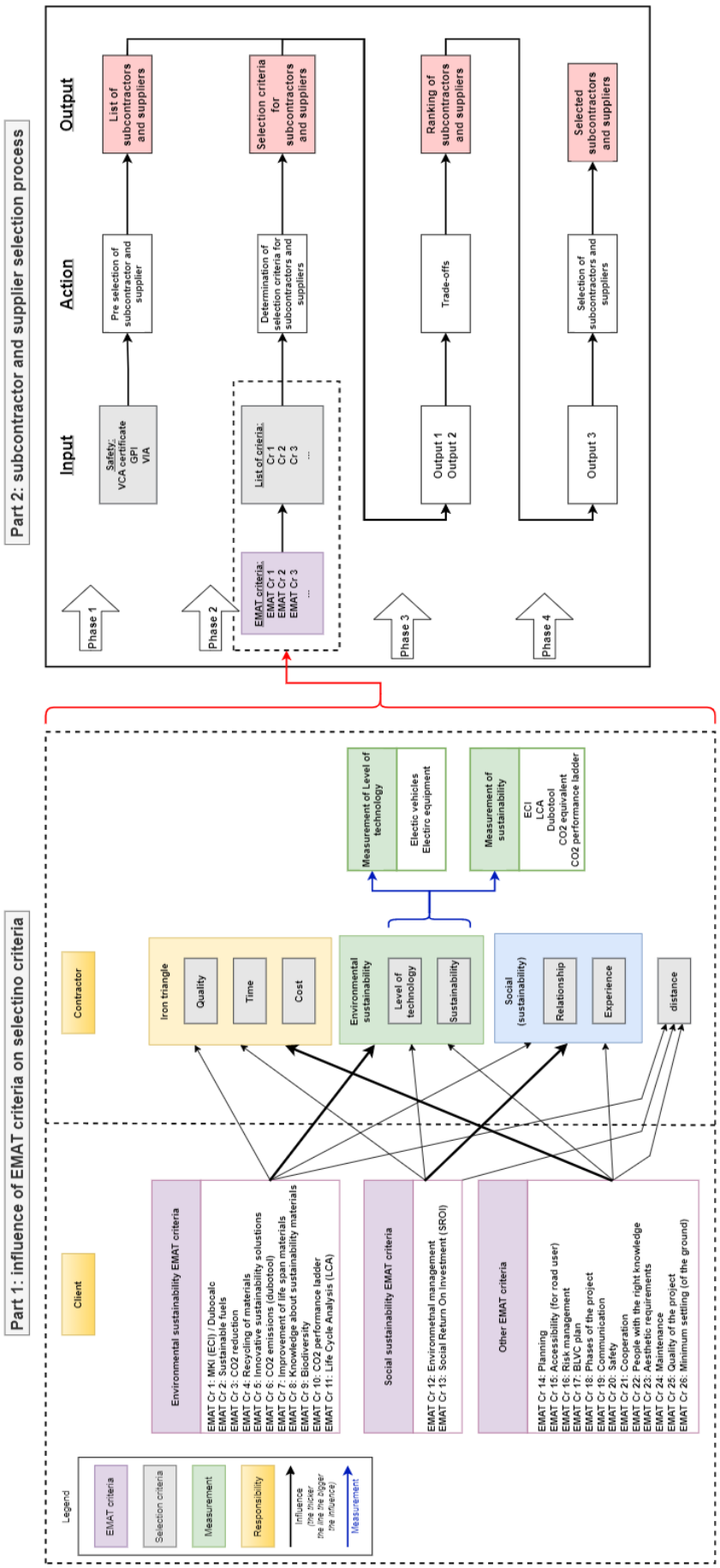

Figure 1: Framework of EMAT influence on subcontractor and supplier selection

Samenvatting

De snel groeiende infrastructuursector heeft een nadelig effect op de klimaatverandering. De infrastructuursector is verantwoordelijk voorongeveer 10% van de wereldwijde uitstoot (United Nations Environment Programme, 2020) . Bovendien is het verantwoordelijk voor een aanzienlijk deel van het houtverbruik, de productie van vast afval, grondstoffen, energieverbruik en wereldwijd watergebruik (Durdyev et al., 2018; (United Nations Environment Programme, 2022).

Er hebben ontwikkelingen plaatsgevonden om duurzaamheid in de bouwsector wereldwijd te implementeren. In de afgelopen jaren is duurzaamheid belangrijker geworden bij de inkoop van infrastructuurprojecten. Een van de manieren om duurzaamheid in infrastructuurprojecten te implementeren, is door gunningscriteria in de aanbestedingsfase van het project (Lenferink et al., 2013; Santen, 2020). Deze gunningscriteria worden EMVI-criteria genoemd, wat staat voor Economisch Meest Voordelige Inschrijving. Op deze manier kan de opdrachtgever of aanbesteder de toegevoegde waarde van de kwaliteit per aannemer bepalen. De EMVI-criteria zijn dus een manier om aan te besteden via de beste prijs/kwaliteitverhouding.

Niet alleen de aannemer wordt aanbesteed door de opdrachtgever, maar ook de onderaannemers en leveranciers van het project worden door de opdrachtnemer geselecteerd. Het selecteren van een geschikte onderaannemer en leverancier zal de professionele dienstverleningsmogelijkheden van de hoofdaannemer aanzienlijk verbeteren (Chen et al., 2020). Ongeveer 80 - 90 procent van de grote infrastructuurprojecten wordt uitbesteed (Ramalingam, 2020). Dit betekent dat om een transitie naar een duurzame sector te hebben, ook de onderaannemers en leveranciers moeten helpen.

Hoewel in dit onderzoek alle gebieden van duurzaamheid zijn meegenomen (zoals de ecologische en sociale duurzaamheid in de EMVI-criteria), lag de focus van dit onderzoek op ecologische duurzaamheid. De resultaten waren daarom gericht op ecologische duurzaamheid, aangezien deze het meest prominent in de EMVI zijn opgenomen en hoogstwaarschijnlijk een impact zullen hebben op de selectie van onderaannemers en leveranciers.
In de tweede plaats wordt alleen het perspectief van de hoofdaannemers meegenomen, aangezien zij degene zijn die verantwoordelijk is voor de selectie van onderaannemers en leveranciers.

Deze scriptie vult de ontbrekende schakel in de literatuur voor de aanbesteding van infrastructuurprojecten met duurzaamheid en de impact op de selectie van onderaannemers en leveranciers. Verder wordt een ontbrekende schakel in de literatuur opgevuld als het gaat om het onderscheiden van verschillende duurzaamheids EMVI-criteria in infrastructuur aanbestedingen.

Dit onderzoek heeft dan ook als doel inzicht te genereren in hoe de EMVI-criteria de selectie van onderaannemers en leveranciers zodanig beïnvloeden dat de meest duurzame partij wordt geselecteerd. In dit onderzoek werd de volgende vraag beantwoord:

> *Hoe beïnvloedt duurzaam bieden (via EMVI-criteria) in infrastructuurprojecten de selectie van onderaannemers en leveranciers door aannemers?*

Een kwalitatief onderzoeksontwerp werd gebruikt om deze vraag te beantwoorden op basis van een literatuuroverzicht, documentonderzoek en meerdere case studies. Het literatuuronderzoek was verdeeld in drie onderwerpen. Het eerste onderwerp was een overzicht van de literatuur over de EMVI-criteria, het tweede van de selectiecriteria voor onderaannemers en leveranciers en het derde van de afwegingen tussen de selectiecriteria. De meervoudige case studie werd uitgevoerd met drie verschillende infrastructuur projecten. In alle gevallen werden drie mensen geïnterviewd die betrokken waren bij de aanbesteding van deze zaken. De negen interviews werden gecodeerd en geanalyseerd met de Atlas.ti-tool .

Uit het eerste literatuuronderzoek (gecombineerd met het documentonderzoek) bleek dat er 26 verschillende EMVI-criteria werden gehanteerd door de opdrachtgevers (veelal gemeenten) in Nederland. Van deze 26 EMVI-criteria gingen er 11 over ecologische duurzaamheid, 2 over sociale duurzaamheid en de andere 13 criteria werden in een diverse categorie geplaatst. In de diverse categorie zijn criteria te vinden zoals planning, bereikbaarheid of risicomanagement. Het tweede literatuuronderzoek vond 8 verschillende categorieën selectiecriteria voor onderaannemers en leveranciers: kosten, ervaring, technologieniveau, kwaliteit, relatie, veiligheid, duurzaamheid en tijd. Op basis van criteria in deze categorieën selecteren aannemers hun onderaannemers en leveranciers voor een project.
Uit het derde literatuuronderzoek bleek dat de afweging tussen kosten en duurzaamheid erg belangrijk is voor een aannemer bij het selecteren van onderaannemers en leveranciers. Bovendien werd vastgesteld dat de kosten het belangrijkste selectiecriterium zijn voor onderaannemers en leveranciers. Ten slotte werd vastgesteld dat er meerdere manieren zijn om de duurzaamheid van een infrastructuurproject te meten: elektrische voertuigen of apparatuur, Milieu Kosten Indicator (MKI), levens Cyclus Analyse (LCA), Dubotool, of CO2-equivalent.

Uit de analyse van de case studie is gebleken dat veiligheid geen selectiecriterium op projectniveau is, maar een voorselectiecriterium voor onderaannemers en leveranciers. Voor de voorselectie van onderaannemers en leveranciers zijn de volgende veiligheidseisen nodig: de 'Veiligheid, Gezondheid en Milieu' (VCA-certificering), 'Generieke Poort Instructie' (GPI) en 'Veiligheid in Aanbestedingen' (VIA). Verder werd een nieuw selectiecriterium aan de categorieën toegevoegd: afstand. Dit was in alle gevallen erg belangrijk. De afstand was een belangrijk selectiecriterium voor onderaannemers en leveranciers, omdat het gaat om de levertijd, de kosten en de duurzaamheid van het project.
Bovendien laten de resultaten zien dat de EMVI-criteria van invloed waren op de selectie van onderaannemers en leveranciers, vooral als het gaat om duurzaamheid. De EMVI-criteria zijn een stimulans voor de aannemer om te kijken naar het duurzaamheidsniveau en de ontwikkeling van de onderaannemers en leveranciers. Wanneer de opdrachtgever in de aanbesteding vraagt om duurzaamheid via EMVI-criteria, zal de opdrachtnemer duurzaamheid gebruiken als een van de selectiecriteria voor onderaannemers en leveranciers. Bovendien is het belang van de EMVI-criteria (lees het percentage korting van de inschrijfsom) ook van invloed op de afwegingen tussen de selectiecriteria. Wanneer de korting voor duurzaamheid in de EMVI-criteria hoger is, zullen de duurzaamheidsselectiecriteria belangrijker zijn in de afwegingen voor onderaannemers en leveranciers.
Een ander belangrijk resultaat uit de case studie is dat zowel de opdrachtgever als de aannemer verantwoordelijk zijn als het gaat om de transitie naar een duurzamere infrastructuursector en duurzamere onderaannemers en leveranciers. De opdrachtgever bepaalt de grenzen en regels voor de aanbestedingen via de EMVI-criteria en stimuleert de aannemers daarmee om te kijken naar duurzaamheid. De aannemer is verantwoordelijk voor

de ontwikkeling en investering van duurzame oplossingen in samenwerking met de onderaannemers en leveranciers.

Er is een raamwerk gemaakt als leidraad voor de aannemers en opdrachtgevers in de infrastructuursector, wat te zien is in figuur 1. Het raamwerk is het gecombineerde resultaat van de literatuurstudie en de case studie die het selectieproces van onderaannemers en leveranciers voor een infrastructuuraanbesteding verklaart en de manier waarop EMVI-criteria deze selectie beïnvloeden, vooral als het gaat om (ecologische)duurzaamheid.

Het raamwerk is een algemeen stapsgewijs selectieproces voor onderaannemers en leveranciers die zijn aangesloten op de momenteel toegepaste EMVI-criteria voor duurzaamheid. Verder kan het raamwerk worden gebruikt als leidraad voor het meenemen van duurzaamheid in de selectie van onderaannemers en leveranciers en de invloed die opdrachtnemer en opdrachtgever op dit proces hebben. Zo heeft de opdrachtnemer een overzicht van de mogelijke EMVI-criteria en de invloed van deze EMVI-criteria op de selectiecriteria voor onderaannemers en leveranciers. Verder laat het raamwerk zien hoe duurzaamheid kan worden gemeten, wat kan worden gebruikt in de afwegingen tussen onderaannemers en leveranciers. De afwegingen zijn projectspecifiek en zullen dus voor elke aanbesteding anders zijn.

Het is aan de opdrachtgever en de opdrachtnemer aan te raden om met elkaar in gesprek te gaan over het meten van de duurzame EMVI-criteria en de verantwoordelijkheid voor de monitoring hiervan. Door duidelijk te maken hoe duurzaamheid wordt gemeten en wat er nodig is om dit te monitoren, worden de aannemers, onderaannemers en leveranciers van de infrastructuursector gestimuleerd om in de toekomst duurzamer te zijn.
Bovendien maakt het gebruik van gelijkgewogen duurzame EMVI-criteria het voor de aannemer gemakkelijker om de meest duurzame onderaannemer of leverancier te selecteren.
Een laatste aanbeveling richting de opdrachtgevers van infrastructuurprojecten is dat duurzaamheid onderdeel moet zijn van EMVI, of onderdeel van alle huidige en toekomstige contracten in het algemeen als we duurzaamheidsdoelen voor de infrastructuursector willen bereiken, maar vooral voor de ambitieuze doelen in Nederland.

De belangrijkste aanbeveling voor toekomstig academisch onderzoek is om rekening te houden met de perspectieven van klanten, onderaannemers en leveranciers bij het onderzoeken van de invloed van EMVI-criteria op de implementatie van duurzaamheid bij de selectie van onderaannemers en leveranciers. Verder kan het onderscheid tussen de invloed van verschillende duurzame EMVI-criteria interessant zijn om naar te kijken.
Ten slotte zou het interessant zijn om dit onderzoek uit te voeren met andere aannemers en meer projecten om te zien of dezelfde resultaten kunnen worden gevonden en of een generalisatie van de resultaten kan worden gemaakt.

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BPQR	Best Price Quality Ratio
BPKV	Beste Prijs Kwaliteit Verhouding
BREEAM	Building Research Establishment Environmental Assessment Method
CEEQUAL	Civil Engineering Environmental Quality Assessment & Award Scheme
CO2eq	CO2 equivalent
Cr	Criteria
ECI	Economic Cost Indicator
EMAT	Economically Most Advantageous Tender
EMAT Cr	Economically Most Advantageous Tender Criteria
EMVI	Economisch Meest Voordelige Inschrijving
GPP	Green Public Procurement
KPI	Key Performance Indicator
LEED	Leadership in Energy and Environmental Design
MEAT	Most Economically Advantageous Tender
MKI	Milieu Kosten Indicator
NPV	Net Present Value
SPP	Sustainable Public Procurement
SQ	Sub-question

01

Introduction

1. Introduction

Climate change is an important subject worldwide. One example of the importance of this subject (within the EU), is the climate conference in Paris in 2015, which states that greenhouse gas emissions must be drastically reduced (Pouikli, 2020). The European Union tries to take the lead in this agreement with innovative ways to reduce GHG emissions in every sector.

The rapidly growing infrastructure sector has a detrimental effect on climate change. The infrastructure sector is responsible for approximately 10% of worldwide emissions (United Nations Environment Programme, 2020). Furthermore, it is responsible for a significant share of timber consumption, solid waste generation, raw materials, energy consumption, and global water use (Durdyev et al., 2018; United Nations Environment Programme, 2022).
Rijkswaterstaat, which is responsible for the infrastructure sector in the Netherlands, aims to operate fully circular and energy-neutral by 2030 (Rijkswaterstaat, 2022), while the EU aims to be energy neutral by 2050 (Government, 2022; Pouikli, 2020). However, implanting energy-neutral ambitions comes with many institutional and market barriers (Djokoto et al., 2014; Kirchherr et al., 2018; Tafazzoli, 2018).

Nevertheless, many developments have taken place to implement sustainability in the construction sector worldwide. In the past years, sustainability became more important in the procurement of infrastructure projects. One of the ways to implement sustainability in infrastructure projects is by award criteria in the tender phase of the project (Lenferink et al., 2013; Santen, 2020). These award criteria are called EMAT criteria, which stands for Economically Most Advantageous Tender. In this way, the client or procurer can determine the added value of the quality per contractor. So, the EMAT criteria is a way of tendering through the best quality/price ratio.

Until April 2013, most of the tenders in the Netherlands were awarded through the lowest-price award method. This means that the contractor with the lowest bid was recognized as the winner (Dreschler, 2009). However, the problem with this way of tendering is the fact that the contractors showed strategic behavior in the construction phase (Dorée, 2004) and did not deliver more than the minimum requirements. This means that the sustainability of the project was most likely not taken into account for the outcome and the cost of the project.

To change the tender procedure and have better outcomes for construction projects, the government of the Netherlands put new contracting regulations in force on the first of April 2013: The procurement law 2012 (in Dutch: De Aanbestedingswet 2012). This obligated Dutch contracting authorities to tender with the Economically Most Advantageous Tender (EMAT) procedure (Ecomonisch Instituut voor de Bouw, 2013).
In the EMAT procedure, not only is the price taken into account, but also the quality is an important part of the tender assessment. There are three types of award criteria when using EMAT in the Netherlands (Rijkswaterstaat, 2017; Pianoo, 2022):

- Best Price Quality Ratio (BPQR) (in Dutch: beste prijs kwaliteit verhouding)
- Lowest cost based on cost-effectiveness (such as lifecycle costs)
- Lowest price

The choice of BPQR as the award criterion is, therefore, according to the Procurement law, the starting point for tendering infrastructure projects (Rijkswaterstaat, 2017).

The Netherlands among other countries such as Croatia and France make the most use of the EMAT tender procedure in their public procurement (Sapir et al., 2022).

Just as there are multiple types of award criteria when using EMAT, there are also multiple categories of dealing with sustainability in the tender procedure. For example, sustainability could be a part of the quality part of the tender, or it could be a separate part of the tender by using tools such as Dubotool or Dubocalc. The Dubotool is a tool to measure the CO2 emissions of the production and transportation of building materials in the infrastructure sector (*Duurzaam Inkopen - Dubotool*, 2022). Therefore, different categories of sustainable EMAT criteria are available in the infrastructure sector and are most likely project-specific.

Not only the contractor is tendered by the client, but also the subcontractors and suppliers of the project material are selected by the contractor. Selecting a suitable subcontractor or supplier will considerably improve the professional services capabilities of the main contractor (Chen et al., 2020). Approximately 80 – 90 percent of large infrastructure projects are subcontracted (Ramalingam, 2020). The contractor chooses subcontractors and suppliers for a project based on a trade-off between costs and benefits (which could be sustainability). Mostly, the subcontractor or supplier that meets the requirements, is trustworthy, but most importantly is known by the contractor, is contracted for the project (Vo et al., 2021). So, the contractor "automatically" chooses the subcontractor with the lowest cost and good previous experience. This does, however, not mean that the best suitable candidate (in terms of sustainability) has been chosen. Some subcontractors or suppliers are more sustainable than others but are not chosen because they are more expensive to hire.
However, the subcontractors and suppliers in the infrastructure sector need to scale up when it comes to sustainability, to help the infrastructure shift towards a sustainable sector. Therefore, this thesis is looking into the subcontractor and supplier selection process by contractors.

1.1 Problem statement

Lots of research has been performed on the procurement of projects and the way sustainability has contributed to this procurement process and outcome (Limpers, 2020; Santen, 2020).

Santen (2020) looked into the role of relational governance when using EMAT criteria to achieve sustainability. This research concludes that relational governance can play a role in achieving sustainability by using EMAT criteria. The research, however, did not look at the effectiveness of the way EMAT criteria are asked in a tender on the sustainability of the project. Dreschler (2009) and Limpers (2020) mentioned the lack of knowledge about the effect of the tender method on sustainability in the realization phase of the project. Although measurement systems such as CO2 performance ladder, LEED, BREEAM, and CEEQUAL[1] are used to measure sustainability (Lenferink et al., 2013), there is also a lack of monitoring environmental performance and research about the measurement of environmental performance (Cheng et al., 2018; Limpers, 2020). This lack is detrimental to the sustainability goals of public procurement (Andhov et al., 2020). This lack also exists for the sustainability of the subcontractor and/or supplier (Mokhlesian, 2014).

Born (2019) investigated the (mis)alignment between tenders and the execution phase. This study concluded that strategic behavior and (the underlying stimulation of strategic behavior) change in circumstances are the most common causes of misalignment. It is recommended to look into whether the improved alignment of promised measures vs additional value results from increased communication between the parties throughout both the tender and execution phases (Born, 2019). This means that better communication could also lead to better-added value by the subcontractor or supplier of the project.

The literature states that when it comes to sustainability in the supply chain there is always a tradeoff between sustainability and costs (Giunipero et al., 2012; United Nations Environment Programme, 2021). Most companies share the ambition of sustainability in the infrastructure sector, but when the cost is too high, not every company follows through with this ambition. However, in some situations, the costs could be reduced by being sustainable. For example, recycling material or utilizing the same equipment for the supply and discharge of materials.

In conclusion, there is a lack of research about the impact of sustainable tendering (with EMAT criteria) on and the monitoring of sustainability of the subcontractor and supplier selected by the contractor. There needs to be more research on this topic to have a better understanding of the inclusion of sustainability in the infrastructure sector.

[1] There are multiple environmental measurement or rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), and CEEQUAL (Civil Engineering Environmental Quality Assessment & Award Scheme) (Arts & Faith-Ell, 2012). BREEAM is an environmental assessment method and system for buildings. It is based on a certification system and applied in housing projects but also sustainable neighborhoods (Dutch Green Building Council, 2018). LEED is a rating system for green buildings. CEEQUAL is an assessment and awards scheme based on a self-assessment carried out by trained assessors (Arts & Faith-Ell, 2012). Applied in housing and infrastructure projects (Arts & Faith-Ell, 2012). In the Netherlands, various specific approaches have been developed such as the “CO2-Ladder” (by ProRail) focusing on CO2 emissions, and “DuBoCalc” or “Dubotool” focusing on sustainable (re)use of materials as both are applied in the Dutch infrastructure sector (Arts & Faith-Ell, 2012).

1.2 Research gap

1.2.1 Research gap and theoretical relevance

In the past years, academic research has been focused on the procurement part of the infrastructure project life cycle when it comes to sustainability (Born, 2019; Limpers, 2020; Santen, 2020). However, there is still a missing link between the subcontractors and suppliers and the sustainability of tendered projects.

Santen (2020) concluded that further research is needed into the categorization of EMAT criteria: “It might be relevant to see what the effectiveness is of the way in which sustainability is asked in MEAT [is the same as EMAT] criteria”.

The same is concluded by De Klein (2018), who states that it is not clear whether abstract sustainability goals, such as reducing CO2 emissions, are more or less effective than more concrete sustainability goals, such as the use of the energy-neutral product or improved energy efficiency. Also here the effect of the categorization of sustainability criteria or goals is not clear and more research is needed on this topic.

Moreover, Bos (2019), concluded that a change towards a more sustainable sector will have a different impact on bigger contractors than on smaller contractors. Therefore, it is recommended to find out what the differences are and how to support the smaller companies in the transition (Bos, 2019). Those smaller companies could also include subcontractors. Furthermore, Testa et al. (2015) conclude that further research is needed on both the award notices and the tendering documents, to assess whether environmental factors had an impact on contract award choices. So, research about the impact of environmental factors (read EMAT criteria) on the selection of subcontractors and suppliers (contract award choices) is needed.

According to Georghiou et al. (2014), policy design as a whole lacks a “clear theoretical or empirical basis for understanding how supplying to the public sector actually influences a firm's innovation capabilities and performance and in what ways desirable behavior and outcomes can be promoted.”. The outcome of the selection of subcontractors and suppliers can be of influence of the performance of the contractor towards the public sector or the client. This is because the subcontractors and suppliers are needed for the project and are therefore factors that can influence the performance or outcome of a project (Chen et al., 2020). So, choosing the right subcontractor or supplier can influence the outcome and performance of the project.

This master thesis, therefore, fills the missing link in the literature for the procurement of infrastructure projects with sustainability and the impact on subcontractor and supplier selection. Furthermore, a missing link in the literature is filled when it comes to the distinguishment of different sustainability EMAT criteria in infrastructure tenders. Moreover, the outcome of this research can stimulate future research about the inclusion of sustainability in subcontractor and supplier selection.

1.2.2 Practical relevance

During the construction of infrastructure projects, lots of contractors, subcontractors, and suppliers work on the project. For the contractors (and the client) it is important to share (sustainable) ambitions with all those parties working on the same project. Since sustainability is particularly important nowadays to contractors and clients, they should also take the subcontractors and suppliers into account when it comes to the procurement of infrastructure

projects. With the data from this research, new ways or incentives for the most sustainable subcontractor and supplier selection can be created in cooperation with Heijmans (see chapter 1.6 for an introduction to the facilitating company).

1.3 Research objective

The objective of this research is to explore the effect of sustainable EMAT criteria on the subcontractor and supplier selection by the contractor. So does the sustainable EMAT criteria lead to more sustainable selection criteria for the subcontractor and supplier? The purpose of this objective is to find out whether public tender strategies such as EMAT can help with the transition towards a more sustainable infrastructure sector, especially for the subcontractors and suppliers. This research is conducted at a contractor firm from the perspective of a contractor.

Schöttle & Gehbauer (2013) and Born (2019) state that when a tender is won by a bid based on the lowest price, negative incentives are set which lead to uncooperative behavior and non-collaboration. Furthermore, criteria based on minimum requirements don't enable companies to stand out concerning sustainability (Melissen & Reinders, 2012). It is challenging for contractor companies to foresee what would be the ideal "direction" for new projects and innovations that exceed those minimal standards (Melissen & Reinders, 2012).

Moreover, Santen (2020) states that EMAT criteria should serve as an incentive for the contractor's creativity, cooperation, and therefore also the sustainability of the projects. Furthermore, Nasiche & Karanja Ngugi (2014) found in their case study that the internal green capacity, incentives, and pressures influenced the implementation of environmental criteria in tenders.
Nevertheless, award criteria are a useful tool for ensuring sustainability in supply chains, but they should contain more sustainable-focused criteria (Testa et al., 2015).

Therefore, this thesis hypothesizes that when there is an incentive (through EMAT criteria) for the contractor to be more sustainable, the selection criteria applied in the subcontractor and supplier selection will be more sustainable as well.

Findings of this thesis are shown in a framework to give an overview of the way that EMAT criteria possibly influence the selection of subcontractors and suppliers. Furthermore, the findings are used to provide recommendations to improve the subcontractor and supplier selection when it comes to sustainability. Improving the selection of subcontractors and suppliers should lead to more sustainable stakeholders for an infrastructure project.

1.4 Research scope

1.4.1 Definition of sustainability

Sustainability does not have a clear definition in the literature (Kuhlman & Farrington, 2010). However, there are three key dimensions in the concept of sustainability: Economic, environmental, and social (Adetunji et al., 2003; Hajian & Kashani, 2021). Economic sustainability is the construction sector's contribution toward high economic growth and

improvement of project delivery. Environmental sustainability is the impact of construction activities on the environment. Social sustainability is about the (ethical) obligations of the construction industry towards its stakeholders and the environment in which it operates (Adetunji et al., 2003). The idea of sustainability having three dimensions stems from the Triple Bottom Line concept, coined by Elkington (Elkington, 1994).

The United Nations (2022) gives the following definition of Sustainable infrastructure:

> "Sustainable infrastructure (sometimes also called green infrastructure) systems are those that are planned, designed, constructed, operated, and decommissioned in a manner that ensures economic and financial, social, environmental (including climate resilience), and institutional sustainability over the entire infrastructure life cycle. Sustainable infrastructure can include built infrastructure, natural infrastructure, or hybrid infrastructure that contains elements of both."

This definition of sustainable infrastructure incorporates the three major elements of sustainability, but it's also worth noting that they describe sustainable infrastructure across the whole infrastructure life cycle. This research focuses on the upstream of the life cycle (see figure 2), explicitly the procurement phase. This is because the subcontractor and supplier selection (by the contractor) take place during the procurement phase of a project. Furthermore, the focus of this research is on the environmental dimension, to delineate this research and make it more manageable.

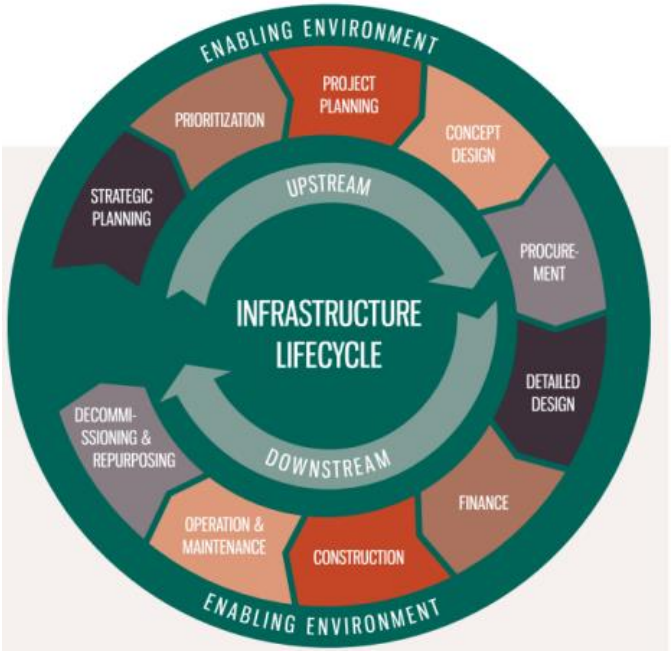


Figure 2: The infrastructure life cycle (source: United Nations Environment Programme, 2022).

1.4.2 Focus on the contractor perspective

The contractor perspective is chosen since there is a lack of contractor perspective in the literature and to make the research more manageable. Moreover, all the data for this research (think about documentation and interviews) will be collected from the Dutch contactor Heijmans. Therefore, only the contractors' perspective will be considered in this research.

1.4.3 Scope of research method

In this research, the scope of the case studies is focused on the tender phase of a project. So the execution or the initiation phases are not taken into account when looking at the influence

of EMAT criteria on the selection of subcontractors and suppliers. The literature review is needed to provide the EMAT criteria and the selection criteria of subcontractors and suppliers. Moreover, the contractor documentation and the interviews are needed to provide additional information about the EMAT criteria and selection criteria and contextual factors such as the reasoning behind the selection of subcontractors and suppliers.

1.5 Research questions

This research aims to investigate the effectiveness of procurement for sustainability in the subcontractor and supplier selection by the contractor. In this research is sustainability defined as environmental (see chapter 1.4.1 Definition of sustainability for explanation). This research aims to answer the following research question (RQ):

> **How does sustainable bidding (through EMAT criteria) in infrastructure projects affect contractors' selection of subcontractors and suppliers?**

The end result of this thesis are shown in a framework to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers. The following four sub-questions are used to help answering the main question of this research:

SQ1: Which (sustainability) criteria are used in the tender of infrastructure projects to achieve environmental sustainability?

The first sub-question aims to find the type of criteria that are used in the tender of infrastructure projects to have a clear overview of the different possibilities of sustainable tendering. This question also explains the EMAT tender and the sustainability in the infrastructure sector. Furthermore, this question results in recommendations in the use of the different sustainable EMAT criteria.

SQ2: How do contractors select their suppliers and subcontractors in the infrastructure sector?

The second sub-question tries to find criteria for subcontractor and supplier selection in the infrastructure sector to have a clear overview of the criteria used for supplier selection when it comes to sustainability.

SQ3: What is the existing trade-off between cost and the level of sustainability?

The third sub-question is to determine how to assess subcontractor and supplier selection when it comes to environmental sustainability. This sub-question consists of three parts:

a. What measurement is available for sustainability?

This part is important to know how to measure environmental sustainability. Answering this part of sub-question 3 provides this research with tools to measure sustainability in the next research question.

b. What are the measurable aspects of sustainability (qualitative and quantitative)?

Furthermore, it is important to know what the measurable aspects of sustainability are. Think about Key Performance Indicators (KPIs) such as 'Environmental Cost Indicator (ECI) (in Dutch 'Milieu Kosten Indicator' (MKI)) or CO2equivalent.

c. A trade-off between the financial part (the costs) of sustainability and the level of sustainability

Not only the measurement of sustainability is important in this third research question, but also the trade-off between the cost of a project and the sustainability of a project. Understanding the choices that are made based on this trade-off (and the incentives that play a role in this trade-off) helps answer the question.

SQ4: To what extent are sustainable EMAT criteria taken into account by the contractor during the selection of subcontractors and suppliers?

This last sub-question tries to find empirical evidence of the influence of sustainable tender criteria on supplier selection.

An overview of what the sub-question deal with when it comes to the tender process can be found in figure 3. So the first sub-question is about the EMAT criteria (especially environmental sustainability). The second sub-question aims to find the selection criteria for the subcontractor and the supplier. The third sub-question concerns the measurement of sustainability and the tradeoff between sustainability and the cost of a project. The measurement and the trade-offs off (sustainable) selection criteria for subcontractors and suppliers are mentioned together, because the measurement is an important input for the trade-offs. And the fourth sub-question is about the "end result", so the degree of taking sustainable criteria (influenced by the EMAT criteria) into account when it comes to supplier and subcontractor selection.

With all these 4 sub-questions answered, the main question can be answered. This research results in recommendations to the infrastructure sector about the influence of EMAT criteria on supplier and subcontractor selection. Moreover, based on the results of this study, a framework is proposed to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers by the contractors.

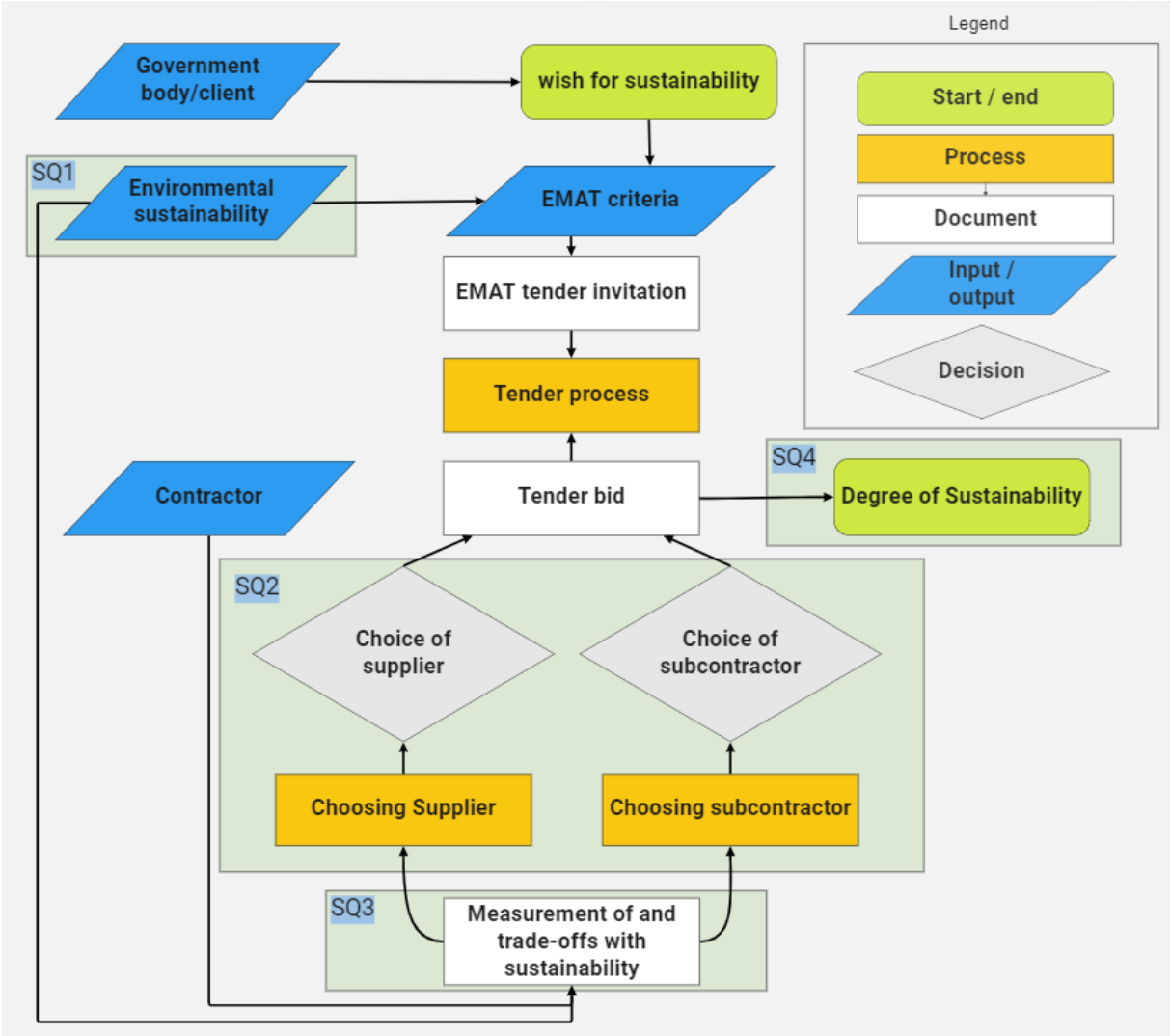


Figure 3: An overview of sub-questions in the tender process

1.6 Facilitating company: Heijmans

This thesis is facilitated by the tender department of Heijmans infra. Heijmans infra is part of Heijmans N.V. employing almost 5.000 people (Heijmans, 2022, b). Heijmans Infra concentrates on building, enhancing, and maintaining Dutch road infrastructure and public spaces, including related installations and site-specific artifacts (Heijmans, 2022, c). Roads, viaducts, tunnels, locks, water treatment facilities, work on cables, pipelines, and energy supplies are all included in this (Heijmans, 2022, c).

Additionally, Heijmans Infra can approach and carry out infrastructure projects in an integrated manner because of the different work disciplines it has on staff, ensuring that design, realization, and management & maintenance are all properly coordinated (Heijmans, 2022, c).

This research is interesting for the company Heijmans since they aim to become CO2-neutral and make energy-neutral solutions for their clients from 2023 onwards (Heijmans, 2022, d). See figure 4 for a representation of the reduction of CO2 emissions by Heijmans in the past few years. However, they cannot do it alone. As Heijmans state: "we will only achieve our objectives if we include colleagues and our cooperation partners in making our activities more sustainable" (Heijmans, 2022, b) (Dutch: We halen onze doelstellingen pas als we collega's en onze samenwerkingspartners meenemen in de verduurzaming van onze activiteiten).
Therefore, they are interested in finding out how to make the selection of subcontractors and suppliers as sustainable as possible.

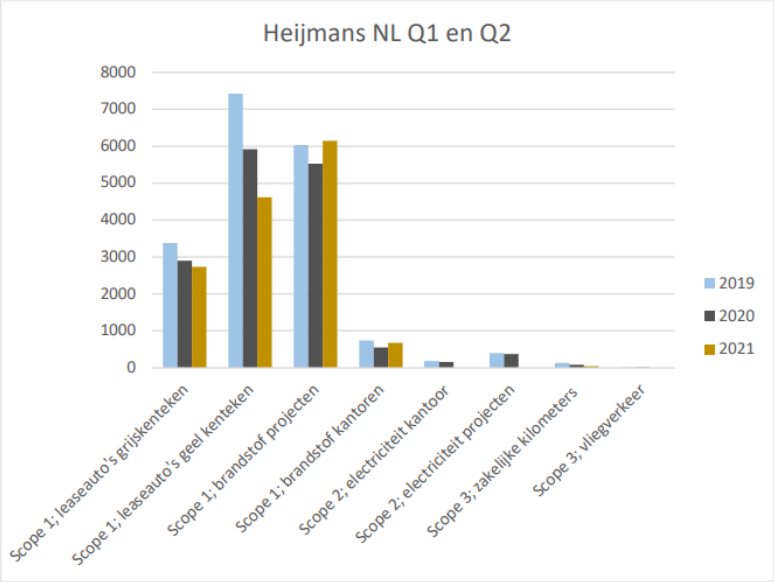


Figure 4: CO2 emission of Heijmans in Q1 and Q2 2021. Source: (Heijmans, 2022, a)

1.7 Structure of the thesis

This thesis is structured as followed: Chapter 2 describes the research methodology. Chapter 3 provides a theoretical background of the sustainable EMAT criteria in infrastructure projects and criteria for subcontractor and supplier selection. The fourth chapter gives an overview of the measurement (tools) of sustainability in the infrastructure sector with the measurable aspects of sustainability. This chapter results in a framework of sustainable EMAT criteria, subcontractor and supplier selection criteria, and the measurement of sustainability and the link between them.
Chapter 5 covers the case studies. In this chapter, three cases were used to find out in what way the different kinds of sustainable EMAT criteria influence the subcontractor and supplier selection for that specific case. In this chapter a framework is proposed to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers.
After this, the discussion and limitations are covered in chapter 6, and the thesis ends with a conclusion and recommendations in chapter 7.
An overview of the thesis outline and the chapter where the questions are discussed can be found in figure 5.

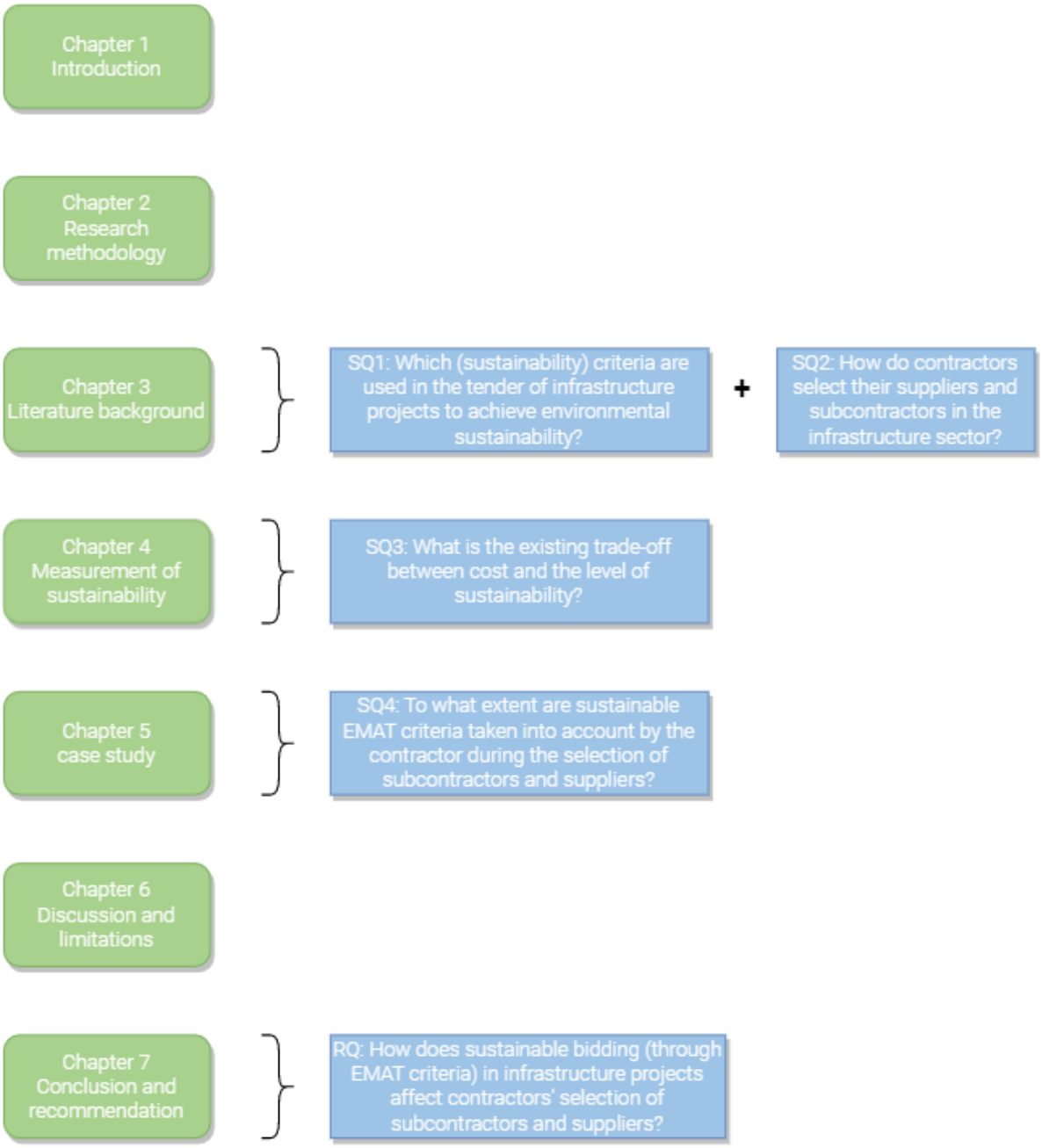


Figure 5: Thesis outline and questions

02

Research Methodology

2. Research methodology

2.1 Overview of methodologies

This is a qualitative research and to answer the (sub) question(s) multiple methods were used (see table 1 and figure 6 for all the methods used to answer the research questions).
This research is qualitative because it relies on qualitative data such as interviews and reports. However, quantitative data is also used to answer the first sub-question.

To answer the first two sub-questions desk research was performed by an extensive literature review and documentation from Dutch infrastructure projects, to give an overview of what the categories of sustainability criteria are in the procurement of infrastructure projects and to give an overview of what the selection criteria for subcontractors or suppliers are.
For the third sub-question, also an extensive literature review was performed to find measurements of the effectiveness of sustainability criteria on the supplier and subcontractor selection and the trade-offs between the selection criteria.
These three questions result in a conceptual framework of how the selection process of subcontractors and suppliers is influenced by the selection criteria and the EMAT criteria taking trade-offs into account.
For the final sub-question, a multiple case study was performed with three cases to explore the effect of the categories of sustainable EMAT criteria and the influence on the subcontractor and supplier selection. In the case study, a total of 9 people were interviewed to find an explanation for the influence of EMAT criteria. After answering this question, a framework is proposed to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers.

Table 1: Summary of research method

	SQ1	SQ2	SQ3	SQ4
Input	Literature on EMAT criteria in the infrastructure sector, and tender documents from Dutch infrastructure projects	Literature on subcontractor and supplier selection, and procurer documents from Dutch infrastructure projects	Literature on sustainability measurement and frameworks of SQ1 and SQ2	Frameworks and overview of EMAT criteria, subcontractor and supplier selection, and sustainability measurement
Research method	Literature study and desk research	Literature study and desk research	Literature study and interviews	Case study with interviews
Output	A framework of sustainable EMAT criteria	A framework of sustainable subcontractor and supplier selection criteria	Overview of how contractors can measure the sustainability of subcontractors or supplier	A proposed framework of the effectiveness of EMAT criteria on the sustainable selection of subcontractors and suppliers

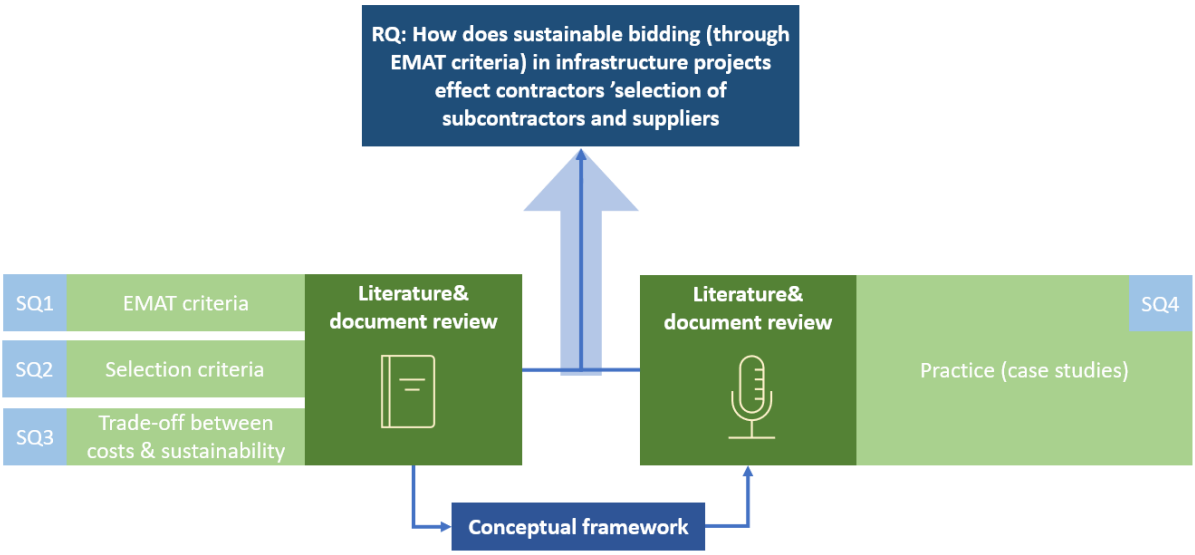


Figure 6: Research methods

2.2 Documentation Research

Documentations from the tenders such as the invitation to bid (from the client) and the bid self of the contractor are used to find the information needed to answer sub-question 1. In these documents, the categorization of sustainability in tenders can be found as the way contractors deal with these categories (of sustainability). Within the database of tender documents, a selection of 64 projects was made. The selection was made on the following criteria: it must be an infrastructure project, between 2018 and 2022 and the award criteria of the tender must be based on EMAT criteria (more specifically: price to quality ratio and quality to price ratio were used as one of the criteria (see chapter 3.1 for explanation)). These criteria were chosen for the tender documents to find data as recent as possible within the scope of this thesis.

2.3 Literature review

The literature review is performed based on the PRISMA model. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) model was designed to help systematic reviewers transparently report why the review was done (Page et al., 2021). This model was used to have a structured way of doing a literature review.

The first step of the literature review is finding the right keywords to use. To do this VosViewer is used. Vosviewer is a software tool for constructing and visualizing bibliometric networks. In Scopus, papers were found within the public construction and sustainability area and these papers were used as input for the VosViewer analysis. In figure 7 can be seen that the most often used keywords were sustainable development, sustainability, construction industry, and public procurement. Furthermore, it is noticeable that they are the center of the green, red, purple, and blue clouds, so the words within their clouds are often associated with them (read: there is a great co-occurrence between those keywords in papers). After analyzing this network of keywords within the public construction and sustainability areas, the following keywords were used for the literature review for respectively research questions 1,2 and 3:

- Dutch "public procurement" AND emat criteria AND infrastructure AND "sustainable procurement" AND environmental and economic sustainability
- "subcontractor selection" AND "supplier selection" AND infrastructure AND green procurement
- measurement of sustainability AND sustainability KPI AND sustainability tradeoffs AND "infrastructure sector"

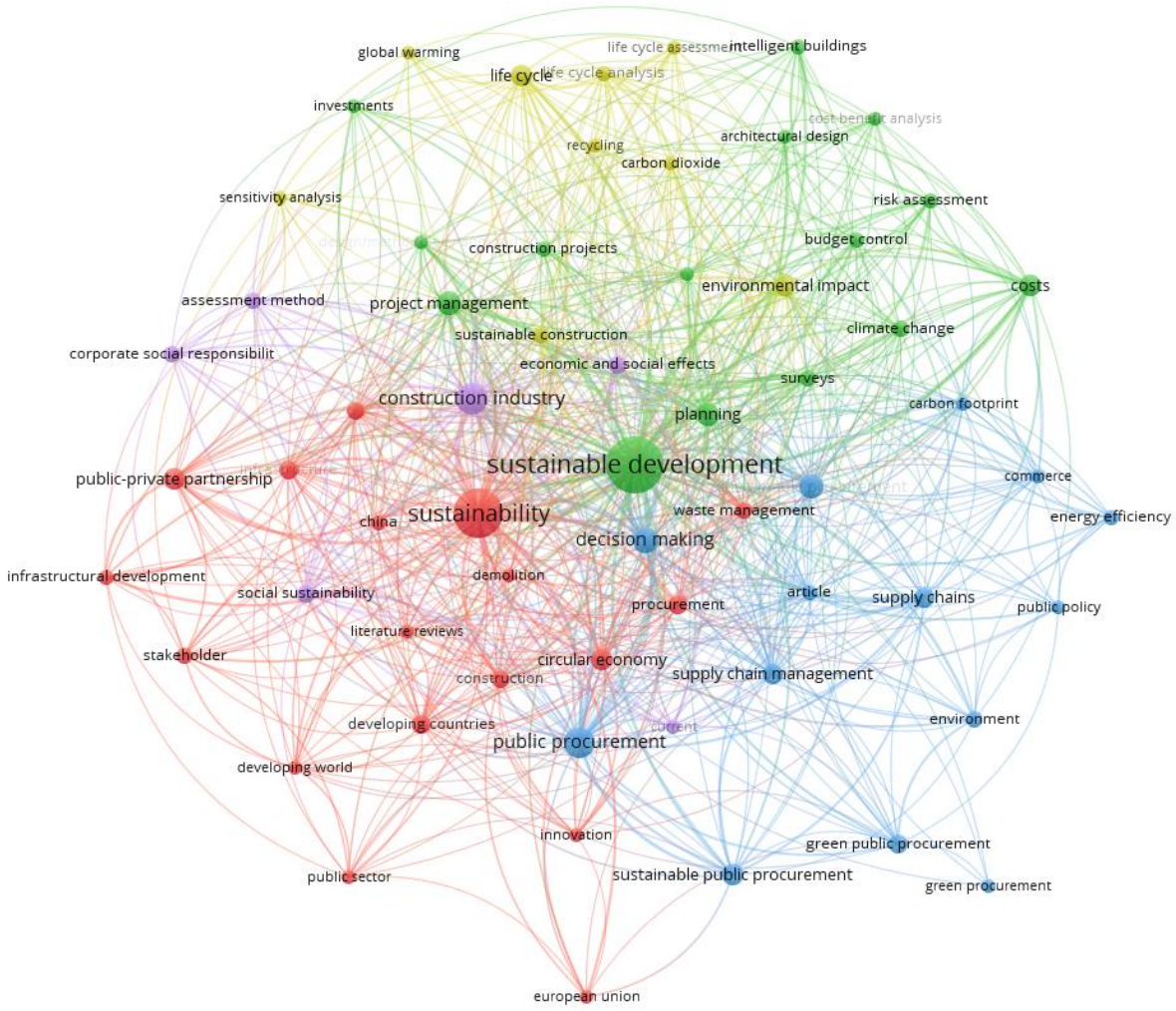


Figure 7: Output of the Vosviewer analysis

After finding the right keywords, the relevant articles were retrieved via Google Scholar. When using these keywords, an amount of respectively 247, 148, and 311 papers was found for the three sub-questions. Lots of papers were eliminated when looking at the titles and abstracts of the papers. A large number of papers were not included in the literature review (as indicated in table 2), since the subject of the papers was the food industry. This was expected since the four essential sectors for sustainable procurement are construction, transport, food, and electrical products (Yu et al., 2020).
The number of papers used in the literature review can be found in table 2. Furthermore, the literature review process for SQ1, SQ2, and SQ3 can be found in respectively figures 8, 9, and 10.

Table 2: Key words and amount of papers used for the literature review

Research question	Keywords	Google Scholar	Papers after elimination
SQ1	Dutch public procurement EMAT criteria infrastructure sustainable procurement environmental and economic sustainability	247	28
SQ2	subcontractor selection supplier selection infrastructure green procurement	148	25
SQ3	measurement of sustainability sustainability KPI sustainability trade-offs infrastructure sector	311	20
Total	-	-	73

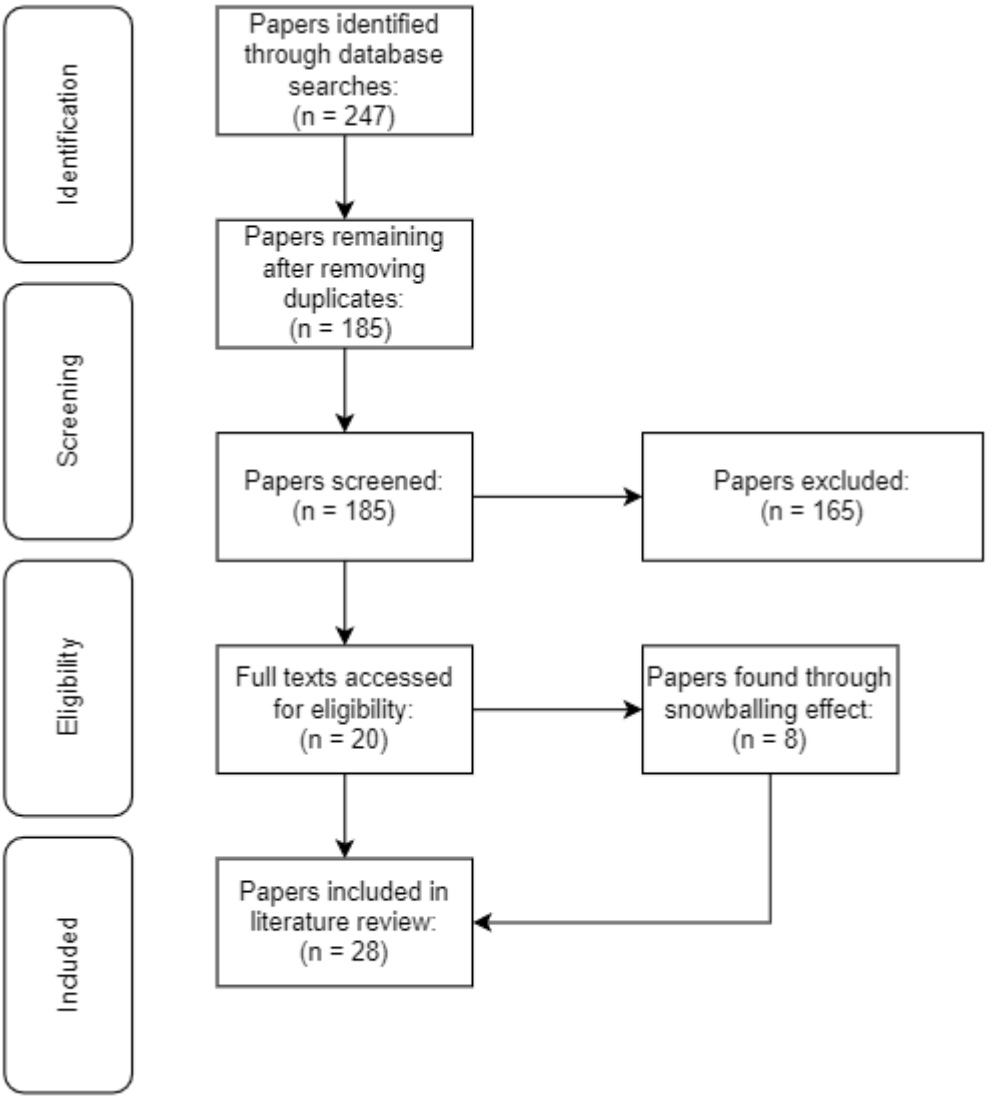


Figure 8: Literature review process SQ1

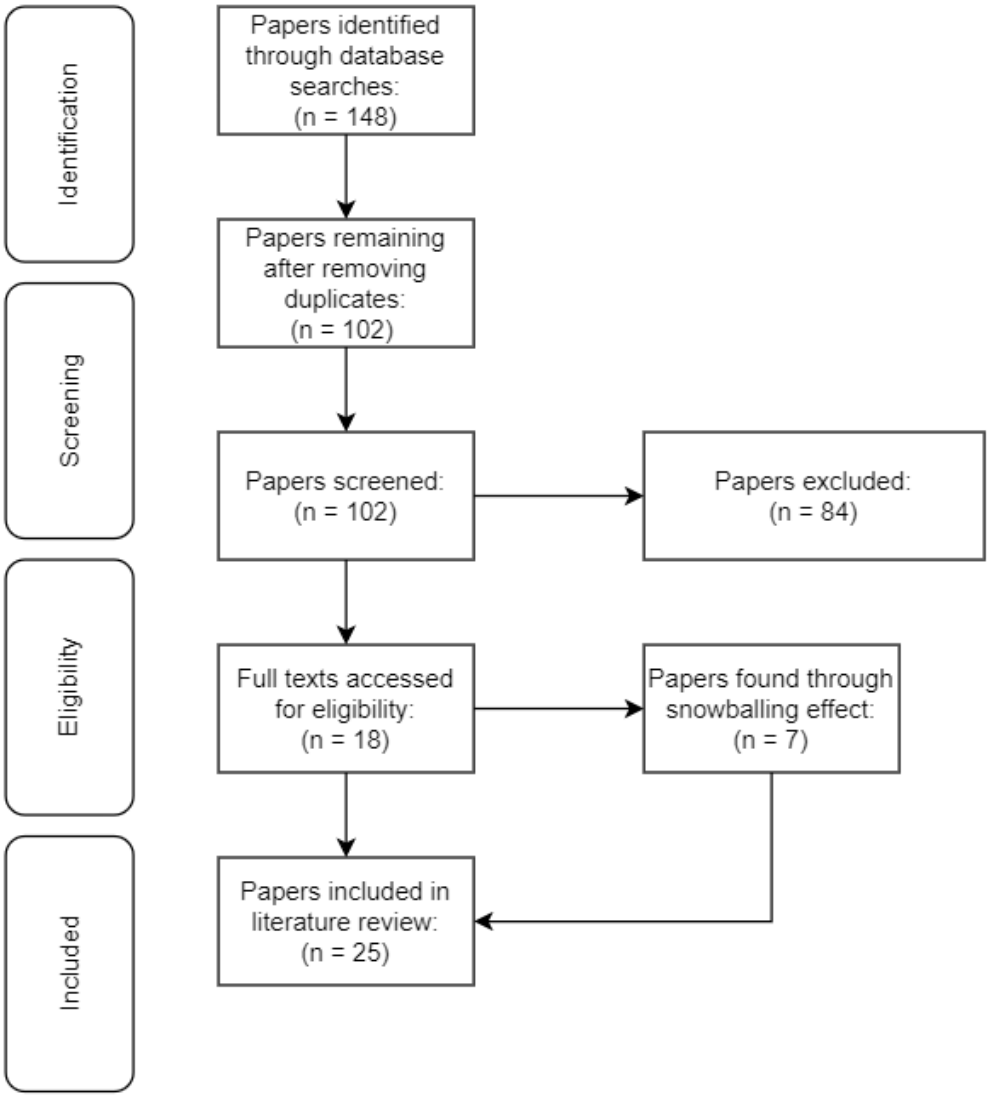


Figure 9: Literature review process SQ2

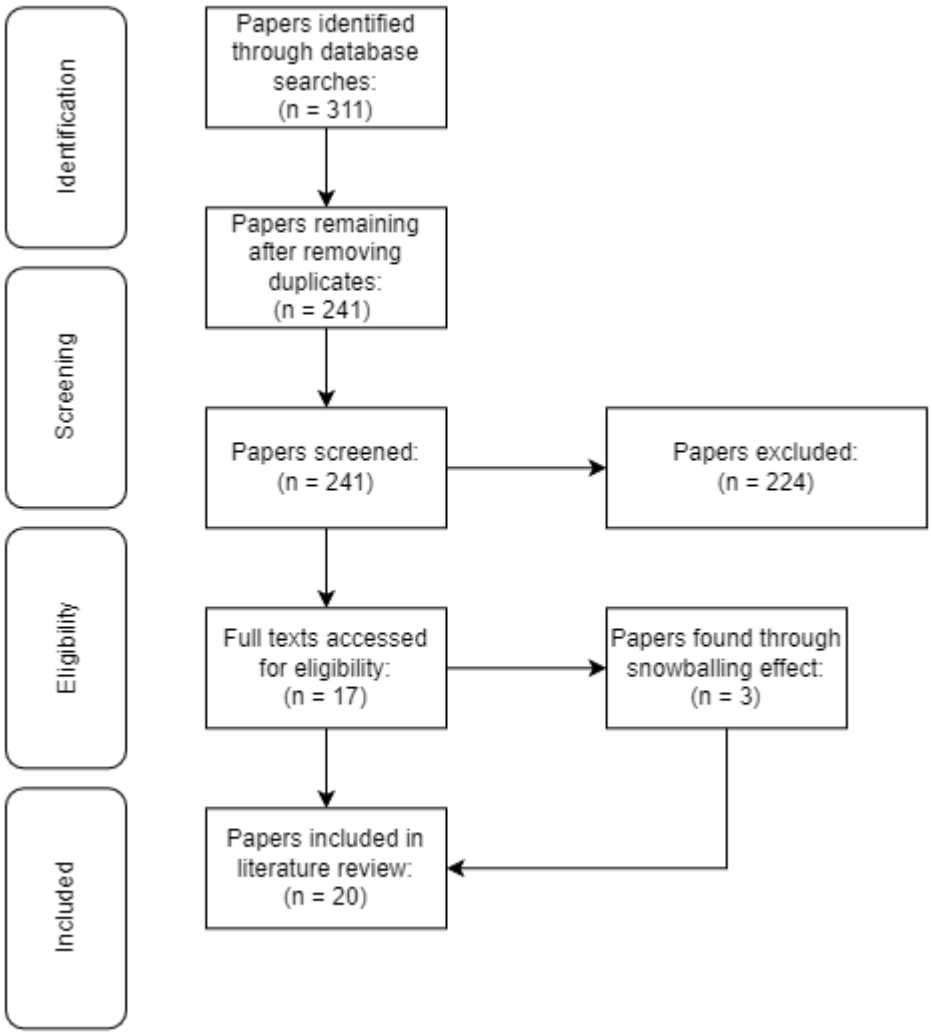


Figure 10: Literature review process SQ3

2.4 Case study

A case study is performed in this research to look into to what extent the EMAT criteria influence the selection criteria of supplier and subcontractor selection. The first step of the case study was the documentation research in chapter 3.3.1. The next step was the selection of three cases from the documentation research (64 potential cases) on the bases of the following criteria:

- Integrated contract
- (Sustainability) criteria in the EMAT tender
- Road infrastructure projects
- Budget (no less than €200.000)

The budget was taken into account for the cases since the results of the studies by Fuentes-Bargues et al. (2017, 2018) show that there is a relationship between the project budget and the use of environmental criteria as award criteria. When the budget is above €10.000.000 the environmental criteria are widespread, but when the budget is below €200.000 such criteria are less used (Fuentes-Bargues et al., 2017, 2018)

The cases selected based on the criteria mentioned above are presented in an overview in table 3.

Table 3: Overview of cases for case study

Case	Name and client	Assets
A	Bezuidenhout, Den Haag	Sewage and refurbishment of streets
B	Middenboulevard, Scheveningen	Refurbishment of public area
C	Woonrijpmaken Binnentuin, Beverwijk	Site preparation of an area

The cases were chosen in a way that it can be tested whether the (sustainable) EMAT criteria influence the supplier and subcontractor selection by the contractor. The award criteria for case 1 include sustainability for the suppliers and subcontractors in the award criteria. The award criteria for case 2 do take sustainability into account for the award criteria but not the suppliers or subcontractors. And case 3 does not take sustainability into account at all for the award criteria.

The next phase of the case study is in-depth research. For every case, the tender documents were used to find information about the tender, such as EMAT criteria and the way the contractor selected the subcontractors and suppliers for the project. These documents were input for the last phase of the case study: semi-structured interviews.

2.4.1 Semi-structured interviews

For the last part of the case study, semi-structured interviews were held. The semi-structured interview method was used, because information was needed that could not be found in the documentation, but can be explained by the experience of the people involved in the tender. Furthermore, semi-structured interviews were used, so that there is space for new ideas to emerge during the interview. The interviews took 30-45 minutes.

Since the semi-structured interviews dealt with the influence of the EMAT criteria on the selection criteria of the subcontractors and suppliers, two main themes were covered in the interview questions. The first theme of the interview for the case study was about the (sustainable) award criteria of the contract and the supplier and subcontractor selection criteria. The second theme of the interview was about the trade-off between cost and the level of sustainability where the conceptual framework of SQ1, 2, and 3 was the basis for the interview questions (see appendix A for the interview questions).

The interviews were held with involved people from the contractors' perspective. For every case, one tender manager, one construction manager, and one procurer were interviewed because all these people are involved with the tender of one of the three cases. Through the different cases, it can be tested whether the suppliers and subcontractors are chosen on different (sustainability) criteria when the (sustainability) award criteria for the tender differs.

Table 4: Overview of interviewees and way of conducting interviews

Interviewees position in company	Way of conducting interview
Tender manager case A	Microsoft Teams
Project manager case A	Face-to-face
Procurer case A	Face-to-face
Tender manager case B	Microsoft Teams
Project manager case B	Face-to-face
Procurer case B	Microsoft Teams
Tender manager case C	Face-to-face
Project manager case C	Microsoft Teams
Procurer case C	Microsoft Teams

The interviews were conducted face-to-face or through Microsoft Teams (see table 4). All interviews were conducted by one interviewer and recorded and transcribed for further analysis. All the data was compared and analyzed based on different and similar answers for each interview question to find patterns. The transcribed interviews were analyzed through Atlas.ti. The coding in the Atlas tool existed of 20 different codes to make a structured overview of the results of the interviews (see appendix B for the full coding list).

The cases were compared, based on the criterion used for the supplier and subcontractor selection in combination with the EMAT criteria for each project. Furthermore, the results from the interviews were used to find an explanation of the differences (or similarities) between the cases.

03

Literature Review
Conceptual Framework

3. Literature Review and Conceptual Framework

In this chapter, a conceptual framework of the influence of selection criteria (and indirect EMAT criteria) on the selection of subcontractors and suppliers is proposed. To make this conceptual framework, the first two sub-questions were answered (SQ1: *Which (sustainability) criteria are used in the tender of infrastructure projects to achieve environmental sustainability?*; SQ2: *How do contractors select their suppliers and subcontractors in the infrastructure sector?*). First, to answer SQ1, the tender of infrastructure projects in the Netherlands is explained (chapter 3.1) followed by the sustainability in the infrastructure sector (chapter 3.2). This was complemented by the findings from the literature and the use of (sustainable) EMAT criteria from the analyzed tender documents (chapter 3.3).
For the second sub-question, chapter 3.4 discuss the results from the literature review about selection criteria for subcontractors and suppliers. The output of the two sub-questions was input for the conceptual framework (chapter 3.5).

3.1 Tender of infrastructure projects in the Netherlands

To answer sub-question 1 it is needed to know what the tender procedures are in the Netherlands and how they are used for the tender of infrastructure projects.

Until April 2013, most of the tenders in the Netherlands were awarded through the lowest-price award method. This means that the contractor with the lowest bid was recognized as the winner (Dreschler, 2009). However, the problem with this way of tendering is the fact that the contractors showed strategic behavior in the construction phase (Dorée, 2004) and did not deliver more than the minimum requirements.
To change the tender procedure and have better outcomes for construction projects the government of the Netherlands put new contracting regulations in force on the first of April 2013: The procurement law 2012 (in Dutch: De Aanbestedingswet 2012). This obligated Dutch contracting authorities to tender with the Economically Most Advantageous Tender (EMAT) procedure (Ecomonisch Instituut voor de Bouw, 2013).
In the EMAT procedure, not only is the price taken into account, but also the quality is an important part of the tender assessment. There are three types of award criteria when using EMAT (Rijkswaterstaat, 2017; Pianoo, 2022):

- Best Price Quality Ratio (BPQR) (in Dutch: beste prijs kwaliteit verhouding)
- Lowest cost based on cost-effectiveness (such as lifecycle costs)
- Lowest price

The choice of BPQR as the award criterion is, therefore, according to the Procurement law, the starting point for tendering infrastructure projects (Rijkswaterstaat, 2017).

Bergman & Lundberg (2013) stated that, apart from the lowest price award method of public procurement, there are three methods of EMAT using award criteria: Quality only, Price-to-quality, and quality-to-price (see figure 11). For the quality-only tender (also called the beauty contest), the price is fixed and a contractor can only win the contract by best-added value through quality (Bergman & Lundberg, 2013). Each submission that satisfies the quality

requirements is assessed against each award criterion, yielding several partial scores (Bergman & Lundberg, 2013). These results are multiplied by the associated weights, then added (Bergman & Lundberg, 2013). The submission with the best overall score is awarded the fixed-price contract (Bergman & Lundberg, 2013). However, this method is complicated, since the scores of a bid cannot simply be added to one overall score (Bergman & Lundberg, 2013).

The other two methods both deal with the BPQR. In the first method (price-to-quality scoring), the price is transformed into a score that can be added to the quality score, making the tender a "price-adjusted highest-quality tender" (Bergman & Lundberg, 2013). The lower prices get higher scores and the bid with the highest score wins the tender.
In the second method (quality-to-price scoring), the added value of the quality is transformed into a monetary value which is deducted from the price of the bid (Bergman & Lundberg, 2013).

Bergman & Lundberg (2013) furthermore argue that the quality-to-price scoring method is a better alternative than price-to-quality scoring when it comes to BPQR. This is because price-to-quality scoring is non-transparent, often open to strategic manipulation, and it tends to impose particular and unjustified non-linearity in bid prices (Bergman & Lundberg, 2013).

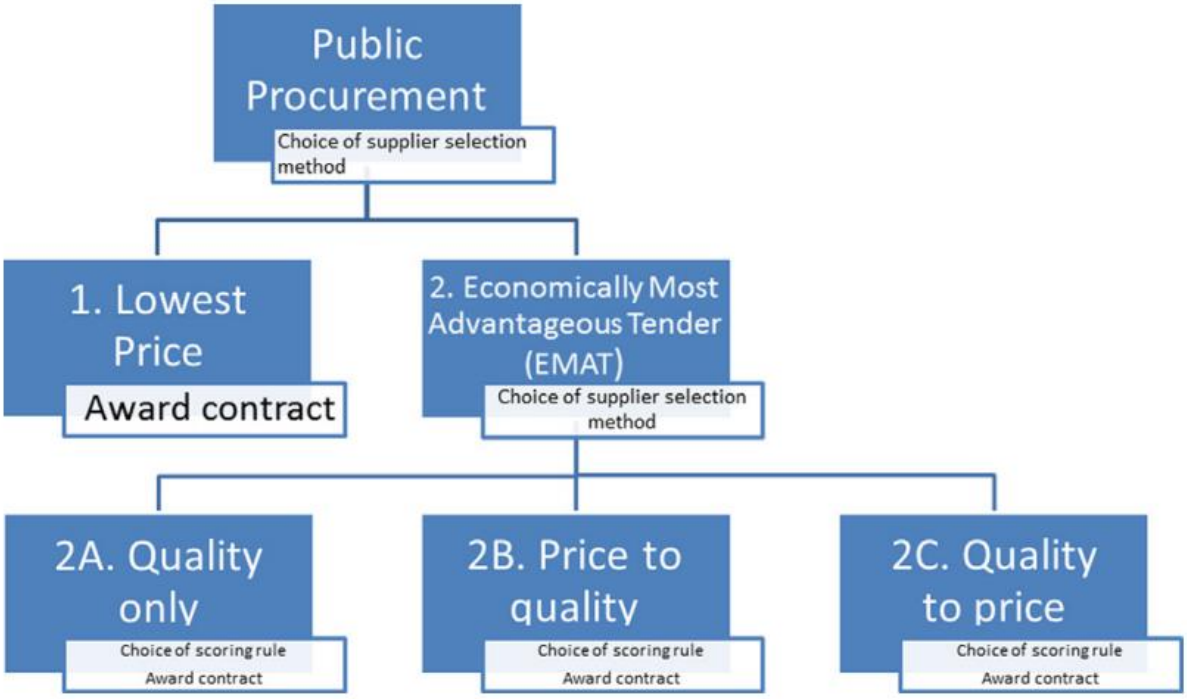


Figure 11: Contractor selection methods and scoring rules (from: Bergman & Lundberg, 2013)

3.2 Sustainability in the infrastructure sector

Sustainability has been an important part of the infrastructure sector for many years. Governments will be helped by incorporating sustainability factors into public procurement to reduce CO2 emissions, safeguard water and energy resources, address issues of poverty, equity, and cohesiveness, and ultimately acquire technical innovations (Pouikli, 2020).

A main difficulty with sustainability in the procurement of infrastructure projects is the ambiguity of the concept of sustainability (Brammer & Walker, 2011; Hueskes et al., 2017).

Therefore, to ensure the successful implementation of a project, it is important to define sustainability in the (EMAT) award criteria of a tender (Pot, 2021).

Bos (2019) concluded that literature about dialogue in the tender of infrastructure projects suggests there is a need for clear and proactive Sustainable Public Procurement (SPP). SPP is a governmental tool to address environmental and societal issues (Grandia & Kruyen, 2020). Meehan & Bryde (2011) define SPP as "the acquisition of goods and services in a way that ensures that there is the least impact on society and the environment throughout the full life cycle of the product". EMAT tendering is also a part of the SPP policy since it could consider environmental and sustainability criteria. Through the involvement of contractors, SPP requirements "can form an essential element of the contractual framework for the environmental and social objectives to be met during project implementation" (Uttam & le Lann Roos, 2015).
Not only the concept of sustainability but also the vagueness and lack of clarity of the environmental criteria themselves are one of the main difficulties in the implementation of Green Public Procurement (GPP)[2] (Ho et al., 2010; Testa et al., 2016; Zhu et al., 2013). Large & Gimenez Thomsen (2011) stated that because it is challenging to monitor environmental conditions during project execution, contracting authorities do not take environmental factors into account.

Moreover, in the literature, it is not clear whether EMAT criteria influence the greenness of a contract. Research by Grandia & Kruyen (2020) shows that the EMAT award method does not necessarily lead to the (better) implementation of SPP since the lowest price award method also has multiple ways of implementing SPP. On the other hand, factors, such as contract value, GPA coverage, joint procurement, competitive dialogue, negotiation with a call for competition, restricted procedure, transport equipment, and food sector increase the possibility of a green contract (Yu et al., 2020). Since, contract value, competitive dialogue, and transport equipment can be award criteria in the EMAT award method, the EMAT criteria could positively influence the greenness of a contract.

3.3 (Sustainable) EMAT criteria in infrastructure tenders

There are lots of ways to tender an infrastructure project (see figure 11), just as there are multiple EMAT award criteria to use in a tender by the client. The last step of answering the first sub-question is an overview of the EMAT criteria for infrastructure project tenders. Therefore, this chapter gives an overview of the EMAT criteria found in the desk research.

In the literature, it is found that not only green (read environmental) criteria but also quality, price, technical merit, aesthetic and functional characteristics, running cost, cost-effectiveness, after-sales service and technical assistance, delivery date and delivery period are mentioned as possibilities (de Klein, 2018; Handler, 2015; Sapir et al., 2022). Furthermore, the criteria can be used to meet social requirements by the contracting authorities (Handler, 2015).

Rijkswaterstaat distinguishes three types of award criteria (Rijkswaterstaat, 2017): Performance criteria, quality criteria, and price criteria. The price criterion is about the price of the project. The performance criteria need to be measurable units, such as functions, CO2 emissions, time, and other quantitative units. The quality criteria are not quantitatively

[2] GPP is a component of SPP in which environmental issues are addressed (Pouikli, 2020)

formulated and are assessed based on the expertise of the assessors (Rijkswaterstaat, 2017). This could be criteria such as risk management, aesthetics, or functionality.

A main difficulty with EMAT award criteria is that there are many aspects to consider when tendering an infrastructure project and all award criteria will account for a small share of the total score (Kadefors et al., 2019). For example, Fuentes-Bargues et al. (2017) performed a study of a hundred Spanish public works tendered between 2008 and 2011 and found that the average weight of environmental criteria was about 5.7 points (out of the 100 points to be obtained).
In another study by Fuentes-Bargues et al. (2018) 61 tenders by Spanish public universities in 2016 and 2017 were analyzed. In this study, it was found that the average weight of environmental criteria was about 6.5 points over a hundred and the maximum weight of the environmental criteria was 37 points over 100 (Fuentes-Bargues et al., 2018). Furthermore, No relationship between the weight of environmental criterion and other criteria was found (Fuentes-Bargues et al., 2018). In the same study, it was found that the price criterion has the greatest weight in tenders (55.5%), followed by work program (24.6%), description of the construction process (18.1%), enhancements (10.6%), and completion time (8.8%) (Fuentes-Bargues et al., 2018). The environmental criteria were found to have similar weights to the guarantee period(6.8%) and quality systems (6.6%) (Fuentes-Bargues et al., 2018).
Lastly, Testa et al. (2015) performed a study of 164 Italian public tenders and found that the average weight given to environmental criteria was about 18%.

So the literature also shows that the EMAT criteria on itself have a small share of the total score in the awarding scheme of a (public) tender. Furthermore, in some case studies, award criteria were used to guarantee that contractors included workers (such as subcontractors and suppliers) with high carbon competence in their teams and to promote awareness of the significance of carbon reduction initiatives rather than to provide stark incentives (Kadefors et al., 2019).

Environmental criteria can be used in four different ways in a tender. First, they can be used to create technical requirements for the final product, service, or work to be produced (Rietbergen & Blok, 2013). Second, the environmental criteria can be used as selection criteria for the possible contractors (Rietbergen & Blok, 2013). These selection criteria can be applied if specific environmental knowledge or experience is needed to fulfill the contract. The third way to use environmental criteria (and also the main focus of this thesis) is the inclusion of environmental criteria in the award scheme of the tender (Rietbergen & Blok, 2013). This is done through the EMAT criteria of tenders. The last way to implement environmental criteria is through contract performance clauses (Rietbergen & Blok, 2013). In that way, it is made to specify how the work or service will be performed (Rietbergen & Blok, 2013).

Melissen & Reinders (2012) state that if the criteria are based on minimum requirements that it does not lead to sustainable innovations and it makes it hard for companies to stand out concerning sustainability.
Furthermore, Uttam & le Lann Roos (2015) state that specifying which award criteria can and cannot be part of a tender, can hinder the inclusion of sustainability in public procurement projects.

van Berkel & Schotanus (2021) conclude in their study that government procurement policies such as “procurement with impact” had a significant positive impact on the inclusion of green award criteria in public tenders in the Netherlands.

Big infrastructure projects may have a detrimental effect on the environment during the construction of the project. However, these impacts can be minimized by integrating (environmental) life cycle costing into the procurement criteria (Handler, 2015; Rainville, 2017). This was, for example, done in 2005 by the Finnish Road Administration in the "Highway 9" project (Handler, 2015). The University of Edinburgh developed an SPP strategy for the years 2003-2006 to ensure the implementation of sustainable values at all stages of the supply chain (Handler, 2015). These examples resulted in motivated contractors to train staff and to adapt technologies and procedures to meet environmental requirements (Handler, 2015).

The application of environmental sustainability award criteria in infrastructure tenders could result in, for example, a reduction in concrete use, an increase in the use of recycled materials, and an increase in green electricity (Sapir et al., 2022).

3.3.1 Results from tender documents

The results of the tender documents show that 56.25% of the tenders do have environmental sustainability EMAT award criteria (see table 5) (Note that the sum of the percentages per year or in total can be higher than 100% since environmental and social sustainability criteria can both be present in the tender documents). The amount of environmental criteria is higher than found in the literature, which can be explained by the more recent focus on inclusion on environmental impact, but also country specifics. Fuentes-Bargues et al. (2017) used data from 2008 to 2011 for Spanish contracts and they found in their research that 35% of the tenders used environmental criteria. Testa et al. (2015) analyzed 164 tenders in the Italian purchase business, however without specifying the date of origin and based on the date of publication of their paper, the data are at least 7-8 years old. They found in their research that the implementation of green criteria in tenders is 39% (Testa et al., 2015). No recent study on this topic was found during the performance of this research.
Another reason why the inclusion of environmental criteria in the tender is higher for this thesis than for the above-mentioned studies is that the Netherlands is part of the 'Green-7' (the other six countries are Austria, Denmark, Finland, Germany, Sweden, and the UK) (Bouwer et al., 2005). The countries that are part of the 'Green7' are more sustainable than other European countries.
In 2021, 40.03% of the tenders initiated by the provinces in the Netherlands had sustainability EMAT criteria included in the tender (Bouwend Nederland, 2022). Compared to the results of this study the number of 2021 is a bit lower. This could be explained by the fact that in this study 2022 is taken into account. Furthermore, in this study, not only the province but also the municipalities in the Netherlands and Rijkswaterstaat were taken into account as clients of infrastructure projects.

Table 5: Percentage of environmental EMAT award criteria in the infrastructure tenders

	2018		2019		2020		2021		2022		Total	
	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total	Percentage	Total documents	Percentage
Environmental sustainability in EMAT criteria	4	44,44%	4	28,57%	12	75,00%	9	60,00%	7	70,00%	36	56,25%
Social sustainability in EMAT criteria	6	66,67%	3	21,43%	10	62,50%	8	53,33%	7	70,00%	34	53,13%
No environmental or sustainability in EMAT criteria	1	11,11%	5	35,71%	2	12,50%	1	6,67%	1	10,00%	10	15,63%
Total documents	9		14		16		15		10		64	

In table 6 all the (sustainable) EMAT criteria are listed that were found in the documentation study. A total of 26 different criteria were found which were categorized into 3 groups: Environmental sustainability, social sustainability, and other criteria. Most of the criteria are categorized under the category 'Environmental sustainability'. Bear in mind that also here the total times a category was found in the documents is not the sum of all the criteria from that category, since they can occur in the same tender document.

Table 6: EMAT criteria from practice

Criteria (Cr)		Number of occurrences	description
Environmental sustainability		36	
EMAT Cr 1	MKI (Environmental Cost Indicator (ECI))/Dubocalc	11	Life cycle analysis of the CO2 emissions of a product transformed into one monetary value, to have an easy overview and comparison. This is done with a program called Dubocalc.
EMAT Cr 2	Sustainable fuels	8	The use of alternative energies (such as electricity, biofuels, etc.)
EMAT Cr 3	CO2 reduction	7	Plan of how to reduce CO2 emissions (not measurable with numbers)
EMAT Cr 4	Recycling of materials	6	The use of recyclable, reusable, or recoverable materials
EMAT Cr 5	Innovative sustainability solutions	5	No description
EMAT Cr 6	CO2 emissions (Dubotool)	4	CO2 emissions of the production Type of transport (electric, diesel, etc.) certification of drivers ("Het nieuwe rijden") Distance of transport All the above-stated factors are transformed into one monetary value score with a program called Dubotool
EMAT Cr 7	Improvement of life span materials	2	The life span of the material should be as large as possible
EMAT Cr 8	Knowledge about sustainability materials	2	The knowledge of using sustainable materials to reduce the CO2 emissions
EMAT Cr 9	Biodiversity	2	The use of materials, knowledge, or written plan to stimulate the biodiversity
EMAT Cr 10	CO2 performance ladder	1	Discount based on the level of CO2 performance (level 1 till 5). The higher the CO2 certificate level, the higher the discount
EMAT Cr 11	Life Cycle Analysis (LCA)	1	The life cycle analysis of a product. The outcome of this analysis is the so-called "milieu profile".

	Social sustainability	34	
EMAT Cr 12	Management of the environment	30	No hindrance to the environment, so residents, road users, public transport, etc. No hindrance means no pollution, no noise hindrance, accessibility, etc.
EMAT Cr 13	Social Return On Investment (SROI)	6	A percentage of the price will be invested in SROI and this could be invested in the following things: Hire unemployed people Hire people/companies/suppliers/ subcontractors that are local
	Other criteria	64	
EMAT Cr 14	Planning	35[3]	The planning of the project should be feasible
EMAT Cr 15	Accessibility (for road users)	35	The accessibility of the road or the availability of the road for the users (cars, bikes, pedestrians)
EMAT Cr 16	Risk management	22	The acknowledgment of risk The management measure of risk The cost of risk
EMAT Cr 17	BLVC plan	16	Contractors need to write a BLVC plan which stands for "Bereikbaarheid, Leefbaarheid, Veiligheid, and Communicatie" (in English: accessibility, quality of life, safety, and communication). All four aspects should be taken into account when writing the plan
EMAT Cr 18	Phases of the project	15	the phasing of the project must be approached in such a way that accessibility and safety can be guaranteed
EMAT Cr 19	Communication	13	The communication with clients, stakeholders, and residents
EMAT Cr 20	safety	12	The safety of the constructors, road users, residents
EMAT Cr 21	Cooperation	10	The cooperation with the client, stakeholders, subcontractors, and residents
EMAT Cr 22	People with the right knowledge	5	No description
EMAT Cr 23	Aesthetic requirements	2	The project should comply with the aesthetic requirements of the tender
EMAT Cr 24	Maintenance	2	The maintenance of the project

[3] EMAT Cr 14 and Cr 15 were seen as one criterion during the desk research. Therefore the result for both criteria is 35 hits.

EMAT Cr 25	Quality of project	1	The quality of the project
EMAT Cr 26	Minimum residual settlement (of the ground)	1	Measurements to make the settling of the ground as less as possible

Table 6 shows that the ECI (in Dutch: MKI) was the most used sustainability EMAT criterion in the tender document. Contrary to the founding of this thesis, Fuentes-Bargues et al. (2017) found that Environmental Plan (EP) (also called Environmental Action Plan (EAP)) was the most used environmental criterion. In this Environmental Plan several systems are integrated, such as preventive and corrective project measures, the use of recycled and reused materials, and the environmental procedures of the tendering company (Fuentes-Bargues et al., 2017).

3.4 Criteria for subcontractor and supplier selection

This paragraph describes the methods and criteria used for supplier and subcontractor selection.

Lots of methodologies for supplier and subcontractor selection have been described in the literature, methodologies like the multi-criteria analytic hierarchy process (AHP) analytic network process (ANP), the Simple Multi-Attribute Rating Technique (SMART), the compromise Ranking method (VIKOR), fuzzy set theory, case-based reasoning (CBR), weighted sum multi-criteria analysis (also called weighted sum model (WSM)), data envelopment analysis (DAE) (Fuentes-Bargues et al., 2018; Safa et al., 2014; Schotanus et al., 2021). Each of these models is capable of handling various qualitative and quantitative criteria (Safa et al., 2014).
In the Netherlands, the most used method for supplier selection is WSM in combination with a relative scoring method (Schotanus et al., 2021). A relative scoring method determines if the scoring of the price and quality criteria is linear or curved (Schotanus et al., 2021).

The above-mentioned methods for the selection of subcontractors and suppliers use a lot of different criteria for their selection process. Literature shows that the selection criteria for suppliers and subcontractors are project-specific (Cheaitou et al., 2019). A distinction can be made between long-term partnering, which lasts the course of numerous projects, and project partnering, which typically entails cooperative arrangements embracing the full construction project or just the early design and planning stages (Barlow & Jashapara, 1998).

Relevant research has demonstrated that choosing a subcontractor only based on bid pricing is no longer an effective method. An excessive focus on pricing may result in hidden safety issues, time delays, bad quality, and cost overruns (Banaitiene et al., 2006). Therefore, the selection of subcontractors and suppliers should not only consider the lowest bid price but also criteria such as quality, experience, sustainability, or reputation (Chen et al., 2020; Deep et al., 2018, 2020; El-Kholy, 2019; Karaman & Sandal, 2022; Kazaz, 2017; Koçak et al., 2018; Shivam & Kashiyani, 2018).

The literature states that Demands from clients, the business roles of those involved in supplier selection within the contracting companies, and supplier expertise all had an impact on the selection process (Mokhlesian, 2014).
Furthermore, the model by Large & Gimenez Thomsen (2011) has demonstrated that evaluating green suppliers and cooperating with them have a positive effect on the environmental performance of the project. However, there needs to be pressure from the stakeholders and NGOs for firms to include green criteria in purchasing decisions (Mokhlesian, 2014)

In the literature review, it is found that a lot of factors or criteria are important for the selection of subcontractors and suppliers, criteria such as price, experience, duration, sustainability, and much more. An overview of all found subcontractor and suppliers selection criteria can be found in table 7.
An optimization strategy was put up by Trapp and Sarkis (2016) to simultaneously address the issues of supplier development, supplier selection, and sustainability. They even suggested selection criteria for the selection of suppliers: “The model introduced here also explicitly incorporates as a selection criterion the amount of development required for a supplier to

achieve an acceptable sustainability level" (Trapp & Sarkis, 2016).
In this criterion, the monitoring of the sustainability level of the suppliers is important.

Table 7: Selection criteria for subcontractors and suppliers found in the literature

Year	Researcher	Criteria
2011	Cheng et al	Construction technique, duration control abilities, cooperative managers, material wastage, services provided after work completion, collaboration with other subcontractors, safe working environment, self-owned tools, clean working environment, effective management capabilities, manager personality, financial condition
2014	Safa et al	Price, lead time, supplier performance, and preferred supplier
2017	Kazaz	Past experience, formal relationship, personal relationship, workload, reputation, litigation history, past performance, financial strength, location of home office, safety records, payment plan, price, labor, technical personnel, equipment, amount of subcontracting, amount of compensation for delay
2018	Deep et al	Ability to control and manage engineering projects, business indicators, corporate reputation and experience, capacity for sustainable development (green construction ability or awareness, staff training, research and development capabilities, introduction rate of new technology, risk management capability), relationship, commitment, reliability
2018	Koçak et al	Price, performance history, quality, technical capability, financial status, delivery/duration, health and safety record, management, production and capacity, reputation, location
2018	Shivam and Kashiyani	Quality of work, completion of work within time, standard of workmanship, lowest bid price, flexibility and cooperation when resolving delays, scale of projects completed, financial stability, physical/equipment resources, health and safety records, reputation
2019	Cheaitou et al	Past performance, past experience, financial stability, technical ability, health and safety, reputation, management capability, bid amount (cost), experience
2019	El Kholy	Estimated tender price, past performance, quality, technical capability, financial status, estimated time of the project, health and safety record, management, production and capacity
2020	Deep et al	Price, expertise, site capacity and facilities, experience, reliability and commitment, performance
2020	Ramalingam	Price, reputation, financial capacity, quality of workmanship, timely completion, past experience, management ability to liaise with the main contractor, familiarity with lean principles, contractor's quality records, technical know-how
2021	Vo et al	Price, financial capacity, technical capacity (measures to protect the environment), competence and experience, quality, relationship
2022	Karaman & Sandal	The soundness of the business and workforce (SBW), planning and control (PC), quality performance, past performance, safety performance, duration, budget, quality, cost

A huge amount of criteria were mentioned in the literature and, as earlier stated, the lowest bid price on itself is not an effective method for the selection of subcontractors and suppliers, however, the price is still the most important criterion (Hartmann et al., 2009; Vo et al., 2021).

To make a conceptual framework for the subcontractor and supplier selection (based on the selection criteria) a categorization was made for the selection criteria. These categorizations would simplify the conceptual framework and create a better overview.

The categorization is based on the criteria in table 7. The following categories for selection criteria were made: cost, experience, quality, time, safety, level of technology, relationship, and sustainability. The last category is miscellaneous selection criteria that were mentioned once or twice in the literature. Table 8 gives an overview of which categories were mentioned in the literature. The categories were made with criteria that deals with the same subject. For example, the category cost deals with price, financial condition/strength/stability, and the compensation for delay. All of these criteria deal with the cost of the subcontractor or supplier and are therefore placed in the cost category. A full overview of which criteria fall under which categories and which paper mentioned them can be found in Appendix C.

Table 8: Categorization of subcontractor and supplier selection criteria

		Selection criterion								
		Cr 1: Cost	Cr 2: Experience	Cr 3: Quality	Cr 4: Time	Cr 5: Safety	Cr 6: Level of technology	Cr 7: Relationship	Cr 8: Sustainability	Cr 9: miscellaneous
Researcher	Cheng et al.,2011	x			x	x	x	x	x	x
	Safa et al., 2014	x	x		x					
	Kazaz, 2017	x	x			x	x	x	x	x
	Deep et al., 2018		x					x		
	Koçak et al, 2018	x	x	x	x	x	x			x
	Shivam & Kashiyani, 2018	x	x	x	x	x	x			x
	Cheaitou et al., 2019	x	x			x	x			x
	El Kholy, 2019	x	x	x	x	x	x			x
	Deep et al., 2020	x	x				x	x		
	Ramalingam, 2020	x	x	x	x		x			x
	Vo et al., 2021	x	x	x			x	x	x	
	Karaman & Sandal, 2022	x	x	x	x	x				x

Table 8 shows that cost, experience, and Level of technology are mentioned a lot in the literature. Furthermore, sustainability is not mentioned that often. This could be because the level of technology also includes sustainability criteria that were not taken into account for the sustainability category (criteria such as expertise or equipment).
Moreover, the table shows that lots of criteria influence the selection of subcontractors and suppliers and is, therefore, a complex decision-making process.

3.5 Conceptual framework

The final step of this chapter is the conceptual framework. The conceptual framework is based on the output of SQ1 and SQ2 (see chapters 3.3 and 3.4).

For the first sub-question, (SQ1: *Which (sustainability) criteria are used in the tender of infrastructure projects to achieve environmental sustainability?*) the literature about EMAT criteria and (public) procurement has been reviewed in combination with a documentation study from 64 projects in the Netherlands. The output of SQ1 is an overview of the EMAT criteria that are used in the EMAT tenders in the Netherlands (this was based on the 64 projects used in the documentation research). In the documents, it was found that 56,25% of the tenders use environmental sustainability EMAT award criteria. Furthermore, the document research results in an overview of award criteria. An overview of these award criteria can be found in table 6. 26 award criteria were found of which 11 environmental sustainability EMAT criteria were found, 2 social sustainability EMAT criteria, and 13 other EMAT criteria. The results show that the ECI (in Dutch: MKI) was the most used sustainability EMAT criterion in the tender document and therefore an important sustainable indicator for infrastructure tenders.

For the second sub-question, (SQ2: *How do contractors select their suppliers and subcontractors in the infrastructure sector?*) the literature about selection criteria for subcontractors and suppliers was reviewed. From the literature, 8 different categories of selection criteria for the subcontractors and suppliers were found. From these 8 different categories (cost, experience, level of technology, quality, relationship, safety, sustainability, and time) cost was found to be the most important selection criterion (Hartmann et al., 2009; Vo et al., 2021). The outcome of SQ 2 is an overview of the different selection criteria for subcontractors and suppliers (see tables 7 and 8).
These 8 different categories and all their selection criteria within are possible selection criteria for subcontractor and suppliers selection (see appendix C for all selection criteria). The selection criteria used for the selection of subcontractors and suppliers is project specific, which means that (based on the project and the criteria) the outcome of the selection can be different for every project (Cheaitou et al., 2019).

These outcomes are used to make a conceptual framework of the influence of selection criteria (and indirect EMAT criteria on the supplier and subcontractor selection). The conceptual framework can be found in figure 12. The framework shows that multiple selection criteria have an influence on the selection of suppliers and subcontractors and that one of these criteria is sustainability. The EMAT criteria in their turn influence the selection criteria of the subcontractors and suppliers since the selection criteria are assumed to be (partially) based on the EMAT award criteria of the tender. In this framework, a division is made between the categories of suppliers and subcontractor selection into three different scopes. The first scope is the iron triangle which consists of the criteria time, cost, and quality. The second scope is environmental sustainability which consists of the criteria level of technology (for example electric vehicles) and sustainability. And lastly, the social (sustainability) scope which consists of the criteria relationship, safety, and experience. Where the iron triangle is self-explanatory, the environmental sustainability scope deals with criteria focused on environmental sustainability and the social (sustainability) scope deals with the social aspects of the subcontractor and supplier. This division into scopes is made since this thesis is focused on sustainability in the infrastructure sector.

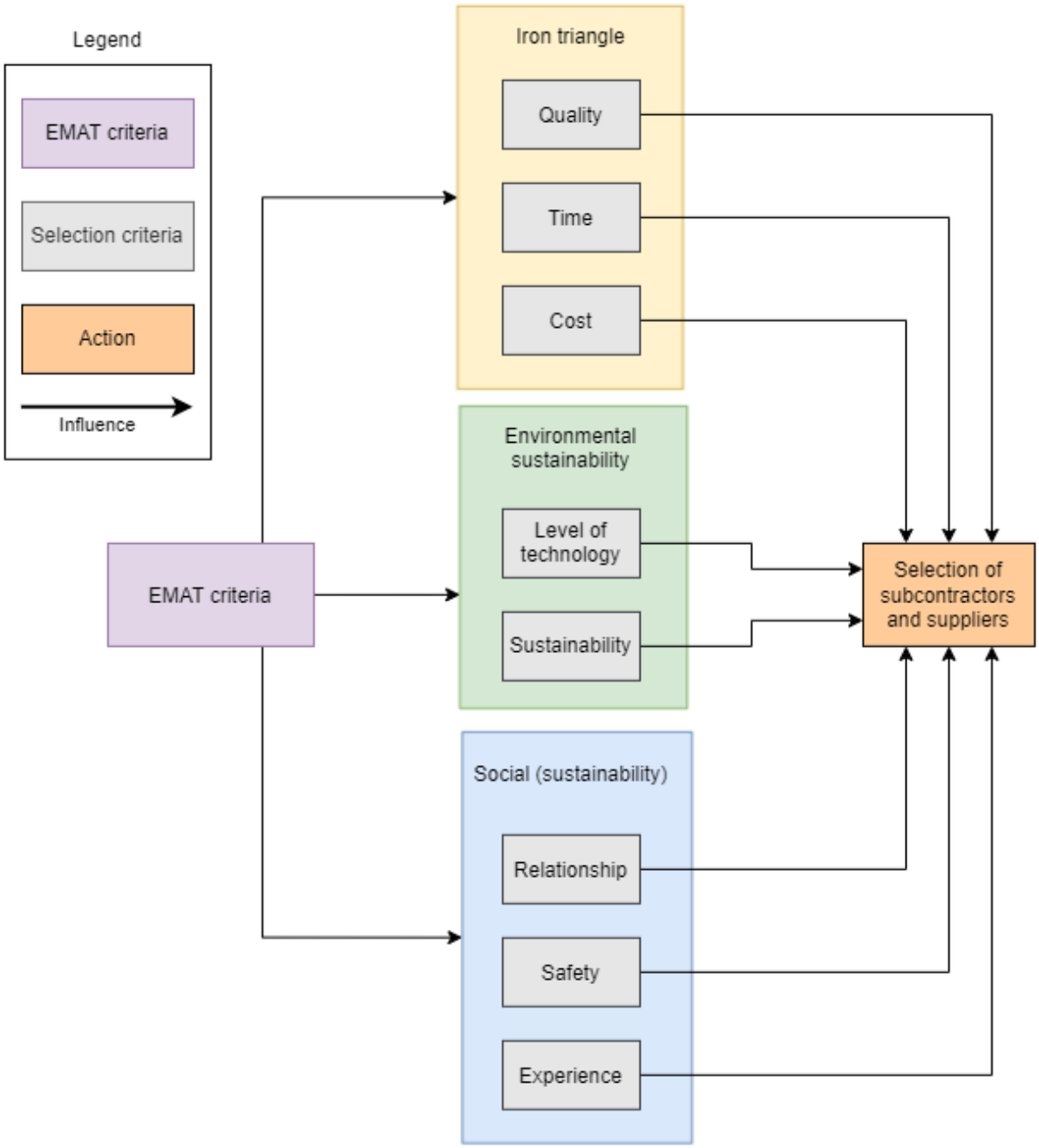


Figure 12: Conceptual framework of selection of subcontractors and

This conceptual framework is incomplete since not only the selection criteria themselves could influence the selection of subcontractors and suppliers but also the trade-off between the selection criteria is important. Therefore, the next chapter adds the trade-offs between the different selection criteria for subcontractors and suppliers to the conceptual framework. Moreover, the next chapter also looks into the influence of the EMAT criteria on these trade-offs. An improved conceptual framework is proposed in chapter 4.

04

Trade-off between the cost and sustainability of the project

4. Trade-off between the cost and sustainability of the project

As indicated in chapter 3, the cost is still one of the most important selection criteria for subcontractors and suppliers. Therefore, it is important to take the trade-off between cost and sustainability into account when looking into the effect of (sustainable) EMAT criteria on the selection criteria of subcontractors and suppliers. This chapter, therefore, answers the third sub-question (SQ3: *What is the existing trade-off between cost and the level of sustainability?*) In this chapter, the existing tools to measure sustainability in the infrastructure sector (chapter 4.1) and the important measurable aspects of sustainability (chapter 4.2) are described. After this, the trade-off between cost and sustainability from the literature is described (chapter 4.3).

4.1 Existing tools for measurement of sustainability in the infrastructure sector

For the awarding of contracts to contractors, the award criteria need to be measurable. Sustainability, in this case, is measurable through multiple different tools. The tools most used for infrastructure in the Netherlands are the CO2 performance ladder, Dubocalc/Dubotool, and ECI (in Dutch: MKI) (OECD, 2014). A short description of these tools is given as the way they measure sustainability and take subcontractors and suppliers into account.

4.1.1 ECI, LCA, and Dubocalc/Dubotool

The ECI is a scoring system that uses Life Cycle Assessment (LCA) to make a monetary score about their CO2 reduction which is measured in CO2 equivalent (CO2eq) (Hillege, 2019). A monetary score is used to make a better comparison between the different award criteria. LCA provides an understanding of whole-of-life costs associated with infrastructure investments and should ensure that resources are allocated appropriately for asset operation and maintenance across their lifespan (Reidy, 2018). LCA is based on assumptions and uncertainties in predicting costs into the future (Reidy, 2018), therefore it can be difficult to make accurate ECI scores.

Dubocalc is a tool that uses the ECI to weigh all the different environmental impacts into a single score (de Klein, 2018). The outcome of the single score gives a deduction of the submission price of a tender (the lower the environmental impact, the bigger the deduction) (Sapir et al., 2022).
Using the ECI as a scoring mechanism has multiple advantages and disadvantages. The advantages of the ECI are that the scores are easy to compare and it provides consistency for the contractors and subcontractors since their products are scored the same by all organizations using this mechanism (de Klein, 2018).
The weighing of the different environmental impacts is subjective and performing a LCA (which is needed for the ECI scores) is time-consuming (de Klein, 2018).

In practice, a variant of the Dubocalc is used (mostly by the municipality of The Hague) and it is called the Dubotool. This tool also uses LCA values in its calculations (Dubotool, 2022). The inputs for the Dubotool are LCA values, type of transportation, type of fuel, and the distance between the production location and the building location from the suppliers of the project. For

the Dubotool a deduction from the submission price is calculated on the bases of the outcome. the Dubotool has a built-in incentive because a fine is imposed if the condition entered by the contractor (in the Dubotool) cannot be met.

4.1.2 CO2 Performance ladder

The CO2 performance ladder is developed by ProRails in 2009 (SKAO, 2022). With the use of the CO2 performance ladder, a tenderer may demonstrate the steps that are taken to reduce CO2 emissions inside the business, on projects, and elsewhere in the supply chain (OECD, 2014). This is done based on a certificate.
Although, Bos (2019) states that the CO2 performance ladder is not yet properly used and governments should better monitor the outcome of the CO2 performance ladder, the measurement tool for sustainability does have a positive impact on the reduction of CO2 (Rietbergen & Blok, 2013).
The CO2 performance ladder has 5 levels of ambitions (see figure 13). The level of ambition of the contractor is based on the following four key process areas: (A) drawing up CO2 emission inventories, (B) setting and achieving CO2 reduction targets, (C) transparency and communication of the company's CO2 footprint and energy policy and (D) participation in (supply chain) initiatives (in Dutch: inzicht, reductive, transparantie en participatie) (Rietbergen & Blok, 2013). The CO2 reduction for the entire supply chain is taken into account as well in this measurement tool. So the emissions of the suppliers are important in this measurement tool. How the certification process for assessing the maturity level (1-5) of a company's CO2 management works can be found in appendix D. A commitment to a higher level of ambition on the CO2 performance ladder results in a higher deduction from the submission price (OECD, 2014).

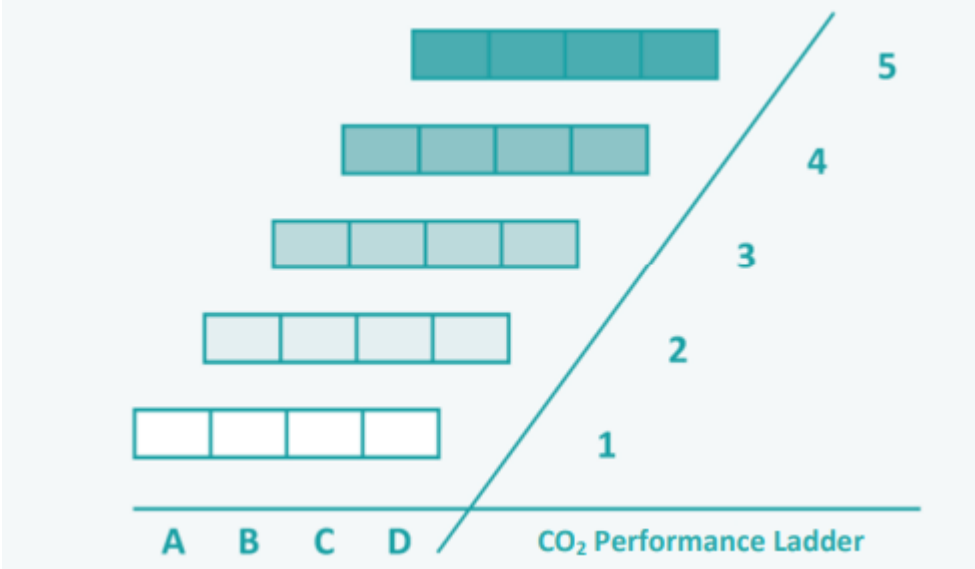


Figure 13: The structure of the CO2 Performance Ladder. Source (SKAO, 2015)

4.1.3 Supplier and subcontractor knowledge

Not only the measurement tools for sustainability can measure the environmental impact of infrastructure projects by subcontractors and suppliers, but also the supplier's knowledge about sustainability has an impact (Mokhlesian, 2014). Various methods can be used by contractors to identify suppliers' knowledge such as including checking reference projects, meeting tender specifications, negotiations, interviews, suppliers' records, and evaluations by environmental and purchasing staff (Mokhlesian, 2014).

4.2 Measurable aspects of sustainability

To measure the sustainability of the subcontractors and suppliers in infrastructure projects through the tools mentioned in chapter 4.1, measurable aspects of sustainability are needed.

It is hard for the client to implement verifiable environmental EMAT award criteria for suppliers (Pouikli, 2020). Moreover, it is quite impossible to aggregate the different environmental impacts (across scale, time, and type of impact) from the supplier or subcontractor (Markard, 2011). Furthermore, it is mentioned in the literature that contract performance can be enhanced by specifying environmental, social, and human rights (Andhov et al., 2020). The contract documentation and signed contract must contain language enabling public procurers to request information and action from suppliers to detect, minimize, and reduce risks as well as to report and remedy violations when they do arise (Andhov et al., 2020). To do so, there are key performance indicators for sustainability that can be used when evaluating suppliers and subcontractors. The following section is about the key performance indicators for sustainability.

4.2.1 Key Performance Indicators

The key performance indicators are important for tender and project managers to know what aspects are needed (and measured) for a successful sustainable project.

In the literature about the measurement of sustainability and sustainable KPIs, a huge amount of (environmental) sustainability indicators is mentioned.
Environmental performance indicators are quantitative measures of certain environmental or social costs and benefits, such as CO2 emissions or acres of newly generated or lost habitat (Bennon & Sharma, 2018). Sustainability procedures, such as the selection of a lead sustainability officer, the release of environmental reports, or the use of third-party sustainability audits for projects, assess secondary aspects that may or may not enhance those performance metrics or the measurement of them (Bennon & Sharma, 2018).

Kucukvar & Tatari (2013) mentioned 8 different environmental sustainability indicators, such as water footprint, carbon footprint, energy footprint, cropland footprint, grazing land footprint, forestland footprint, fishery land footprint, and C02 uptake land.

Ferrarez et al. (2020) found 97 selection indicators of which 63 were focused on the environmental dimension with the focus on environmental preservation, pollution management and control, environmental management, environmental risk management, and sustainable practices. Moreover, they found 10 economic indicators with a focus on environmental cost and economic benefits (Ferrarez et al., 2020).

(Stanitsas et al., 2021) mentioned 18 different environmental sustainability indicators as well.

Shen et al. (2007) looked in their paper at a checklist for project sustainability performance for the whole project life cycle. They found 10 environmental sustainability indicators for the project initiation and project design stage (the other stages of the project are not within the scope of this research and therefore are not worth mentioning).

One of the widely acknowledged environmental performance indicators to measure the impact on an infrastructure project is CO2 (Phair, 2018). CO2 is commonly measured by CO2 footprints or the LCA tool (in other words CO2eq) (Bennon & Sharma, 2018; Ferrarez et al., 2020; Kucukvar & Tatari, 2013; Phair, 2018; Stanitsas et al., 2021; Sveum et al., 2020).

4.3 Trade-off between cost and sustainability

When selecting subcontractors and suppliers trade-offs influence the decision making process. In public infrastructure, trade-offs are often characterized by difficulties in measurement and comparison (Reidy, 2018). The measurement of sustainability is treated in chapters 4.1 and 4.2. However, the comparison and the measurement of cost and sustainability and especially the trade-off between them when selecting subcontractors and suppliers are described in this chapter.

A bunch of trade-offs could be made between the different selection criteria for subcontractors and suppliers depending on the importance of the selection criteria for the contractor. For example, trade-offs based on the availability of equipment, geographic location, and project dynamics (Ramalingam, 2020).

Another example is when a major contractor may value tender price and expertise as very relevant factors in the selection process, yet the subcontractor with the lowest bid may have less experience performing identical work than rivals (Hartmann et al., 2009). When selecting a subcontractor for this specific project, the primary contractor must determine whether to forego price negotiation in favor of the best offer or to make a concession on either expertise or price (Hartmann et al., 2009).
Furthermore, Bennon & Sharma (2018) mentioned a trade-off between "measuring environmental performance indicators and management practices associated with projects", where management practices in some ways are more verifiable than measuring the environmental costs of a project.
Another trade-off that could be made when selecting subcontractors and suppliers is between the environmental sustainability indicators themselves. For example, on the one hand, the environmental indicators highlight the need of minimizing pollution and on the other hand enhancing preservation, which are two crucial and complimentary acts for a city's or region's environmental health (Ferrarez et al., 2020). So a trade-off could be made between the preservation or the reduction of the environmental impact.

However, as mentioned in chapter 3.4, the most important selection criteria for subcontractors and suppliers are the costs. Therefore the trade-off between the cost and other criteria is the most important one to look into. In this thesis, the main focus is on the trade-off between cost and sustainability.

Cost VS sustainability

Standards for sustainability can include trade-offs in transaction costs, just like all other types of assessment and evaluation. The comprehensiveness, impartiality, and clarity of a standard can be improved by weighing these goals against the expenses associated with creating and maintaining these sustainability developments (Bennon & Sharma, 2018). The biggest issue is who is going to pay for the (development of) sustainability part of the project. Real rates of return[4] on total capital employed of between 5 and 10% are often required for new investments by companies whose operations are dependent on infrastructure assets: For water and power utilities, 5 to 6 percent, energy firms, 7 to 8 percent, and engineering and construction firms, 9 to 10 percent (Bielenberg et al., 2016). So the decision on whether to invest in the project is the ability of the project to meet this requirement.

[4] The real rate of return is known as the yearly percentage of profit on an investment that has been adjusted for inflation (Hargrave, 2022).

The same goes for contractors that place a bid for an infrastructure project. They want to make a profit on the project.

Even though the net present value (NPV[5]) of sustainable infrastructure is positive during its lifespan, these projects can have greater upfront costs for the builder while saving money for the operator or owner (Bielenberg et al., 2016). For example, developers (such as contractors) pay more for sustainable solutions such as recycled asphalt (which need less maintenance), while the operator is left with the savings of fewer maintenance costs. This is a reason why innovative technological changes in infrastructure could take a lot of time to develop (Markard, 2011).

Moreover, Mokhlesian (2014) found in their study that unsustainable materials are a more attractive choice for the contractor when they have a lower cost compared to sustainable materials, especially when the client is not willing to meet the higher cost. Again, the trade-off between cost and sustainability is important and especially the question of who is going to pay for the (development of) sustainability.

The infrastructure industry does innovate at the moment, but it is driven by the need to make money rapidly (Bos, 2019). Not on the hypothesis that a new (more sustainable) invention may perform better based on ECI (Bos, 2019).
Possible economic gains of environmental activities might not be assessed (by the client or contractor) and are therefore thought to be more expensive (de Klein, 2018).

Moreover, Ferrarez et al. (2020) concluded that The opinion of the experts about the sustainability of infrastructure projects was significantly impacted by the environmental consideration of the economic indicators found in their study. The indicators that were produced also showed a tendency to use a larger percentage of environmental sustainability measures (Ferrarez et al., 2020)

So the appraisal and measurement of the economic benefits from sustainable solutions are important to make a trade-off between the cost and the sustainability of a project.

An important part of the trade-off between the cost and sustainability of a project is also the incentive for a contractor to be as sustainable as possible (Halsnæs et al., 2011). The literature states that environmental pressures (read incentive) may cause the (power) supply industry to undergo a more fundamental shift by replacing existing technological routes (Markard, 2011). The CO2 Performance Ladder also plays a role in the incentives for sustainable development. Most contractors are now accredited at the highest level thanks to the CO2 Performance Ladder, which has enhanced competence standards in the infrastructure sector in the Netherlands (Kadefors et al., 2020). Although this was seen as a positive thing, it also meant that these contractors had little reason to advance their sustainability development (Kadefors et al., 2020). So there is no incentive for the contractors to invest in more sustainable solutions, which means that in this situation no trade-off is going to be made between the cost and sustainability.

[5] The NPV is used to by investors to calculate whether a project is profitable. So when it is positive, the rate of return is above the discount rate and when it is negative it is not (Fernando, 2022).

4.4 Improving the conceptual framework

The final step of this chapter is the improvement of the conceptual framework from chapter 3 based on the literature review of SQ3.

For the third sub-question, (*SQ3: What is the existing trade-off between cost and the level of sustainability?*) the literature about the measurement of sustainability and the trade-off between sustainability and the cost or investment was reviewed. The literature review found that lots of possible trade-offs could be made in selecting subcontractors and suppliers. Trade-offs between selection criteria such as cost, availability of equipment, geographic location, and project dynamics (Ramalingam, 2020), experience (Hartmann et al., 2009), and sustainability (Ferrarez et al., 2020). However, the trade-off deals most of the time with cost on the one hand and other selection criteria on the other hand.

Furthermore, the literature states that a trade-off between cost and sustainability is common. For example, Mokhlesian (2014) found in their study that unsustainable materials are a more attractive choice for the contractor when they have a lower cost compared to sustainable materials, especially when the client is not willing to meet the higher cost.

Moreover, it was found that an incentive in the form of environmental pressure is needed for the contractors, subcontractors, and suppliers for them to invest in sustainability development (Halsnæs et al., 2011; Kadefors et al., 2020). One way of applying environmental pressure is through the EMAT criteria which are determined for every project by the client (most of the time a governmental institution). Another way of applying environmental pressure (but left out of the scope of this research), is by shareholders and potentially new colleagues.

In figure 14 an improved conceptual framework of the selection of subcontractors and suppliers from chapter 3 can be found. Just like the first conceptual framework, this one shows that multiple selection criteria have an influence on the selection of suppliers and subcontractors and that the EMAT criteria in their turn have an influence on the selection criteria of the subcontractors and suppliers. The possible trade-offs between the selection criteria for subcontractors and suppliers are added to the conceptual framework and the influence of the EMAT criteria on these trade-offs. And the trade-offs in their turn indirectly influence the selection of suppliers and subcontractors. Making a ranking out of the possible trade-offs (except for the fact that cost is the most important selection criterion) is hard since the trade-offs are project specific.

This conceptual framework is input for the interview questions for the case study in the next chapter (chapter 5). In the next chapter, this conceptual framework is modified into a proposed final framework to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers.

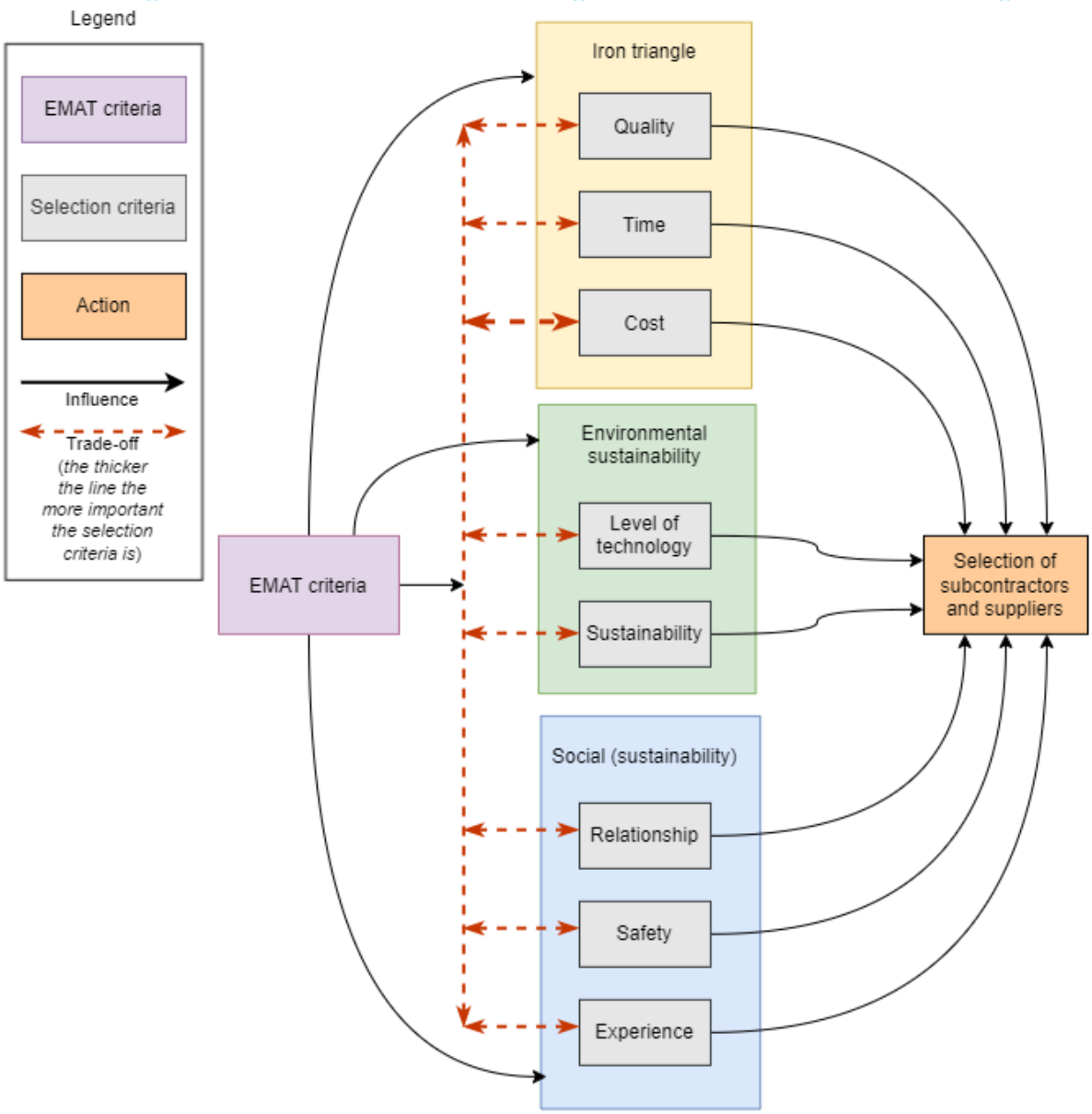


Figure 14: Improved conceptual framework of selection of subcontractors and suppliers

05

Case Study

5. Case Study

In this chapter, the fourth and final sub-question is answered (SQ4: *To what extent are EMAT sustainability criteria taken into account by the contractor during the selection of subcontractors and suppliers?*). This question is answered through a case study with three different cases (see table 9 for an overview of the cases). The cases were chosen in a way that it can be tested whether the (sustainable) EMAT criteria influence the supplier and subcontractor selection by the contractor. The award criteria for case 1 include sustainability for the suppliers and subcontractors in the award criteria. The award criteria for case 2 do take sustainability into account for the award criteria but not the suppliers or subcontractors. And case 3 does not take sustainability into account at all for the award criteria.

Table 9: Overview of cases

Case	Assets	Client	(Sustainability) EMAT criteria (based on table 6)	Interviewees
A: Bezuidenhout (2021)	Sewage and refurbishment of streets	Municipality of The Hague	EMAT Cr 6: CO2 emissions Dubotool EMAT Cr 12: Management of the environment	Tender manager Construction manager Procurer
B: Middenboulevard Scheveningen (2022)	Refurbishment of public area	Municipality of The Hague	EMAT Cr 1: ECI EMAT Cr 2: Sustainable fuels EMAT Cr 4: Recycling of materials EMAT Cr 12: Management of the environment EMAT Cr 16: Risk management EMAT Cr 18: phases of the project CR 21: Cooperation	Tender manager Construction manager Procurer
C: Woonrijp maken Binnentuin (2019)	Site preparation of an area	Municipality of Beverwijk	EMAT Cr 19: Communication EMAT Cr 21: Cooperation	Tender manager Construction manager Procurer

In this case study, a document research was performed and semi-structured interviews were held with three involved people of the tender from that case. The interview questions were based on the conceptual framework from chapter 4.

All three cases are discussed in separate chapters (chapters 5.1, 5.2, and 5.3) followed by a cross-case analysis of the results (chapter 5.4) and a concluding chapter (chapter 5.5) in which a framework is proposed to give an overview of the influence of EMAT criteria on the selection of subcontractors and suppliers.

5.1 Case A

5.1.1 Description of case A

Bezuidenhout-Oost phase 3 is a sewerage project. This is the third and last project in Bezuidenhout-Oost that is part of the PiW (Parking in Residential Areas) program. It concerns the refurbishment of streets and squares, including refurbishment to 30 km/h. The activities mainly consist of replacing existing pavements and sewers. Additional activities include the planting of trees, the installation of other green areas, and street furniture. The contract duration of this project is 2 years. The project is still in the execution phase.

5.1.2 Tender procedure case A

This project was tendered through the EMAT procedure. This means that the awarding of the contract was based on the BPQR. For the quality part of the award criteria, 50% of the deduction was awarded for the "sustainability" award criteria and 50% of the deduction was for the "Management of the environment" award criteria (of which 10% was for the coordination with third parties and 90% for the hindrance limitation for the environment).

5.1.3 EMAT award criteria case A

As mentioned above, this tender had 2 award criteria: sustainability and management of the environment. In this part, the award criteria and their assessment are discussed.

Sustainability

(EMAT Cr 6 from table 6)

For the sustainability part, the Dubotool was used as a tool to measure the sustainability reduction of the suppliers for this project. In the Dubotool (which is comparable to an excel sheet) the CO2 emissions of the production of the material are used which is measured in gram CO2 / kg produced product (see chapter 4.1.1 for a description of the Dubotool). Furthermore, the type of vehicle used for transportation (car or boat), the type of fuel (electric, diesel, HVO100, etc), and extra certification for drivers called "Het nieuwe rijden" which means that the drivers know how to use their car sustainably. Lastly, the distance of transportation from the production of material to the construction site is important for the Dubotool.

After filling in all these categories for all materials required according to the contract (in this project the materials required for the Dubotool are sewage pipes, curbs, concrete tiles, paving stones, sand, and granulates), the end result is a single score which determines the (monetary) deduction from the tender bid.

The contractor needs to discuss and negotiate the asked information for the Dubotool with the possible suppliers.

Management of the environment

(EMAT Cr 12 from table 6)

The management of the environment part exists of coordination with third parties and the hindrance limitation for the environment. 10% of the deduction of this part of the quality is for the coordination with third parties and 90% of the deduction of this part is for hindrance limitation.
The contractor needs to clarify how they coordinate the project with activities from third parties such as public lighting, parking meters, and charging stations.

For the second part, the contractor needs to clarify how they limit the hindrance to the environment when it comes to accessibility and safe workspace.

5.1.4 Results of case A

In this part, the results of case A are discussed. First, the selection criteria for the subcontractors and suppliers are discussed, followed by the influence of the EMAT criteria and the trade-offs that were made during the selection of the subcontractors and suppliers.

Selection criteria subcontractors and suppliers

The selection criteria for the suppliers used for this case are the cost (Selection cr 1)[6], experience (Selection cr 2), safety (Selection cr 5), level of technology (Selection cr 6), sustainability (Selection cr 8), and distance for transportation between the production of materials and construction site (Selection cr 10).

Among these criteria, safety is one of the most important ones. Safety is important as a prior criterion for the selection of subcontractors and suppliers and meets certain prerequisites. As stated by interviewee A1:

> *"I can be very brief about safety. Subcontractors and suppliers must meet certain safety requirements before we select them at all. If they do not comply with this, they will not be on our list of potential companies. So safety is also a criterion, but that is already checked before I look at the parties."*

What is noticeable about the selection criteria is that out of all the things asked (by the client) for the sustainability in the EMAT criteria (CO2 emission of production, type of vehicle, type of fuel, distance of transportation, and extra certification), only the type of vehicle and the distance of transportation was named by the interviewees (apart from the fact that sustainability, in general, was mentioned as selection criteria).

Influence EMAT criteria on selection criteria

The influence of the EMAT criteria on the selection of subcontractors and suppliers differs for the subcontractors and the suppliers. The most subcontractors in this case were parties that have long-term contracts with the contractor and are not chosen based on the EMAT criteria. However, the supplier selection was influenced by the EMAT criteria. One of the EMAT criteria was about the sustainability of the suppliers and this influenced the way that the contractor selected the supplier (EMAT Cr 6). They looked very specifically at the needed information for the Dubotool such as the CO2 emissions, the type of vehicle (Selection cr 6), the type of fuel, and the distance of transportation (Selection cr 9). The influence of the EMAT criteria on sustainability is expected since the award criteria concern the suppliers.

Trade-offs between selection criteria

The trade-off between the cost (Selection cr 1) and sustainability (Selection cr 8) and the trade-off between the different aspects of sustainability (see chapter 5.1.3 for the different aspects) were the only trade-offs mentioned by the interviewees.

[6] Note the difference in this chapter between the acronyms EMAT Cr and Selection cr. EMAT Cr is for the EMAT criteria discussed in table 6 chapter 3.3.1. And Selection cr is for the selection criteria for subcontractors and suppliers discussed in table 8 chapter 3.4.

The cost, however, is still the most important selection criterion for the supplier. Interviewee A1 states the following regarding costs:

> *"you make choices between the criteria. It remains the case that price is often decisive. You always have to deal with the competition."*

Furthermore, trade-offs were made between the different sustainability criteria (read the different aspects of the Dubotool mentioned in chapter 5.1.3). As explained earlier, the Dubotool results in one score which is translated into a monetary deduction for the tender bid. To receive the highest deduction possible based on the information the suppliers give, trade-offs were made between the different aspects of the Dubotool. For example, a trade-off was made between the distance of the transportation (Selection cr 10) and the type of vehicle (Selection cr 6) as stated by interviewee A2 when he talked about the difference between the Dubotool and other tools:

> *"In many tools, the distance is not taken into account. While generating electricity for the 180 km with an electric car is perhaps worse than the 10 km with HVO [a type of diesel fuel]. In such a tool, HVO is therefore rated worse than electric."*

Although a trade-off between the sustainability aspects was made, the overall deduction on the tender bid (so the cost) was still important.

Influence EMAT criteria on trade-offs

The influence of the EMAT criteria on the trade-offs is through the incentive of a deduction in the tender bid for the sustainability part of the award criteria (EMAT Cr 6). The deduction influenced the trade-offs between the cost (Selection cr 1) and sustainability (Selection cr 6, 7, and 10) in such a way that a more sustainable supplier was chosen because the deduction made up for the increased price for the selected supplier (the price was increased because of the sustainability level of the supplier). So the sustainability part of the award criteria (EMAT Cr 6) influenced the trade-offs between the cost (Selection cr 1) and the sustainability selection criteria (Selection cr 6, 7, and 9).

5.2 Case B

5.2.1 Description of case B

Middenboulevard is a renovation project of the Middenboulevard in Scheveningen. This project is part of the programme 'De Kust Gezond' (DKG). The project will be carried out in 2 phases. Important in this project is that the catering establishments remain open during the execution, so accessibility is important here for the entrepreneurs and visitors. The project will take 1.5 years and is still ongoing.

5.2.2 Tender procedure case B

This project was tender through the EMAT procedure. This means that the awarding of the contract was based on the BPQR. For the quality part of the award criteria, 50% of the deduction was awarded for the “cooperation” award criteria, 40% of the deduction was for the “management of the environment” award criteria, and 10% of the deduction was for the “sustainability” award criteria.

5.2.3 EMAT award criteria case B

As mentioned above, this tender had 3 award criteria: cooperation, management of the environment, and sustainability. In this part, the award criteria and their assessment are discussed.

Cooperation
(EMAT Cr 16, 18, and 21 from table 6)

The cooperation part of the award criteria exists of cooperation with other parties, the planning and the phasing of the project, and risk management.
For the cooperation part, the contractor was assessed based on the cooperation with other parties such as the client and subcontractors. Furthermore, the cooperation part was assessed on the transparency, flexibility, and proactive way of dealing with the project.

The assessment for the phasing of the project and the planning is through the time needed for the project and the way the contractor deals with all the other “building streams” on the construction site (so the phasing of the project).

Finally, the risk management of the project is assessed through risk management files and the measurement taken by the contractor to avoid risk.

Management of the environment
(EMAT Cr 12 from table 6)

The environmental part of the award criteria is assessed on the bases of the (building)logistics during the execution of the project, and the accessibility for stakeholders and hospitality companies such as restaurants, cafes, and hotels. So the hindrance to the environment needs to be minimized during the execution of the project.

Sustainability
(EMAT Cr 1, 2, and 4 from table 6)

For the sustainability part, the ECI was used as a tool to measure the environmental impact of the project. This was measured in euros/ton. Furthermore, the limitation of waste flows and facilitation of recycled or reusable building material are indicators for this EMAT award criteria.

Moreover, the use of sustainable equipment and the optimization of pavement constructions were sustainable indicators for this project.

So the ecological footprint needs to be minimized during the project.

5.2.4 Results of case B

In this part, the results of case B are discussed. First, the selection criteria for the subcontractors and suppliers are discussed, followed by the influence of the EMAT criteria and the trade-offs that were made during the selection of the subcontractors and suppliers

Selection criteria subcontractors and suppliers

The selection criteria for the suppliers used for this case are the cost (Selection cr 1)[7], experience (Selection cr 2), quality (Selection cr 3), delivery time (such as planning and accessibility of the material) (Selection cr 4), safety (Selection cr 5), sustainability (Selection cr 8), and distance of transportation (Selection cr 9).

What is noticeable is that the sustainability selection criterion was not very important (read less important than the other criteria) for the selection of subcontractors and suppliers as interviewee B1 said:

> *"So we spent a lot of time with the suppliers with an eye on price and an eye on the time. Because Scheveningen has a beach season and before this starts you have to finish your work. Sustainability emerged to a lesser extent there. So, we had not done much with suppliers in the tender."*

One of the explanations for this is given by the interviewee: The fact that there is a time restriction for the project. Another possible reason why the sustainability part of the award criteria was not that important during the tender could be the fact that it only counted for 10% of the deduction of the tender bid.

Influence EMAT criteria on selection criteria

The only influence the EMAT criteria had on the selection of suppliers and subcontractors was the quality of the work or production. When it comes to sustainability, not much influence was given by the award criteria. In the end, the criteria are related to each other since the better quality of the work or production results in a longer life span of the materials used, which is sustainable as well.

Trade-offs between selection criteria

Multiple trade-offs were found in this case. One of the trade-offs is about the cost (Selection cr 1) and quality (Selection cr 3)of the delivered work. Quality was important in this case, and a more expensive subcontractor was chosen knowing that the quality would also be higher of their work.

Another trade-off was between the delivery time (Selection cr 4) and the quality (Selection cr 3) of the project. One of the suppliers of a specific type of material was a supplier outside of Europe while there were suppliers from Europe available as well. Although the negative impact on the cost, the distance of transportation, and indirectly on the sustainability of the project

[7] Note the difference in this chapter between the acronyms EMAT Cr and Selection cr. EMAT Cr is for the EMAT criteria discussed in table 6 chapter 3.3.1. And Selection cr is for the selection criteria for subcontractors and suppliers discussed in table 8 chapter 3.4.

was higher with this supplier, they still chose this one because they had a qualitatively better product.

However, the distance (Selection cr 10) and indirect cost (Selection cr 1) and sustainability (Selection cr 8) were also important for the client. Therefore, the suppliers for the other materials were chosen as locally as possible. For example, the distance to a machine to break down and reuse concrete as stated by interviewee B1:

> *"We had to decide about the processing of concrete. The device that did this was called a Smartcrusher. At a certain point, you want to handle as much as possible on location. It was about removing an existing retaining wall and we could then remove it because it could be broken with a Smartcrusher and reused, but then you have to deal with a great distance. So we did look at distance because the closer to the project the better it is. You use less diesel and that is more sustainable and therefore cheaper. It all brings benefits."*

Lastly, a trade-off between sustainability (Selection cr 8) and cost (Selection cr 1) was visible for this tender. A trade-off between the cost and the use of electric vehicles was made. This was eventually solved by selecting a transporter with whom the contractor has a long-term contract for using their electrical vehicles. However, by making this decision the cost of the project increased.

Influence EMAT criteria on trade-offs

The influence of the EMAT criteria on the trade-offs is through the incentive of a deduction in the tender bid. The logistics during the execution (EMAT Cr 12) and the phasing of the project (EMAT Cr 18) had a higher percentage of the award criteria (so a higher deduction on the tender bid) than sustainability (EMAT Cr 1,2, and 4). It can be seen in the trade-offs that the cost (Selection cr 1), distance (Selection cr 10), time (Selection cr 4), and quality (Selection cr 3) were more important than the sustainability (Selection cr 8)for the suppliers. It can be concluded that the EMAT criteria (in this case EMAT Cr 12 and 18) influenced the trade-offs during the selection of suppliers and subcontractors.

5.3 Case C

5.3.1 Description of case C

Binnenduin is a site preparation project for the Binnenduin district. During this project, the groundwork, asphalt paving, and street furniture work will be carried out. In addition, facilities are also installed such as final hardening, drainage systems, street lighting, and green areas. The management of this area is also for the contractor until the end of 2023, after which it will be transferred to another party in 2024.

5.3.2 Tender procedure case C

This project was tendered through the EMAT procedure. This means that awarding the contract was based on the BPQR. For the quality part of the award criteria, approximately 60% of the deduction was awarded for the "communication" award criteria, and approximately 40% of the deduction was for the "cooperation" award criteria. So no environmental sustainability EMAT criteria are used for this tender.

5.3.3 EMAT award criteria case C

As mentioned above, this tender had 2 award criteria: communication and cooperation. In this part, the award criteria and their assessment are discussed.

Communication
(EMAT Cr 19 from table 6)

Although the communication is a responsibility of the municipality, the contractor is also responsible for communication with the residents and the environment of the project. For the communication part, the contractor is assessed based on the communication with various stakeholders such as residents, (sub)contractors, and the municipality during the execution of the project.

Furthermore, the measures taken to minimize complaints by residents or causes of hindrance are important for the assessment of this part of the quality of the tender.

Cooperation
(EMAT Cr 21 from table 6)

The cooperation part of the award criteria exists of the cooperation with other parties such as the municipality (the client), project developers, and other (sub)contractors).
For the cooperation part, the contractor is assessed based on the cooperation with other parties to minimize the hindrance to the environment for the different activities during the execution of the project.

5.3.4 Results of case C

Selection criteria subcontractors and suppliers

The selection criteria for the suppliers and subcontractors used for this case are the Cost (Selection cr 1)[8], experience (Selection cr 2), quality (Selection cr 3), time (Selection cr 4), safety (Selection cr 5), cooperation (Selection cr 7), and distance (local subcontractors) (Selection cr 9).

What is noticeable, is that sustainability is no selection criteria for the subcontractors and suppliers. This could be because there was no incentive to select them based on the sustainability of their activities, as stated by interviewee C2:

> *"We then have no incentive to offer a more sustainable product. It wasn't worth it for this project either. We are not improving in terms of image, finances, or planning. It is rather a risk for us to do so."*

Influence EMAT criteria on selection criteria

As discussed in the paragraph above, there was no incentive for the contractor to look at the sustainability level of the suppliers and contractors for this project. However, for the other selection criteria such as experience (Selection cr 2), time (Selection cr 4), and cooperation (Selection cr 7), the EMAT criteria (EMAT Cr 19 and 21) were important to choose subcontractors and suppliers.

Trade-offs between selection criteria

Three different trade-offs were mentioned by the interviewees for this case. The first trade-off was between the quality (selection cr 3) of the project and the cost (selection cr 1). The second trade-off was between the experience (selection cr 2) and the cost (selection cr 1). And the third trade-off was between the distance of transportation (selection cr 9) and the cost (selection cr 1). For the first two trade-offs, quality and experience were very important for this project since communication with and cooperation with the residents were very important for the client. So the contractor was willing to pay more for a better-skilled subcontractor or supplier. For the distance, the contractor had to make a trade-off for the suppliers as close as possible to the project, since this is the best option for the tender bid. However, the quality and experience need to match as well. So this means that if they had the right experience and quality of the product, the nearest supplier of the project was chosen.

Influence EMAT criteria on trade-offs

Since the EMAT criteria valued cooperation and communication with the subcontractor and supplier, the EMAT criteria did influence the trade-offs made as listed above. The experience was a very important selection criterion (of subcontractors and suppliers) for the contractor since the client cared deeply for the communication between the parties and the cooperation to minimize the hindrance to the environment. Interviewee C1 explains the influence of the EMAT criteria on the trade-off between experience and cost:

> *"the EMAT [criteria] also looked at cooperation and communication. We normally score very well on this. We knew in this work that local medium-sized companies were also*

[8] Note the difference in this chapter between the acronyms EMAT Cr and Selection cr. EMAT Cr is for the EMAT criteria discussed in table 6 chapter 3.3.1. And Selection cr is for the selection criteria for subcontractors and suppliers discussed in table 8 chapter 3.4.

very important for the municipality of Beverwijk. When you look at such work, you look for a local party with whom you have done business before. … It had already been decided in advance that we were going to include this party in the action plan, and price plays a slightly subordinate role in this tender. Because then you really choose it because you can benefit from the plan of action and the tender."

So the EMAT criteria influenced the trade-offs between the selection criteria for the selection of subcontractors and suppliers.

5.4 Cross-case analysis

In the previous chapters, the results of the three cases were discussed separately. In this chapter, the similarities and differences are identified through cross-case analysis. The three cases are compared on the bases of the criterion used for the supplier and subcontractor selection in combination with the EMAT criteria for each case. First, the comparison between the EMAT criteria and selection criteria of subcontractors and suppliers is discussed (chapter 5.4.1), followed by the influence of the EMAT criteria on the selection criteria and the explanation of the comparison (chapter 5.4.2). After this, the findings of the cases for the measurement (chapter 5.4.3), responsibility (chapter 5.4.4), and the (non-monetary) incentive (chapter 5.4.5) are discussed. The findings presented in this chapter are the basis for the final framework shown in the next chapter (chapter 5.5).

5.4.1 The criteria: EMAT and selection criteria for each case

In this section, the EMAT criteria and the selection criteria for the suppliers and subcontractors are compared between the different cases.

The first two cases do have sustainability and management of the environment award criteria, whereas the third case does not. The second and third cases have cooperation as one of the award criteria, whereas the first case does not. And the third case has communication as award criteria, whereas the first two cases do not.

Similarities in selection criteria for all cases

Table 10 shows an overview of the EMAT criteria per case and the used selection criteria for the selection of subcontractors and suppliers. First of all, the table shows that safety is a base criterium for subcontractors and suppliers. This means that they need to meet safety requirements such as 'Veiligheid, Gezondheid en Milue' (VCA) certification, 'Generieke Poort Instructie' (GPI), and 'Veiligheid in Aanbestedingen' (VIA) to be a possible subcontractor or supplier for any project. If they don't meet the requirements, the contractor will not work with them. So, a trade-off with this selection criterion is not possible.
Furthermore, the table shows that regardless of the EMAT criteria, the cost is the most important selection criterion for subcontractors and suppliers. This is consistent with the literature on the selection criteria of subcontractors and suppliers (Hartmann et al., 2009; Vo et al., 2021).

Distance seems important in all cases as well, whereas based on the literature review presented in chapter 3, there is a lack of "distance" included as a criterion for subcontract and supplier selection. One of the reasons for this could be that the distance of transportation affects the cost, delivery time, and sustainability of the project. These three things are taken into account already separately in the selection criteria found in the literature review.

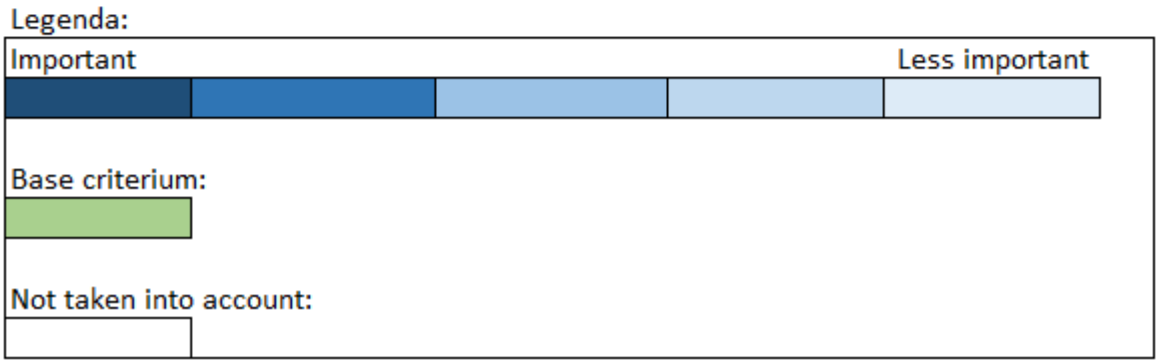
Differences in selection criteria for all cases

The comparison between the cases shows that in the first two cases, sustainability is taken into account as a selection criterion and in the last case it is not. Furthermore, the relationship with the subcontractor is taken into account in the last case and not in the first two.
Another thing that is different between the cases is the importance of the selection criteria. In the first case, the sustainability criteria are important and in the second case it is less important (this is explained in chapter 5.4.2). Experience is more important in the third case than in the first two cases. Another difference is the fact that the quality and the delivery time

are taken into account as selection criteria for the subcontractors and suppliers in the second and third cases but not for the first case.

Table 10: Comparison of the EMAT and selection criteria for all cases

Cases	Information	EMAT criteria	Selection criteria								
			C1: Cost	C2: Experience	C3: Quality	C4: Time	C5: Safety	C6: Level of technology	C7: Relationship	C8: (Environmental) sustainability	C9: Distance
Case A	Year: 2021 Construction: refurbishment of streets	Sustainability and Environmental management									
Case B	Year: 2022 Construction: refurbishment of public area	Sustainability, environmental management, and cooperation									
Case C	Year: 2019 Construction: site preparation of an area	Cooperation and communication									



5.4.2 Influence of EMAT criteria on the selection of subcontractors and suppliers

All three cases made clear that the EMAT criteria influence the selection of subcontractors and suppliers through the influence on the selection criteria and the trade-offs between them. One of the interviewees stated the following about the influence of EMAT criteria on the selection of subcontractors and suppliers:

"Normally you request 3,4 or 5 quotations, put them together, and make a trade-off for price. If the sustainability aspect is included in the EMAT, you will also include this. If someone has a better LCA or MKI value of a certain product and then you weigh it: It is slightly more expensive, but what does it yield to me in terms of CO2 savings? And if you can achieve more added value through a higher price but a better LCA value, this will be included in the price formation."

In his example sustainability is named as a selection criterion, but the same applies to other criteria such as quality, distance, and experience.

Furthermore, table 10 also shows the influence of EMAT criteria. When sustainability is asked, it is taken into account as a selection criterion for the selection of subcontractors and suppliers. But when it is not asked, the contractor will not assess the subcontractors or suppliers on this requirement. And the same applies to the experience of the subcontractor or supplier. Although in all three cases, the experience was taken into account in the selection, for each case the importance of the experience is different.

What is noticeable is that when the percentage of the award criteria for sustainability is higher, the sustainability selection criterion becomes more important for the selection of subcontractors and suppliers (see table 10). In the first case, the sustainability in the award criteria is accountable for 50% of the deduction and sustainability as a selection criterion is quite important. For the second case, the sustainability in the award criteria is accountable for 10% of the deduction and the sustainability as a selection criterion is not that important. In the last case, no sustainability is asked in the award criteria and as a result, sustainability is not taken into account for the selection of subcontractors and suppliers. So, the greater the incentive in a tender to be sustainable, the more the contractor will look at these requirements for their subcontractors and supplier for that project.

5.4.3 Measurement of sustainability

When it comes to the measurement of sustainability there are two important factors. The first important factor in measuring the sustainability of an infrastructure project is the measurable aspect. What is measured is important to compare the sustainability of the project with the other aspects of the project such as cost, quality, or time. Two different aspects were mentioned by the interviewees for the measurement of sustainability. An often-used measurement of sustainability is through an ECI score (in Dutch MKI), which is used in the Dubotool as well. In this case, the (measured) CO2 reduction (CO2eq) is translated to a single monetary score. 5 out of 9 interviewees mentioned this measurement method for sustainability.
Another measurement of sustainability is the CO2 performance ladder (see chapter 4.1.2 for an explanation). This measurement is also translated into one score, namely the ambition level (levels 1 to 5) and this score is based on four elements: Insight, reduction, transparency, and participation. Although this measurement was not used in the cases, it was mentioned by 3 out of 9 interviewees as a measurement for sustainability.
A final method to measure sustainability is through the innovation of technology. For example, the use of solar panels or the use of electric vehicles.

This last measurement is a good example of the second important factor for the measurement of sustainability. The second factor is the comparison of sustainability between the different bids of contractors in the tender. When the contractor is asked about technological innovation when it comes to sustainability, one contractor could promise A and another contractor could promise B. And this is very hard to compare and score the amount of

deduction for. In the case of ECI, when one score is given to the outcome of the tool, it is easy to compare the sustainability between the different contractors in the tender process. The contractor with the highest score, in this case, will have a higher deduction than the contractors with a lower score on the sustainability aspect of the EMAT criteria in the tender.

So there must be a measurable or equally weighted aspect of the sustainable EMAT criteria to make the tender process as transparent and honest as possible.

5.4.4 Responsibility of sustainability in the infrastructure sector

Based on the literature review it was not clear who is responsible for the sustainable transition in the infrastructure sector and importantly who is going to pay for this transition. Therefore, the responsibility and payment for sustainability were subjects for the interviews. Most interviewees responded that the responsibility is for multiple parties in the infrastructure sector. For example, interviewee B1 said:

> *"I think everyone has a responsibility. The client must outline the correct frameworks and preconditions to comply with them. Consider, for example, the presence of electrical charging facilities. They must be there if we are going to purchase electric vehicles and those charging facilities are often purchased by the municipality [the client]. As a contractor, we cannot just ask a subcontractor or supplier to purchase electrical equipment, because it is an extremely large investment for them. … But we are now making agreements with suppliers that we purchase at least a minimum number of hours for electric trucks so that they have a guarantee that it will be purchased. We cannot, therefore, oblige them, but we can make agreements that they manage their fleet properly. Of course there is also a personal responsibility."*

Another example from interviewee B2:

> *"It lies indirectly with the customer. It is often more expensive and you need more facilities. And it is certainly up to us to encourage the subcontractor to invest in this. They will also expect a certain amount of effort in return from the subcontractor. So that they make an investment and that it is used. I think it is an interaction between several parties."*

So, the responsibility is for the client in a way that they set the boundaries for the playing field and set the rules or stimulate the sector to innovate. And the responsibility of the contractor is to stimulate and cooperate with the subcontractors and suppliers to make themselves and the other parties and activities as sustainable as possible. Both the client and the contractor are responsible for the monitoring of the sustainability performance (this was claimed by 2 out of 9 interviewees). However, again the responsibility here for the client is to set the boundaries and the rules for the monitoring of sustainability.

The second topic is about who is going to pay for the transition to a more sustainable sector. Interviewee A1, for example, divided the investment in sustainable equipment and the development of sustainable material:

> *"There is a difference between developing and investing here. Development is always up to you. But the moment you invest in an electric car, the costs of building it are passed on in the tender price. It is the customer's turn to pay for an investment, and it is up to us to pay for the development. This is, of course, also indirectly calculated."*

So, when it comes to the payment of the transition a division can be made between the investment in sustainability and the development of sustainability. However, in one way or

another, it will be calculated in the tender price, which means that the client (in most cases the municipality; or even further the taxpayers) will pay for the sustainability transition of the infrastructure sector.

5.4.5 (Non-monetary) incentive

As discussed earlier, an incentive is needed in order for the contractor and subcontractor to be sustainable. The most obvious and most commonly used incentive is money. When the client sets the EMAT criteria and gives a deduction on the tender bid it stimulates the contractor and indirectly the subcontractor and supplier in their turn to be more sustainable. In what form necessary, an incentive is needed for the sector to be more sustainable:

> *"In the end, the subcontractor or supplier only does it [being more sustainable] when we ask it, just as we only do it when the client asks." (Interviewee C3)*

Other forms of incentives can be found in table 11.

Table 11: (Non-monetary) incentives for sustainability

Incentive	Description	Named by interviewee
Image towards the environment and the employees	In this way, the contractor has an image towards the different clients, but also towards potential employees that they are sustainable and are therefore more attractive for certain projects or for employees to work for	A1, A2, B1, B2, C1, C2, C3
The ambition or policy of the company	The company's sustainability policy is an incentive for employees within the company to be as sustainable as possible during the projects but also in their private life (through electric vehicles for example). Furthermore, being sustainable can save money	A1, B1, B3, C1
Laws and regulations	Laws can 'force' companies to be more sustainable. In this case, the incentive does not directly yield the company anything. Indirectly their image will improve.	A3, B3

Although these non-monetary incentives are named by the interviewees, indirectly the incentives can deal with money. When the image of the company is to be very sustainable, it will give them an advantage when clients look for sustainability in their projects and they most likely will be invited for a tender and even win the tenders. And the more tenders a company win the more money it will make.
The ambition of a company or the policy can also indirectly lead towards money since this is linked with their image towards the clients. Another reason for the company to have a sustainable policy is that sustainability can save money, which is mentioned by 2 out of 9 interviewees. Although, money can be yielded with a sustainable ambition, the companies can (as indicated in the interviews) have a wish to be more sustainable or have a bigger positive sustainable impact.

The incentive through laws and regulations does not per se have to deal with money. This incentive 'forces' the companies to be more sustainable, which in the end will most likely yield money because of an improved image. So, indirectly is money the incentive for contractors and subcontractors to be more sustainable.

5.5 Final framework

This chapter displays the final framework. The framework combines the results from literature review, document review, and the case studies to not only give overview based on the currently scientific state-of-the art, but also in consideration of the practical relevance. The framework is an overall stepwise selection process for subcontractors and suppliers connected to the currently applied sustainability EMAT criteria. Furthermore the framework can be used as a guideline for clients and contractors to see how they can implement sustainability in the infrastructure sector. So this framework is an overview of the results from the main question (*How does sustainable bidding (through EMAT criteria) in infrastructure projects affect the contractor's selection of subcontractors and suppliers?*).

The final framework (for the remainder of the thesis called framework) consists of two parts (see figures 15 and 16). The first part (figure 15) is based on the conceptual framework from chapter 4.4) and the second part (figure 16) is a result of the case study. The left side of the framework is input for the right side of the framework.

The first part of the framework is about the selection criteria for the selection of subcontractors and suppliers (see figure 15). This framework shows the influence of the EMAT criteria on the selection criteria. As discussed in chapter 5.4, the EMAT criteria influence whether selection criteria such as sustainability, quality, time, distance, or experience are taken into account for the selection of subcontractors and suppliers for an infrastructure project. Furthermore, the responsibility of the client for the infrastructure sector to be more sustainable is to set the boundaries for the playing field and set the rules or stimulate the sector to innovate. This is done through the determination of the EMAT criteria for the tender of the project. Therefore, the client is responsible for this part of the framework (see figure 15 left side). The contractor in their turn is responsible for the selection of the subcontractors and suppliers based on the (by them selected) selection criteria (see figure 15 right side). The arrows between the EMAT criteria and the selection criteria are the influence that the EMAT criteria have. When the arrow is thicker, it means that the influence is bigger. For example, the arrow from the environmental sustainability EMAT criteria to the environmental sustainability selection criteria (green box in figure 15) is thicker since this influence is bigger than the influence of these EMAT criteria on the other categories of selection criteria.
In this thesis, the main focus is on the environmental part of sustainability. Therefore, the measurements found in the literature and the case study are presented in the framework. The measurement for environmental sustainability can be (based on the selection criteria and the EMAT criteria) about electrical vehicles or equipment, the ECI score, LCA score, Dubotool results, CO_2 equivalent (emissions), or the level of the CO2 Performance Ladder. Moreover, these measurements are easy to use and compare among the different subcontractors and suppliers.
For the contractor, it is useful to know which selection criteria can be used for the selection of subcontractors and suppliers and how to measure, monitor, or evaluate these criteria to select the best possible party.
For example, when a tender has a sustainability EMAT criterion such as the improvement of the ECI score. The contractor can see that this deals with EMAT Cr 1: MkI (ECI)/Dubocalc. This framework will show the contractor that this is connected to the selection of subcontractors and suppliers when it comes to sustainability. Furthermore, it shows the contractor that the selection criterion can be measured in an LCA or ECI score or even in tool such as Dubocalc or Dubotool. So, the contractor can see immediately what the impact is of the sustainable EMAT

criteria and how to measure this for the trade-offs made in the selection of subcontractors and suppliers. This framework can be used as a guideline through the tender of infrastructure projects and the additional selection of subcontractors and suppliers for that tender.

The second part of the framework exists of the decision-making process for the selection of subcontractors and suppliers (see figure 16). The first phase is the pre-selection of subcontractors and suppliers. In this phase, the parties will be assessed on their safety standards. The subcontractors and suppliers need the following requirements: 'Veiligheid, Gezondheid en Milue' (VCA) certification, 'Generieke Poort Instructie' (GPI), and 'Veiligheid in Aanbestedingen' (VIA). These requirements are certifications that shows the infrastructure sector that the subcontractor or supplier know how to deal with safety on the construction site. When they meet the requirements they will be put on the list of subcontractors and suppliers that can be used for the projects of the contractor (see figure 16 output phase 1).
The second phase of the process is the determination of the selection criteria for the subcontractors and suppliers. This is based on the first part of the framework (figure 15). So the input for this phase of the process is the list of possible selection criteria and the list of possible EMAT criteria which influences the choice of selection criteria (see chapter 5.4.2). the output of this phase is the chosen (and therefore important) selection criteria for the selection of subcontractors and suppliers.
The third phase of the process is about the trade-offs that are made during the selection of subcontractors and suppliers. The case study showed that the trade-offs were (indirectly) influenced by the importance of the EMAT criteria (see chapter 5.4.2). The input of this phase is the outputs from phase 1 and phase 2 (in figure 16 called 'output 1' and 'output 2'), so the list of possible subcontractors and suppliers and the selection criteria for the tender with possible measurements for the environmental sustainability selection criteria. Based on this the trade-offs between the selection criteria and the different subcontractors and suppliers can be made to have a ranking of the subcontractors and suppliers. The trade-offs are project specific, since for every tender different EMAT criteria can be selected by the clients. Furthermore, the contractors are also dependent on the information the subcontractors and suppliers provide about the sustainability of the company. This has an influence on the trade-offs that are made by the contractors. The ranking of subcontractors and suppliers is the output of phase 3 and the input for the last phase (phase 4).

In phase 4 the selection of subcontractors and suppliers take place. This is based on the trade-offs made between the different parties and the selection criteria. So this whole process is (indirectly) influenced by the EMAT criteria (the purple box in figure 16 on the left side). The outcome of this process are the chosen subcontractors and suppliers for the infrastructure project.

Furthermore, the scientific relevance of this framework consists of the increased knowledge and insights into the procurement of infrastructure projects with sustainability criteria and the impact on subcontractor and supplier selection (see chapter 1.2 research gap). This framework illustrates step by step the selection process and the way that the client and contractor can influence this process when it comes to the inclusion of sustainability.

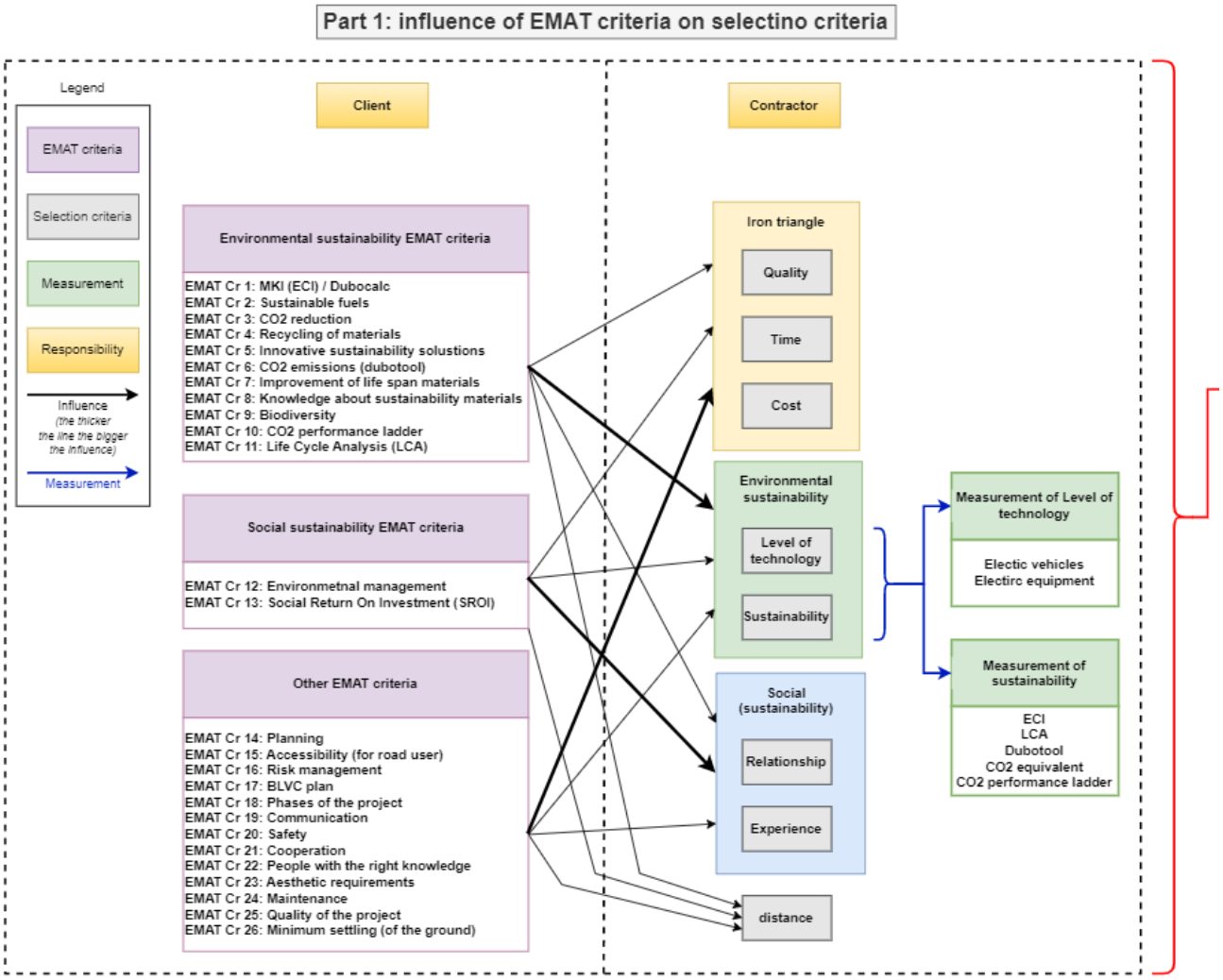


Figure 15: First part of final framework of EMAT influence on subcontractor and supplier selection

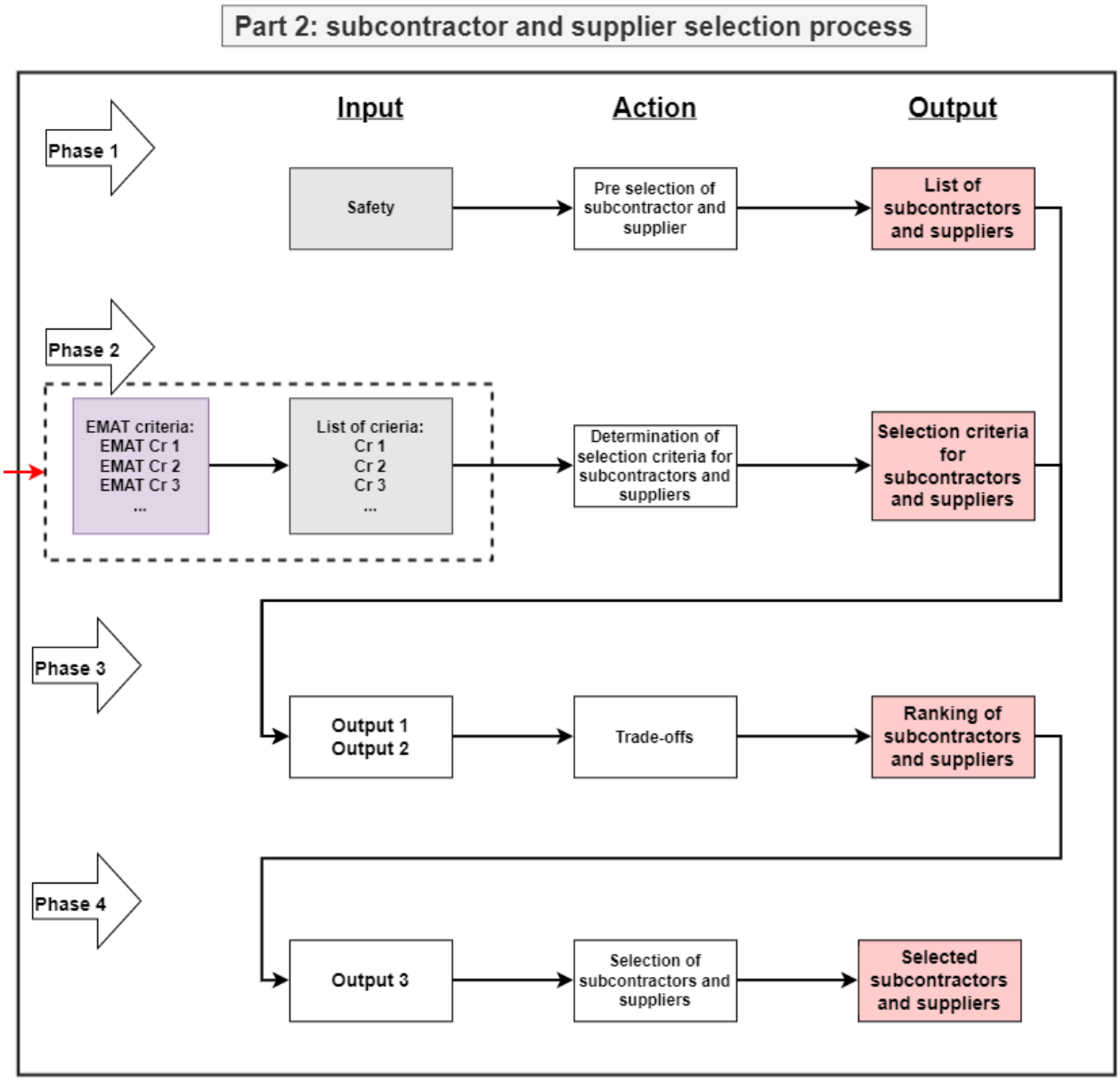


Figure 16: Second part of final framework of EMAT influence on subcontractor and supplier selection

06

Discussion and Limitations

6. Discussion and limitations

In this part, the discussion of the results of the thesis (chapter 6.1) and the limitations of the thesis (chapter 6.2) are discussed.

6.1 Discussion

This chapter first discusses the EMAT criteria, followed by the selection criteria and the trade-offs between the selection criteria. And finally, the influence of the EMAT criteria on the selection criteria and the trade-offs between them.

EMAT criteria

In this research, it was found that 56.25% of the tenders do have environmental sustainability EMAT award criteria. In the literature, it was found that 40.03% of the tender had sustainability EMAT criteria included in the tender in the Netherlands in 2021 (Bouwend Nederland, 2022). The increase in environmental sustainability EMAT criteria in infrastructure tenders could be explained due to the fact that this study is performed in 2022 and is more recent. Therefore, it can be that with the sustainability development in the Netherlands, more tenders are tendered with a sustainable EMAT criterion. Another difference is the fact that in the study of Bouwend Nederland (2022) the tenders were initiated by provinces, whereas the tenders in this study were initiated by the provinces as well as the municipalities and Rijkswaterstaat. There could be a difference in the use of sustainable EMAT criteria between provinces and municipalities.

Furthermore, in this study, 26 different EMAT criteria were found based on 64 tender documents. Of this 26 criteria, 11 were in the category of environmental sustainability and 2 in the category of social sustainability. The other 13 criteria were categorized in the same category: “others”. The three most used environmental EMAT criteria were ECI, sustainable fuels, and CO2 reduction. Since the reasoning behind the EMAT criteria from the client’s perspective has not been part of this thesis, it cannot be said with full certainty what the explanation is for the frequency of the different EMAT criteria. However, the measurement and monitoring of the EMAT criteria could be important reasons for the use of ECI, sustainable fuels, or CO2 reduction, because these criteria are easy to measure and compare. For the other criteria, it was harder to measure, compare, and monitor of them.

The least two used environmental EMAT criteria are the CO2 performance ladder and LCA. In the case of LCA, it must be said that ECI and the Dubotool are based on LCA scores. So, therefore this is used a lot, not on its own, but in combination with other tools or used in other tools. The CO2 performance ladder is not used that often, which can be due to the fact that most contractors are in the highest level possible (level 5) and therefore there is no added value between the different contractors bidding on a tender (and therefore the tool is not as useful as it was).

Selection criteria

In this study, 9 different categories of selection criteria for subcontractor and supplier selection were found. The 9 different categories were cost, experience, quality, time, safety, level of technology, relationship, and sustainability. And there was a ninth category of miscellaneous selection criteria that were only mentioned once or twice in the literature. So, sustainability is one of the criteria that influence the selection of subcontractors and suppliers.

The case study found, just as in the literature (Hartmann et al., 2009; Vo et al., 2021), that the cost is the most important selection criterion and is always taken into account when selecting subcontractors or suppliers. This would mean that the incentive to be more sustainable is not big enough when this is compared with the costs of being sustainable.

Contrary to the findings in the literature review, the case study found that the distance of transportation is important for the contractor. The distance (or in literature called location) was only found two times in the literature (Kazaz, 2017; Koçak et al., 2018) and was therefore placed in the miscellaneous category. A reason for the fact that the distance turned out to be more important is that the distance also deals with the cost of the project, the planning (time of delivery), and the sustainability and these categories are important for the selection of subcontractors and suppliers.

Lastly, the case study found that the safety criterion is not used as a selection criterion on the project level (the other criteria could be used on a project level), but is a pre-selection criterium for subcontractors and suppliers to be a possible partner for a project. So, safety is a threshold to be a possible partner. The subcontractors and suppliers either meet the safety requirements and are therefore feasible future partners or they don't meet the safety requirements and will not be selected at all. This means that safety is always a selection criterion for the selection of subcontractors and suppliers. In the long term, it is possible to think that standardization or a so-called threshold applies to sustainability as well (just as the example of the CO2 Performance ladder in section 6.1: EMAT criteria). This would mean that the sustainability selection criteria will become more important in the future.

Trade-offs between selection criteria

To have trade-offs between selection criteria it is important to have a good measurement of the selection criteria. In the case of cost, the measurement is money. In the case of time, the measurement is in days, weeks, or months. But for the sustainability of a project lots of different measurements are proposed in the literature. Measurements such as CO2 reduction, ECI values, or the CO2 performance ladder. However, in practice, this is not very useful for the trade-off between sustainability and the other selection criteria. In the literature, it was found that most trade-offs are based on the cost of the project (Mokhlesian, 2014). When sustainability is translated into one score or monetary value (as done with ECI or the Dubotool) (an equally weighted criterion) it is easy to make a trade-off with the cost and the level of sustainability of the project or a trade-off between the sustainability and other selection criteria.
It is therefore important that the measurement of the sustainability aspect of the tender is clear to have a proper trade-off with this selection criterion.

It was found that the trade-offs between the selection criteria are project specific, just as the selection criteria are project specific. When, for example, sustainability is not part of the EMAT criteria in the tender it will most likely not be a part of the selection criteria for the subcontractors and suppliers and therefore also not be part of a trade-off for that specific project.

Influence EMAT criteria

The results from this study suggest that there is an influence of the EMAT criteria on the selection of subcontractors and suppliers and especially on sustainability. First of all, it is noticeable that when sustainability is part of the EMAT criteria, it is also part of the selection criteria for subcontractors and suppliers. This could be in the form of sustainability, but also in

the form of the level of technology when it comes to equipment or electrical vehicles. This is in line with the hypothesis of chapter 1.3: When there is an incentive for the contractor to be more sustainable, the selection of subcontractors and suppliers will be based on sustainability as well. So, the incentive is very important in this case. This means that the contractor follows the client when it comes to the selection of sustainable subcontractors and suppliers. Following the client can have a positive impact when the EMAT criteria are clear and measurable. However, it can have a negative impact on the sustainable development of contractors, subcontractors, or suppliers when there is no incentive provided for implementing sustainability.

Furthermore, the importance (read the percentage of the deduction on the tender bid) of the EMAT criteria influences the trade-offs between the selection criteria, at least the trade-offs with sustainability. the more important the sustainability EMAT criteria the more important the sustainability becomes in the trade-offs between the selection criteria for the subcontractors and suppliers. This is also in line with the hypothesis because there is even a higher incentive for the contractor to look at sustainability if the importance of the sustainability part of the EMAT criteria is higher as well. From the results, it can be concluded that if there is no incentive to be sustainable or the incentive is not big enough that the cost is the most important selection criterion in the trade-off.

Moreover, this study found that the responsibility for a transition toward a more sustainable infrastructure sector is for multiple parties. The client or municipality in most cases is responsible for setting the boundaries for the playing field and setting the rules or stimulating the sector to innovate. And the responsibility of the contractor is to stimulate and cooperate with the subcontractors and suppliers to make themselves and the other parties and activities as sustainable as possible. In the end, the incentive to be more sustainable is important. Having long-term contracts or long-term cooperation with subcontractors or suppliers can stimulate them to invest in sustainable development because they know that the contractor will help them or use the development or investment. For example, the investment in electric vehicles. If the subcontractor knows that the contractor will use the vehicles for at least a couple of years they are more likely to invest in this since they will earn back their investment.

Sustainability framework

The framework is an overview of the end result of this thesis and is a guideline for the clients and contractors in the infrastructure sector when it comes to the selection process of subcontractors and suppliers for an infrastructure tender. Furthermore, the framework shows the way that EMAT criteria influence this selection, especially when it comes to (environmental) sustainability. The framework also shows that safety is an important selection criterion for the subcontractors and suppliers.

The framework is the combined result of the literature study and the case study which explains the selection process of subcontractors and suppliers for an infrastructure tender and the way that EMAT criteria influence this selection, especially when it comes to (environmental) sustainability. For the client, the responsibility in the infrastructure is to set the playing field and rules for the tenders. In this case, and visible in the framework, the client can influence the transition towards a more sustainable infrastructure sector through the EMAT criteria.
The contractor in their turn is responsible for the selection of subcontractors and suppliers. They can influence the decisions and trade-offs that are made in the selection process of subcontractors and suppliers. To make the trade-offs for the best suitable and most

sustainable party, the contractor needs to know how to measure the sustainability of the selected party. Therefore, the measurement of sustainability is taken into account in the framework to create an overview of the possibilities.

6.2 Limitations

6.2.1 Limitations scope

In this thesis, only the company Heijmans has been used for the data. For generalization of the results to the Dutch infrastructure sector, more research about this topic need to be conducted at different companies in the Netherlands. Furthermore, the results and conclusion of this research are based on three cases. More cases are needed to generalize the results.

Secondly, this research looked into infrastructure projects. However, it did not look at the difference in EMAT influence between different infrastructure projects or other construction projects. For example, an infrastructure project can have different specifics in sustainable subcontractors and suppliers than the construction of buildings. This is also because of the supply chain and materials used. For example, roads are usually made from asphalt which already has a lot of recycled content, while the construction of buildings can use a lot of different materials with all different sustainability or reusability such as wood, bricks, or concrete.

Thirdly, the focus of this thesis was on environmental sustainability. So the influence of the EMAT criteria on the other selection criteria has been a relatively small part of this thesis. More research should be needed about the influence on all different selection criteria and not only sustainability. Ideas about this are elaborated upon in chapter 7.4.

Furthermore, in this thesis the contractor's perspective on the influence of the EMAT criteria on the selection of subcontractors and suppliers was taken into account. The client's perspective is not taken into account. The EMAT criteria on their own are the perspective of the client on the project since they chose them. However, the reasoning behind the EMAT criteria for the projects is not known. Knowing this could add value to this research and maybe another insight into the results.

Another limitation is that not all different types of environmental sustainability EMAT criteria were taken into account in the case study. So the differentiation of the influence between the different sustainable EMAT criteria could not be tested.

6.2.2 Limitations method

The sample size of the case study is limited to three cases. Therefore, the results can only be generalized to projects with the same characteristics as the cases in this research. So, more cases would increase the generalization of the results.
Furthermore, only three people per case have been interviewed which means that if one person gives a different answer or would not answer the question that 33% of the data would have been missing. To make this probability smaller, more interviews would be useful.

07

Conclusion

7. Conclusion

In this chapter, the conclusion of the thesis is discussed. First, the conclusions of the sub-questions are discussed (chapter 7.1), followed by the conclusion of the main question (chapter 7.2). And finally, the recommendations for the sector (chapter 7.3) and the recommendations for future research (chapter 7.4).

7.1 Conclusion of sub-questions

In this part, the conclusions of all four sub-questions are discussed.

SQ1: Which (sustainability) criteria are used in the tender of infrastructure projects to achieve environmental sustainability?

As a result of the literature study about EMAT criteria and the documentation study (64 tender documents were used), a list of 26 different EMAT criteria was made (see table 12 for an overview). From these EMAT criteria, 11 were about environmental sustainability, 2 were about social sustainability, and the other 13 were put in a category called “other criteria”. So there are multiple ways of having sustainable requirements for a project. These categories were used during the research because the focus of this thesis is on (environmental) sustainability. Therefore it is in the interest of this study to know more about the sustainability categories of the EMAT criteria.

Table 12: Summary of results SQ1

Criteria (Cr)		Number of occurrences
Environmental sustainability		**36**
Cr1	MKI (Environmental Cost Indicator (ECI))/Dubocalc	11
Cr2	Sustainable fuels	8
Cr3	CO2 reduction	7
Cr4	Recycling of materials	6
Cr5	Innovative sustainability solutions	5
Cr6	CO2 emissions (Dubotool)	4
Cr7	Improvement of life span materials	2
Cr8	Knowledge about sustainability materials	2
Cr9	Biodiversity	2
Cr10	CO2 performance ladder	1
Cr11	Life Cycle Analysis (LCA)	1
Social sustainability		**34**
Cr12	Environmental management	30
Cr13	Social Return On Investment (SROI)	6
Other criteria		**64**
Cr14	Planning	35
Cr15	Accessibility (for road users)	35
Cr16	Risk management	22
Cr17	BLVC plan	16
Cr18	Phases of the project	15
Cr19	Communication	13
Cr20	Safety	12
Cr21	Cooperation	10
Cr22	People with the right knowledge	5
Cr23	Aesthetic requirements	2
Cr24	Maintenance	2
Cr25	Quality of project	1
Cr26	Minimum settling (of the ground)	1

SQ2: How do contractors select their suppliers and subcontractors in the infrastructure sector?

For this sub-question, a literature review was performed about the supplier and subcontractor selection criteria. In this review, it was found that 8 different categories of selection criteria influence the selection process. A ninth category was added for miscellaneous selection criteria, which existed of, for example, the distance or management of the subcontractor and supplier.

1. Cost
2. Experience
3. Quality
4. Time
5. Safety
6. Level of technology
7. Relationship
8. Sustainability
9. Miscellaneous

Only 2 of the 9 categories deal with the sustainability of the supplier or subcontractor: level of technology and sustainability. So lots of selection criteria influence the selection of subcontractors and suppliers and a part of this is sustainability.

The cost was found to be the most important selection criterion. For the other criteria, no ranking was found in the literature review.

Furthermore, the case study found that the fifth criterion “safety” was not used as a selection criterion on project level but as a pre-selection criterion for the contractors and suppliers to be a possible future party to have a cooperation with. After this pre-selection, the selection of subcontractors and suppliers could take place with the chosen selection criteria for that specific tender.

SQ3: What is the existing trade-off between cost and the level of sustainability?

For this sub-question, a literature review was performed about the measurement of sustainability and the trade-offs of selection criteria, which was complemented with the findings of the case study.

In the literature review it was found that the measurement of sustainability in the infrastructure sector is done through different tools or methods such as CO2 performance ladder, LCA, ECI, or Dubocalc. In all these measurement tools the CO2 value is transferred into one (monetary) value to make it easier for the client and contractor to compare the scores among the different tender bids.

Moreover, in the literature review it was found that one of the widely acknowledged environmental performance indicators to measure the impact on an infrastructure project is CO2eq or the CO2 footprints of a project.

Knowing the measurable aspects of sustainability can provide an easy way to make trade-offs in the selection of subcontractors and suppliers. A trade-off often made, is between the cost of a project and the level of sustainability. Therefore, a less sustainable supplier or subcontractor

could be selected for a project because they are cheaper. However, when the incentive is big enough (for example, a deduction on the tender bid), a more sustainable supplier or subcontractor is selected although that option is more expensive.

Not only trade-offs between cost and sustainability but also between other selection criteria are made. However, the trad-offs made between the selection criteria are project specific and can shift depending on the incentive or the importance of the EMAT criteria.

SQ4: To what extent are sustainable EMAT criteria taken into account by the contractor during the selection of subcontractors and suppliers?

For this sub-question, a case study was performed with three infrastructure cases. For each case, three people involved with the tender of the project were interviewed. The sustainable EMAT criteria influenced the selection of subcontractors and suppliers in a way that when sustainability was not asked in the EMAT award criteria it was also not taken into account in the selection of subcontractors and suppliers and the other way around. Furthermore, the importance of the sustainable EMAT criteria (read the % of deduction on the tender bid) influenced the trade-offs that were made with sustainability for the selection of subcontractors and suppliers. The more important the sustainability EMAT criteria the more important the sustainability selection criteria are for the selection of subcontractors and suppliers.

Another conclusion based on the case study is that the responsibility for a more sustainable infrastructure sector and therefore more sustainable subcontractors and suppliers is for both the client and the contractor. The client sets the boundaries of the playing field and sets the rules and incentives for the tender. The contractor on the other hand is responsible for the investment and development of sustainability in cooperation with (if possible) the subcontractors and suppliers.

7.2 Final conclusion

The main question this thesis answers is:

How does sustainable bidding (through EMAT criteria) in infrastructure projects affect the contractor's selection of subcontractors and suppliers?

The sub-questions serve as a structured way to answer the main question. The EMAT criteria from SQ1 influence the selection criteria from SQ2, which are in their turn needed for the trade-offs in SQ3. The result of these questions was a conceptual framework that was used as the basis for the case study for SQ4. The answer to these questions leads to the end result of this thesis.

Based on this research it can be concluded that the EMAT criteria influence the choice of selection criteria for subcontractors and suppliers for a tender and that the importance of the EMAT criteria (the percentage of the deduction on the tender bid) influences the trade-offs made between the selection criteria. Furthermore, not every selection criterion is influenced by the trade-offs in a tender. When it comes to safety a subcontractor or supplier meets the safety requirements or they don't. when they do, it is possible that they are selected for a project and when they do not the contractor will not cooperate with them. When it comes to sustainability, the environmental sustainability EMAT criteria are important to provide the contractor with an incentive to look for the most sustainable subcontractors and suppliers. The more important the sustainability EMAT criteria are (as defined in the tender by the client) the more important sustainability will become for the contractor when selecting subcontractors and suppliers.

It can therefore be concluded that the client, but also the contractor to a lesser extent, have a responsibility towards the infrastructure sector (and in the case of this thesis towards the subcontractors and suppliers in the infrastructure sector) to provide an incentive to be more sustainable. Without the incentive to be more sustainable, the price will be the most important selection criterion for subcontractors and suppliers.

A framework is proposed to give the contractor an overview of how the subcontractor and supplier selection process can be influenced by the EMAT criteria. The framework shows that the client and the subcontractor can influence (directly or indirectly) the selection criteria of subcontractors and suppliers when it comes to sustainability. Furthermore, the framework helps the contractors to identify the possible EMAT criteria and the possible measurement of sustainability for a tender when selecting subcontractors and suppliers.

7.3 Recommendations for the infrastructure sector

It is recommended to the client and the contractor to have dialogue sessions with each other about the measurement of the sustainable EMAT criteria and the responsibility for the monitor of this. Making clear how sustainability is measured and what is needed to monitor, will stimulate the contractors, subcontractors, and suppliers of the infrastructure sector to be more sustainable in the future.
Furthermore, the use of equally weighted sustainable EMAT criteria makes it easier for the contractor to select the most sustainable subcontractor or supplier.
A final recommendation is that sustainability should be part of EMAT, or part of all present and

future contracts in general if we are to achieve sustainability goals for the infrastructure sector, but mostly for the ambitious goals in the Netherlands

7.4 Recommendations for future research

- The perspective of the client, subcontractor and suppliers was not included in this research. It might be relevant to see what their point of view is on the (sustainable) subcontractor and supplier selection and the influence of EMAT criteria.

- A study involving more cases and different companies might bring new proof of the findings of this paper so that it can be generalized. Moreover, different companies could bring a different perspective to the selection of subcontractors and suppliers.

- In this study a higher percentage of environmental EMAT criteria was found in the tender. It might be relevant to look into the effect of the different types of clients on the percentage of environmental EMAT criteria in tenders to see if there is a difference between the different clients.

- For future research it is relevant to find out whether there is a difference in the influence of EMAT criteria between the different types of environmental EMAT criteria. It is useful for both client and contractor to know the ranking of the influence of sustainable EMAT criteria.

- More research is needed on the effect of the trade-offs for the selection of sustainable subcontractors or suppliers.

- In this research the focus was on the environmental sustainability of a tender. For future research, the influence of the EMAT criteria on the social sustainability of the selection of subcontractors and suppliers or the social sustainability of the project could be interesting.

08

Reflection

8. Reflection

The goal of this thesis was to create useful insights into the subject and have an end product to be proud of.

During the Master study, a lot of projects were group projects. So doing this master thesis on my own was a new experience that I was confident to experience. With this experience, I learned a lot when it comes to planning and organizing the thesis. Because of Covid 19, it was normalized to have online meetings. This allowed to schedule all of my meetings within one week of the busy agendas of the interviewees.

The qualitative case study research method was new to me and therefore I took a lot of time to think about the research method and the results it would generate. I had no experience with processing a large number of interviews for a study before. Transcribing, coding, and analyzing the results of the interviews was not possible without the help of the Atlas tool. This tool really helped me to think about the interview questions upfront to know what kind of information I wanted. This made the coding a lot easier and helped me to realize that knowing upfront what you want from the thesis and how you want to present your results is very important for the process of the thesis.

I also learned to use the Vosviewer tool and the PRISMA method for the literature review. This really helped me to search for as many as possible academic papers about the subject. In the beginning, I had no clue where to start reading and making use of these kind of tools and the use of PRISMA method structured the literature review.

Furthermore, I learned a lot from the expertise of my committee members, but also from the colleagues and interviewees from Heijmans. Asking people for help is something I do not hesitate to do and I am glad that I did. I learned a lot from everyone that helped me and sometimes they made me look at my thesis from a different perspective.

During my time as a student at the University of Technology in Delft, my writing skills were improved. However, my style of writing (really to the point) turns out to be an advantage and disadvantage for my thesis. The thesis is only a hundred pages long because of the short writing style, however, writing chapters such as the discussion or conclusion was found to be more difficult for me. During the thesis process, I learned that having a mixture of writing styles can be very convenient.

Looking back at my thesis and its process of it, I am very proud of the results and the time I took to carefully implement all aspects of my thesis. I probably could have written my thesis in a shorter time span, but I am glad that I took the time needed to improve and enhance my thesis.

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Appendix A – Interview questionnaires

In this appendix, the interview questions for semi-structured interviews can be found. There were three different interviews with different questions. The first is for the tender manager, the second for the procurer, and the third for the project manager. Note that the interviews in this thesis were conducted as semi-structured interviews. This means that not all questions asked are stated below. The list of questions in this appendix is the list that was made in preparation for conducting the interviews. During the interview, some new questions were added which could provide the answers needed for the thesis.

Tender manager:

Introduction:

- What is your role in the company?
- What is your experience with subcontractors and suppliers?
- What is your experience with sustainability within the company?

EMAT tender:

- Do you believe that EMAT tendering is the best way to tender sustainability? Why (not)?
- Did the EMAT criteria of this project influence your perspective on the trade-off or the selection of the selection criteria?
- Do you believe that EMAT criteria play a role in the selection of subcontractors and suppliers and how?

Supplier and subcontractor selection:

- Which selection criteria did you use for the subcontractors and suppliers and why? Think for example about the cost, experience, or sustainability of the subcontractor or supplier
- How are the selection criteria for subcontractors and suppliers determined?
- What are the most important selection criteria?
- Which trade-offs were made between the selection criteria?
    - And did the EMAT criteria influence this trade-off?

Sustainability:

- Do you believe that the contractor has a responsibility to the supplier and subcontractor when it comes to sustainability?
    - Think about creating awareness, education, or the right equipment
- Is there a (non-monetary) incentive to be more sustainable?

Procurer:

Introduction:

- What is your role in the company?
- What is your experience with subcontractors and suppliers?
- What is your experience with sustainability within the company?

EMAT tender:

- Do you believe that EMAT tendering is the best way to tender sustainability? Why (not)?
- Did the EMAT criteria of this project influence your perspective on the trade-off or the selection of the selection criteria?
- Do you believe that EMAT criteria play a role in the selection of subcontractors and suppliers and how?

Supplier and subcontractor selection:

- Which selection criteria did you use for the subcontractors and suppliers and why? Think for example about the cost, experience, or sustainability of the subcontractor or supplier
- How are the selection criteria for subcontractors and suppliers determined?
- What are the most important selection criteria?
- Which trade-offs were made between the selection criteria?
    - And did the EMAT criteria influence this trade-off?

Sustainability:

- How do you keep track of the sustainability of the supplier and subcontractor in general? Think about evaluations or checking reference projects.
- How do you measure the sustainability of the supplier for this project?
    - What do you believe is the best way to measure sustainability? and how can we best compare?
- Is there a (non-monetary) incentive to be more sustainable?

Project manager:

Introduction:

- What is your role in the company?
- What is your experience with subcontractors and suppliers?
- What is your experience with sustainability within the company?

EMAT tender:

- Do you believe that EMAT tendering is the best way to tender sustainability? Why (not)?
- Did the EMAT criteria of this project influence your perspective on the trade-off or the selection of the selection criteria?
- Do you believe that EMAT criteria play a role in the selection of subcontractors and suppliers and how?

Supplier and contractor selection:

- Do you feel that the supplier and subcontractor deliver their promised level of sustainability for this project?
    - What do you do when they don't?
- Is a trade-off visible during the execution of a project when it comes to sustainability?
    - Are there other criteria for the selection of suppliers and subcontractors that are important to you? And Why?
- Is there a (non-monetary) incentive to be more sustainable?

Appendix B – Coding Atlas tool

Table 13: Overview of codes in the Atlas tool

Code	Description
Comparison sustainability	This code was about the comparison of different sustainability measurement tools
EMAT change	This code was about the fact whether the selection criteria changed if the EMAT criteria changed as well for a project
EMAT influence case A	This code was about the influence of EMAT criteria on the selection criteria and trade-offs for case A
EMAT influence case B	This code was about the influence of EMAT criteria on the selection criteria and trade-offs for case B
EMAT influence case C	This code was about the influence of EMAT criteria on the selection criteria and trade-offs for case C
EMAT influence in general	This code was about the influence of EMAT criteria on the selection criteria and trade-offs for projects in general
Measurement sustainability case A	This code was about the measurement of the sustainability aspect of case A
Measurement sustainability case B	This code was about the measurement of the sustainability aspect of case B
Non-monetary incentive	This code was about the (non-monetary) incentive for contractors, subcontractors, and suppliers to be more sustainable
Responsibility	This code was about the responsibility for the transition towards a more sustainable infrastructure sector
Selection criteria case A	This code was about the selection criteria used for the selection of subcontractors and suppliers in the tender of case A
Selection criteria case B	This code was about the selection criteria used for the selection of subcontractors and suppliers in the tender of case B
Selection criteria case C	This code was about the selection criteria used for the selection of subcontractors and suppliers in the tender of case C
Tracking sustainability	This code was about the tracking of sustainability during a project and the responsibility for this
Trade-off selection criteria case A	This code was about the trade-offs between the used selection criteria in case A
Trade-off selection criteria case B	This code was about the trade-offs between the used selection criteria in case B
Trade-off selection criteria case C	This code was about the trade-offs between the used selection criteria in case C

Appendix C - categorization selection criteria

Table 14: categorization of selection criteria for subcontractors and suppliers

		Researchers											
		Cheng et al.,2011	Safa et al., 2014	Kazaz, 2017	Deep et al., 2018	Koçak et al, 2018	Shivam & Kashiyani, 2018	Cheaitou et al., 2019	El Kholy, 2019	Deep et al., 2020	Ramalingam, 2020	Vo et al., 2021	Karaman & Sandal, 2022
CAT 9	Soundness of the business and workforce												x
	familiarity with lean principles										x		
	flexibility when resolving delays						x						
	workload			x									
	service after work completion	x											
	Location			x		x							
	Manager personality	x											
	management capabilities	x				x		x	x		x		
CAT 8	Clean working environment	x											
	Material waste	x											
	Sustainable development			x								x	
CAT 7	Reliability and/or commitment				x					x			
	Relationship/collaboration with others	x		x	x							x	
CAT 6	Expertise									x			
	Technical capability					x		x	x			x	
	Technical personnel			x							x		
	Construction technique	x											
	Equipment	x		x			x						
	production and capacity					x			x	x			
CAT 5	Health					x	x	x	x				
	Safety	x		x		x	x	x	x				x
CAT 4	Duration	x	x			x	x		x		x		x
CAT 3	Quality of work					x	x		x		x	x	x
CAT 2	Reputation			x	x	x	x	x			x		
	(Past) performance		x	x		x		x	x	x			x
	(Past) experience			x	x			x		x	x	x	
CAT 1	Compensation for delay			x									
	Financial condition/strength/stability	x		x		x	x	x	x		x	x	
	Price		x	x		x	x	x	x	x	x	x	x

CAT 1: Cost; CAT 2: Experience; CAT 3: Quality; CAT 4: Time; CAT 5: Safety; CAT 6: Level of technology; CAT 7: Relationship; CAT 8: Sustainability; CAT 9: Management; CAT 10: Miscellaneous

Appendix D – Certification process of the CO2 performance ladder

Table 15: Requirements for the CO2 performance ladder

General audit requirements for each key process (A–D) for the different certificate levels (1–5).

Level	1	2	3	4	5
A Insight	The company has partial insight into its energy consumption.	The company has an insight into its energy consumption.	The company has converted its energy consumption into CO_2 emissions.	The company reports its carbon footprint in accordance with ISO 14064-1 for Scope 1, 2 & 3.	The company requires that its A-suppliers have a Scope 1 and 2 emissions calculation in accordance with ISO 14064-1.
B Reduction	The company investigates opportunities for reducing energy consumption.	The company has an energy reduction target, described in qualitative terms.	The company has quantitative CO_2 reduction objectives for its own organisation.	The company has quantitative CO_2 reduction objectives for Scope 1, 2 & 3 CO_2 emissions.	The company reports on a structural and quantitative basis the results of the CO_2 reduction objectives for Scope 1, 2 & 3.
C Transparency	The company communicates its energy reduction policy on an *ad hoc* basis.	The company communicates its energy policy internally (to a minimal degree) and possibly externally.	The company communicates about its carbon footprint and reduction objectives both internally and externally.	The company maintains dialogue with government bodies and NGOs about its CO_2 reduction objectives and strategy	The company is publicly committed to a government or NGO CO_2 emission reduction programme.
D Participation	The company is aware of sector and/or supply chain initiatives.	The company is a passive participant in initiatives aimed at reducing CO_2 emissions in or outside the sector.	The company is an active participant in initiatives aimed at reducing CO_2 emissions in or outside the sector.	The company initiates development projects that facilitate reductions in CO_2 emissions in the sector.	The company takes an active part in setting up a sector-wide CO_2 emission reduction programme in collaboration with the government or an NGO.