Decision-making for Large-scale Bridge Maintenance

Designing a Decision Support System for determining which bridges should be renewed simultaneously and with what strategy, using Amsterdam as a case study

A.S. (Annelotte) Piekema

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by

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to obtain the degree of Master of Science
in Transport, Infrastructure & Logistics

at the Delft University of Technology,
to be defended publicly on Thursday March 2, 2023

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Preface

This thesis, ”Decision-making for Large-scale Bridge Maintenance,” is written as the final step to complete the master program Transport, Infrastructure & Logistics at the Delft University of Technology.

I want to thank Witteveen+Bos for the opportunity to conduct this research at Witteveen+Bos, and especially to my supervisor Jeroen de Leeuw for his enthusiasm (as well during graduation and for my time as a working student), involvement, and excellent guidance! I also want to thank my daily supervisors from TU Delft, Jan Anne Annema and Adam Pel, for their valuable feedback and for always making time. Although we did not meet often, Bert van Wee, the chairman of my thesis committee, provided very relevant and insightful input, which I also want to thank. Finally, I would also like to thank my family and friends for their love and support!

Throughout this project, I have gained valuable insights into the complex challenges associated with large-scale bridge maintenance. This experience has inspired me to pursue complex projects in my coming career. I hope that the findings of this research will contribute to a deeper understanding of decision-making in large-scale bridge maintenance and lead to improvements in the future!

A.S. (Annelotte) Piekema
Rotterdam, February 2023

Summary

Situation

The infrastructural networks in Europe are among the densest in the world. However, due to several social-economic reasons, the budget for the maintenance of ageing infrastructure has been cut back for several decades. Postponing maintenance leads to high costs: it reduces internal market mobility, raises the possibility of accidents, and increases CO2 emissions in the transportation industry (European Construction Industry Federation, 2020). A backlog of maintenance is also present in the Netherlands (Stadszaken, 2021).

This research examines the decision-making process for the planning of bridge maintenance in the Netherlands, specifically in Amsterdam, where a large-scale renovation project is currently in progress. In the upcoming years, more than 200 km of quay wall and 850 traffic bridges in Amsterdam will be renovated or replaced; most of these are located in the historical center of Amsterdam. This enormous project has a massive impact on the surroundings and daily life in Amsterdam (Gemeente Amsterdam, n.d.). This project with, as a client, the Municipality of Amsterdam is called 'Programma Bruggen en Kademuren' (in English: Program Bridges and Quay Walls). Witteveen+Bos, in collaboration with the Engineering Firm of the Municipality of Amsterdam, is in charge of the project's management and engineering.

Delayed maintenance is a major issue in the Netherlands. The city of Amsterdam recently started a large-scale maintenance project to renew (renovate or replace) many bridges: an issue that other cities will have to face soon. These kinds of projects have an impact on transportation, surroundings and daily life (Gemeente Amsterdam, n.d.). Many bridges are considered in this maintenance project, but only a part can be taken into account at the same time. Therefore a decision should be made on what bridges should be renewed simultaneously; this planning about the scheduling of bridge renewal, is called 'programming'. The method used to renew an individual bridge must also be considered in the programming. Possible strategies for this renewal are entire closure, a phased building process, or using a temporary bridge.

Since the Municipality of Amsterdam started this project, various decisions on the programming have already been made. However, the current programming has some major drawbacks: trams are out-of- service for a long time, early replacement of bridges, and high costs due to temporary bridges. Currently, many temporary bridges are used; these are built next to the renewed bridge. On the other hand, strategies such as entire closure or a phased building process might lead to better outcomes. Hence, the current decision-making is not structured, not all choices have been evaluated, and the decision is based on only a few aspects. As a result, this programming has led to enormous expenses and project delays (J. de Leeuw, personal communication, June 15, 2022).

Making the decision of which bridges to address simultaneously with which strategy can potentially be supported by a Decision Support System (DSS). The literature review shows that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities.

Research Objective

The current decision-making in Amsterdam is not structured; as a result, not all options have been considered, and only a few factors are taken into account. Consequently, this programming has resulted in massive costs and project delays. Since municipal money must be spent wisely, an informed decision must be made. From the literature review, it can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities. Besides Amsterdam, this decision is also an issue in other Dutch cities. If no support is provided, every municipality has to make its own decisions. Since it is essential to make an informed decision, there is a need to develop a method to look at decision-making in an integral and systematic sense. This leads to the following main objective of this study:

"Designing a Decision Support System to provide insight into the Decision-making for Bridge Programming for Dutch Municipalities"

The Decision Support System (DSS) is a tool that provides insight into the decision-making regarding which bridges should be renewed simultaneously using what strategy (entire closure, phased building, or a temporary bridge). Because this is a very complex decision, the DSS will not make or optimize the decision but will only provide insight by creating an interactive tool where various alternatives can be explored, and different factors influencing this decision are shown.

Methodology

A design process was applied to design a Decision Support System (DSS). The underlying theory used is the 'Triple Diamond Approach,' as shown in Figure 1. Various methods were used at each step of the 'Triple Diamond Approach'. These methods included desk research, observational studies, expert interviews, conceptual modelling, and a case study.

The output of the first diamond is the Conceptual Design, which has been designed using desk research and observational studies. This Conceptual Design consists of the Decision-Making Framework (DMF) and the System Diagram (SD). In the DMF, the decision-making process will be described in general. This includes which steps should be performed to arrive at a plan for the next few years. For each bridge, it should be decided in which year it should be renewed and what strategy should be chosen. The SD is on a smaller scale and relates to a part of the DMF. The SD shows what aspects play a role when choosing a specific strategy for an individual bridge. In the second diamond, the Conceptual Design (DMF + SD) will be adapted given the relevant findings from the expert interviews, resulting in a Final Design. In the third diamond, the Decision Support System will be developed given the theoretical scientific input of the Final Design (DMF + SD), using the southwestern part of Amsterdam as a case study.

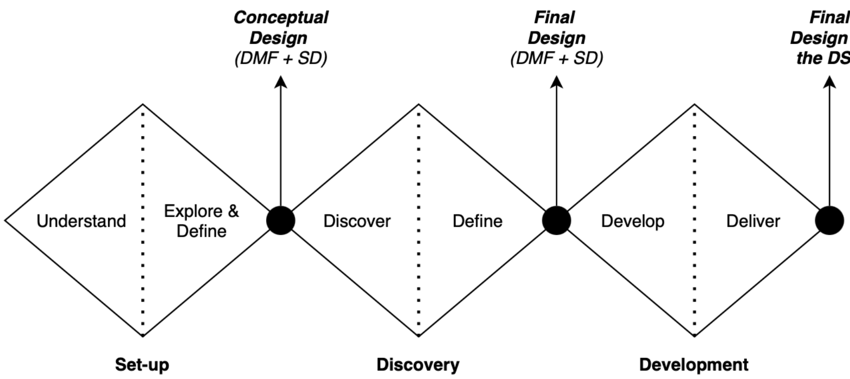

Figure 1: 'Triple Diamond Approach' used as Design Methodology

Results

The Final Design (DMF + SD) is the theoretical input to develop the Decision Support System (DSS). The DSS is made in Microsoft Excel since this is an easily accessible, widely known tool for civil servants and is, therefore, user-friendly. A case study is used to develop the Decision Support System. Amsterdam is chosen as case study, but only partially taken into account because the entire city would be too complex and time-consuming. As a result, the best scenario from the DSS is not necessarily the best option in practice because only one part of the city is included. Additionally, not all aspects from the DMF and SD are included for simplification purposes. This is also unnecessary because the focus is on testing the method rather than the final result.

Figure 2 shows the steps involved in the DSS. This 'Overview DSS' shows how it is related to the DMF (blue circles), the SD (green circles). All steps are indicated with grey blocks. The light grey blocks show which information from the case study was included for each step. Consequently, this overview of the DSS reveals how it relates to the theoretical part, as seen in the DMF and SD. As a result, the applicability of the DMF and SD in practice also emerges.

In total, 23 bridges are taken into account. The 'Oranje Loper' and the 'Leidse Corridor' are present in the case study. The 'Oranje Loper' is currently under construction, and the 'Leidse Corridor' is waiting for the work at the 'Oranje Loper' to be completed before work can start. Besides the bridges of the 'Oranje Loper,' only urgent bridges have been included because it was found from the expert interviews that it is not convenient to replace non-urgent bridges.

Information was needed about the 23 included bridges in the case study, as shown in Figure 2. Information was found considering their state, general information (presence of tram, shopping area, the width of the bridge, and the number of accidents), and traffic. This information is used to estimate for each bridge which strategy might be a good option. On the other hand, the relation between the bridges is researched. It is investigated which bridges are each other's alternative bridge and which bridges are on the same route next to each other or on the same tramway. This is useful to know for creating good scenarios with flexible planning.

Five scenarios have been created (as shown in block 'defining scenarios' of Figure 2) to determine if the DSS works appropriately. For each scenario, the 23 bridges were assigned to one of four phases. Also, a strategy has been chosen for each bridge, where the earlier estimate of which strategy might be a good fit is used. Finally, each scenario will be tested against the criteria. The criteria considered are shown in the 'testing of the scenarios' block of Figure 2. These criteria are loss of business, vehicle loss hours for car and active modes, safety, construction costs, early replacement, late replacement, and flexibility.

Scenario 1 is the reference scenario; this scenario is relatively similar to the current programming in Amsterdam. The remaining four scenarios are good options considering the criteria being assessed. While creating the other four scenarios, a trade-off must be made between scheduling the bridges with the best possible consideration of residual life or the most flexible planning; considering both in one scenario is not possible. Scenarios 2 and 3 have the bridge's state as its main principle, putting planning flexibility in second place. All the different strategies are applied in scenario 2. However, the excel reveals earlier that a temporary bridge is possibly not a good option. For this reason, in scenario 3, only entire closure and phased building are applied as strategies. For scenario 4, the choice has been made to take the flexibility of planning as the starting point, putting the state of the bridges in second place. In this scenario, the same strategy was chosen per bridge as in scenario 2 (i.e., all different strategies are used). In scenario 5, only entire closure and phased building are applied, which are the same per bridge as in scenario 3. The classification of when a bridge is classified is the same as scenario 4 and thus has planning flexibility as a starting point. When the default settings are used for the parameters, it can be concluded that scenario 5 has the lowest total and out-of-pocket costs. Scenario 3 emerges as second-best with hardly any difference. Both have the highest costs in terms of active mode loss hours, but this difference is not substantial compared to scenarios 2 and 4.

The sensitivity analysis investigated different values of parameters. For example, the Value of Time, the costs of a temporary bridge, and the costs related to safety can be changed. From this sensitivity analysis, changing the parameters does not lead to a completely different outcome. Which is beneficial since the found best scenarios are, therefore, stable solutions. Other scenarios may be better when other scenarios are created, additional criteria are added, and/or the parameter values are changed.

From these results, scenario 5 is the best option considering the total and out-of-pocket costs. Given the boundaries, used criteria and assumptions. However, several limitations should be kept in mind. Nevertheless, the DSS provides insight into the consequences of choosing a scenario and comparing the scenarios. Furthermore, it is examined how the DSS needs to be used in practice.

An expert evaluated the DSS. According to J. de Leeuw (personal communication, January 23, 2023), the DSS is a rational approach to decision-making. Nevertheless, some other factors in Amsterdam play a role in the decision-making that are not captured in this model, which is why this model is presumably not applied in Amsterdam.

Conclusion

The designed DSS can support a municipality in making decisions. It also provides insights into decision-making as it presents a broad picture of the whole situation in the city and how the many elements involved in the decision-making are related. Current decision-making in Amsterdam only considers a few factors (e.g., tram accessibility and active modes), while the DSS considers more factors (e.g., costs, safety, and residual life of bridges). The designed DSS provides a broader view than the current decision-making; however, some aspects of the DMF + SD still need to be implemented to arrive at a complete view. Moreover, the DSS has some simplifications and limitations, as further explained in the discussion. However, the DSS clearly shows how this method works and offers insights. Finally, the DSS provides a systematic and user-friendly approach for municipalities to think about their decision-making. The designed DSS is plausible and leads to meaningful insights into decision-making, as can be concluded from the expert evaluation. However, other choices are made in Amsterdam, which means that unobserved factors, not included in the model, play a role in the decision-making process in Amsterdam.

Discussion
The research has been limited since not all elements from the DMF and SD were included in the design of the DSS. Furthermore, only a small part of the city was used in the case study. These choices were made because, otherwise, it would be too time-consuming. When the DSS is applied in practice, several things need to be done differently from the case study.

As presented in the expert evaluation, it is unlikely for the DSS to be applied in Amsterdam, as choices are made based on factors that are not considered in the DSS. Moreover, this choice is often made by instinct without considering multiple options. Moreover, the expert interviews revealed that both the municipalities of Delft and Amsterdam are satisfied with their current decision-making, making it questionable whether they see the usefulness of a DSS.

Furthermore, this DSS can be used for any city, but depending on the situation, the DSS should be adapted, making it more or less complex. When applied to a less complex city, fewer adjustments must be made. Since the DSS was created for a few bridges, it is easily adaptable to cities with a similar number of bridges, compared to making it adaptable for the entire city of Amsterdam. This DSS can, with some modification, also be used for other city maintenance projects.

Recommendations
For the municipalities, it is recommended to gather data on the condition of the bridges since these conditions are often unknown. Furthermore, recommendations were provided for municipalities when the DSS is used in practice, i.e., including other aspects that may play a role, checking whether the parameters' values are correct and using available transport models. In addition, municipalities are advised to be critical of their current decision-making and assumptions.

It is advised to conduct further research on including components of the DMF + SD, which are not yet included. It is also recommended to do further research on quantifying the current impacts. Furthermore, it was found in the expert interviews that there were significant differences between Delft and Amsterdam regarding their current approach and vision; therefore, it is also interesting to research other municipalities. Finally, it is recommended to develop a Decision Support System for large groups of bridges using a linear programming model to arrive at good scenarios. Indeed, this will ensure that the DSS can be easily applied in practice, helping cities get through this enormous renovation challenge in the best possible way.

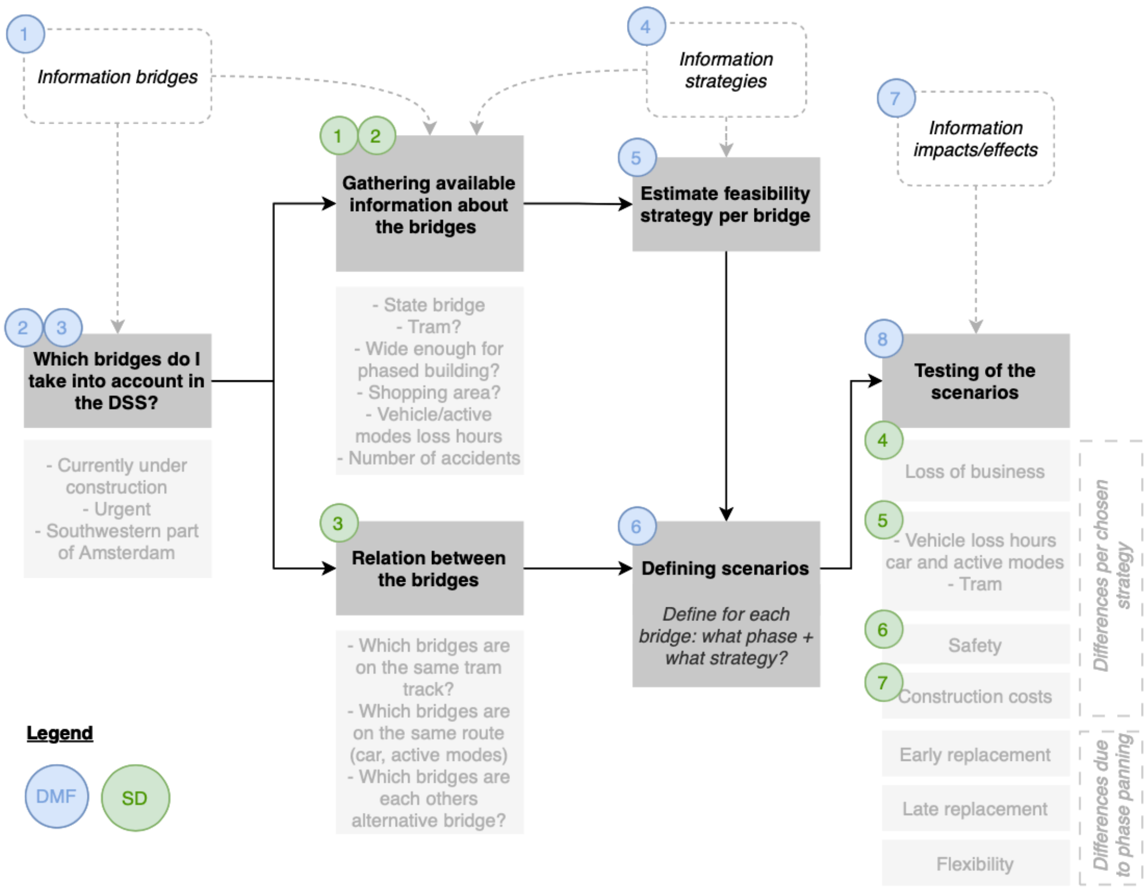

Figure 2: Overview DSS: relation with DMF and SD

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List of Abbreviations

PBK(A) = Programma Bruggen en Kademuren (Program Bridges and Quay Walls) (Amsterdam)
DSS = Decision Support System
DMF = Decision-making Framework
SD = System Diagram
W+B = Witteveen+Bos

1 Introduction

1.1. Context

The infrastructural networks in the EU are among the densest in the world. Due to several global social-economic reasons, such as the economic crisis and the COVID-19 pandemic, the budget for maintaining ageing infrastructure has been cut back for several decades. As a consequence, the maintenance has been delayed. Postponing maintenance leads to high costs: it reduces internal market mobility, raises the possibility of accidents, and increases CO2 emissions in the transportation industry. Delaying maintenance also results in misleading savings because the infrastructure can deteriorate to the point where replacement is necessary, which is more expensive than routine maintenance (European Construction Industry Federation, 2020).

A backlog in maintenance is also present in the Netherlands. Much of the Dutch infrastructure is in disrepair; bridges, viaducts, locks, and other structures were built shortly after 1950 and urgently need renovation or replacement. This delayed maintenance already has a daily impact on road and water transportation. Bridges have been taken out of service or are closed for months for heavy vehicles, many locks have been blocked, and multiple quay walls in Amsterdam and Utrecht have collapsed in recent years. There are several reasons why infrastructure projects in the Netherlands are at a standstill; such as the nitrogen impasse, the annual budget limit of RWS, and insufficient funding for municipalities' infrastructure projects. Furthermore, according to van Berenschot, about 1 billion is cut annually on infrastructure, while TNO says there should be 2 to 3 billion more budget to keep the Dutch infrastructure in order (Stadszaken, 2021). J. de Leeuw (personal communication, June 15, 2022) revealed that, in general, the infrastructure is failing due to increased traffic load. In the Dutch city centers, bridges and quay walls were built before 1950. However, since they did not collapse until now, there was no urgency to replace these for a very long time.

This research examines the decision-making process for the planning of bridge maintenance in the Netherlands and specifically in Amsterdam, where a large-scale renovation project is currently in progress. According to Gemeente Amsterdam (n.d.) more than 200 km of quay wall and 850 traffic bridges in Amsterdam will be renovated or replaced in the upcoming years; most of these are situated in the historic city center of Amsterdam. This enormous project has a huge impact on the surroundings and daily life in Amsterdam. The livability, safety, and accessibility will be affected by this project.

This project with, as a client, the Municipality of Amsterdam is called 'Programma Bruggen en Kademuren' (in English: Program Bridges and Quay Walls). Witteveen+Bos in collaboration with the Engineering Firm of the Municipality of Amsterdam is in charge of the project's management and engineering.

1.2. Problem Definition

Delayed maintenance is a major issue in the Netherlands. The city of Amsterdam recently started a large-scale maintenance project to renew (renovate or replace) many bridges: an issue that other cities will have to face soon. These kinds of projects have an impact on transportation, surroundings and daily life (Gemeente Amsterdam, n.d.). Many bridges are considered in this maintenance project, but only a part can be taken into account at the same time. Therefore a decision should be made on what bridges should be renewed simultaneously; this planning about the scheduling of bridge renewal, is called 'programming'. The method used to renew an individual bridge must also be considered in the programming. Possible strategies for this renewal are entire closure, a phased building process, or using a temporary bridge. These strategies will be discussed in more detail later.

Since the Municipality of Amsterdam started this project, various decisions on the programming have already been made. However, the current programming has some major drawbacks: trams are out-of-service for a long time, early replacement of bridges, and high costs due to temporary bridges. Currently, many temporary bridges are used; these are built next to the renewed bridge. On the other hand, strategies such as entire closure or a phased building process might lead to better outcomes. Hence, the current decision-making is not structured, not all choices have been evaluated, and the decision is based on only a few aspects. As a result, this programming has led to enormous expenses and project delays (J. de Leeuw, personal communication, June 15, 2022).

Making the decision of which bridges to address simultaneously with which strategy can potentially be supported by a Decision Support System (DSS). The literature review in Section 3.1 shows that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities, leading to a scientific gap. From this, the theoretical gap about how decision-making should be done is lacking. Moreover, effects can be found in the literature. However, a clear overview of which ones are relevant to consider in decision-making is unknown, leading to a second theoretical gap. Finally, a methodical gap arises because it should be made sure that measuring these effects is feasible for the municipality. Ultimately, the DSS should be a user-friendly tool easily accessible to a municipality.

1.3. Research Objective

The previous Subsections demonstrate how decision-making for bridge programming (deciding which bridges should be renewed simultaneously using what strategy) is a contemporary issue. The current approach in Amsterdam is not structured; as a result, not all options have been considered, and only a few factors are taken into account. Consequently, this programming has resulted in massive costs and project delays. Since municipal money must be spent wisely, an informed decision must be made. From the literature review, it can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities. Besides Amsterdam, this decision is also an issue in other Dutch cities. If no support is provided, every municipality has to make its own decisions.

Since it is essential to make an informed decision, there is a need to develop a method to look at decision-making in an integral and systematic sense. This leads to the following main objective of this study:

" Designing a Decision Support System to provide insight into the Decision-making for Bridge Programming for Dutch Municipalities "

The Decision Support System (DSS) is a tool that provides insight into the decision-making regarding which bridges should be renewed simultaneously using what strategy (entire closure, phased building, or a temporary bridge). Because this is a very complex decision, the DSS will not make or optimize the decision. Instead, as the name suggests, the DSS will support this decision. By supporting this decision, municipalities can make an informed decision. This will be done by creating a clear overview of the situation. The DSS will show which main effects play a role, the options a municipality can choose, and their advantages and disadvantages. Moreover, it will reveal the trade-offs a municipality will have to weigh when making its choice. Through the designed DSS, municipalities will become aware that this is an issue and that their decision-making can be improved. Furthermore, the user-friendly DSS provides practical guidance to make it as accessible as possible to municipalities to motivate them to use it and critically examine their own decision-making. Once there is a DSS, it can be used and improved collectively, and municipalities can cooperate in this decision-making.

The research will first be conducted at the theoretical level to arrive at a DSS that can be applied in practice. Then, as will be further discussed in Chapter 2 (Methodology), two frameworks (DMF + SD) will be designed, which will be the theoretical input for the DSS. Finally, this translation from theory to practice will be reflected in the DSS and clarifies how municipalities' decision-making relates to both parts.

1.4. Scope

The Decision Support System will be relevant to Dutch cities with a high number of bridges, which cannot be renewed at the same time as this would make the city inaccessible, but capacity (people or money) can also play a role in limiting the number of bridges that can be renewed simultaneously. The DSS will serve as the planning tool for the bridges in which the impacts and available budgets are included. The DSS will primarily provide information on the consequences of certain programming. Nevertheless, the municipality must ultimately make its own decision.

Amsterdam has already begun a large-scale bridge maintenance project on which Witteveen+Bos works, allowing relatively easy access to information. For this reason, the case study will be conducted in Amsterdam, which will be discussed in more detail later. This research will focus on the city of Amsterdam for the design of the DSS because a case study will be held there. However, the Decision Support System will eventually also be relevant to other Dutch cities.

In Amsterdam, both bridges and quay walls need to be renewed. For simplification, this thesis project will focus on bridges. The reason for this is the essential function of a bridge in the city transport network. This study will look at the problem from a transport point of view, not elaborating on the construction of the bridges in much detail. For this reason, the distinction between completely replacing or renovating a bridge is irrelevant since this decision depends on the construction. Moreover, both replacing and renovating affect the city's network.

1.5. Limitations and Disadvantages of DSS

In this research, a Decision Support System will be designed. Several limitations and disadvantages come with a DSS. These should be taken into account as much as possible. According to the Management Study Guide (n.d.) the following three limitations and three disadvantages play a role. The first limitation is that there may be difficulties in collecting and quantifying data, as it is challenging to find and analyze intangible or undefinable data. Second, a DSS makes certain assumptions about which the decision-maker must be aware. Third, some decision-makers do not have much knowledge of technology, this should not be overlooked.

A disadvantage of DSS is the potential for too much information, which makes it difficult for the decision-maker to determine what is essential. Furthermore, decision-makers must remain independent and avoid becoming dependent on the DSS. They must also maintain good independent thinking. Due to the rational character of the DSS of weighing options, loss of subjectivity may also be a problem. Furthermore, the study by Uran and Janssen (2003) found that Decision Support Systems are often not used in practice due to the difficulty of capturing all scenarios and the effort required to use the DSS.

1.6. Research Relevance

This research has the potential to benefit several goals. The following paragraphs will provide an outline of the research's impact on society and science.

1.6.1. Societal Relevance

Large renovation projects have a huge impact on the city and, therefore, on society. The problem that Amsterdam has will also occur in other cities with canals. Therefore, it is essential to create awareness among municipalities about this problem and support them in making decisions. This is because municipalities must make the right choice to ensure that municipal money is spent wisely. Due to the user-friendly nature of the DSS to be designed, it is easy for municipalities to use.

1.6.2. Scientific Relevance

The literature review shows that no Decision Support System about this subject exists. Therefore, This study aims to fill this gap by designing the DMF and SD first. The DMF shows what decision-making should look like in theory. The SD shows the impacts of choosing a strategy and how the impacts relate to each other. The DMF and SD show decision-making from the scientific perspective, which is then applied in practice through the DSS. In terms of design, the designed DSS may inspire the design of other Decision Support Systems. The designed DMF and SD may be relevant for other researchers when decisions need to be made for similar types of (maintenance) projects.

1.7. Thesis Structure

The context, problem definition, research objective, scope, limitations and disadvantages of Decision Support Systems and research relevance have all been elaborated on in this first Chapter. Chapter 2 will show the methodology used in this research. The theoretical element, which consists of the DMF + SD, is developed in Chapters 3 and 4. Whereafter, in Chapter 5, when the DSS is designed, translation from theory (DMF + SD) to practice (DSS) occurs. Chapters 3, 4, and 5 will consider one of the three diamonds of the 'Triple Diamond Approach', which will be explained in Chapter 2. Finally, Chapter 6 provides a conclusion, a discussion and recommendations.

2 Methodology

This Chapter will discuss the methodology used in this research. A design process will be applied to develop a Decision Support System. Various methods will be used at each step of this process. These methods include desk research, observational studies, expert interviews, conceptual modelling, and a case study. This Section will first explain the design process in general with a further explanation of each step of the process. After this, an overview of the methodologies used in each step will be provided.

2.1. Design Process

To design a Decision Support System, a design process will be used. The underlying theory that will be used for this is the 'Triple Diamond Approach.' The 'Triple Diamond Approach' has many different appearances, therefore the approaches of Lyons-Grose (2017), Burton (2019) and Sensaco (2019) are combined, together with own input, into a method for this research, as shown in Figure 2.1. This method was chosen since it results in a goal, and because each diamond has a particular type of output, each diamond brings the objective one step closer. Furthermore, the divergent and convergent nature forces the designer to think about the complete system and only extract from it the relevant findings.

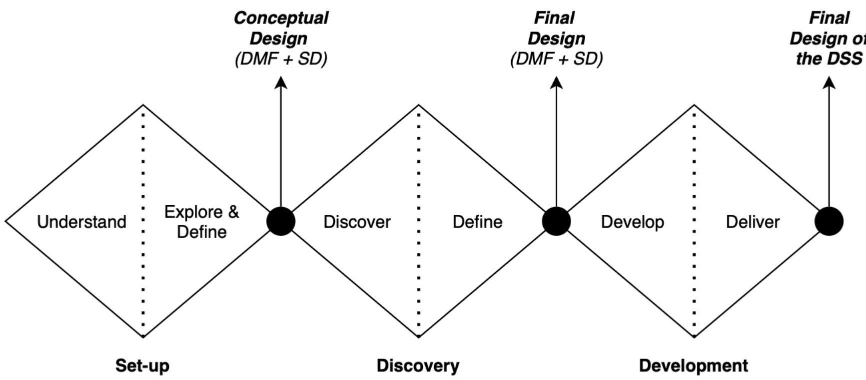

Figure 2.1: 'Triple Diamond Approach' used as Design Methodology

The design process consists of three diamonds; each Chapter will discuss one of these diamonds. Every diamond has two steps; therefore, there are six steps. The process diverges in the first step of each diamond; new information and findings will be looked into. Then, the process converges in the second step in each diamond; the most relevant information will be collected and used for the design. The first two diamonds contain the theoretical part. In diamond 3, this theoretical foundation will be used to design the DSS that can be applied in practice.

The first diamond is about the Set-up. This diamond considers 'understand' (step 1) and 'explore & define' (step 2). In step 1, information will be conducted using various methods. In step 2, all the gathered information will be used to develop a Conceptual Design. This Conceptual Design consists of two frameworks: the Decision-Making Framework (DMF) and the System Diagram (SD). In the DMF, the decision-making process, in general, will be described; this includes which steps should be gone through in order to arrive at a plan for the next few years regarding in which year what bridge should be renewed and what strategy (entire closure, phased building, temporary bridge) should be chosen. The SD is on a smaller scale and relates to a part of the DMF since this framework only considers one bridge. In the SD, the decision-making regarding which aspects play a role when choosing a specific strategy for one bridge is shown.

In the first step of the second diamond, this Conceptual Design (DMF + SD) will be validated using expert interviews. After these interviews, the insights will be analyzed. In the second part of this diamond, the Conceptual Design (DMF + SD) will be adapted, given the relevant findings from the expert interviews, resulting in a Final Design (DMF + SD).

In the first part of the third diamond, the Decision Support System will be developed given the theoretical scientific input of the Final Design (DMF + SD), using Amsterdam as a case study. After testing this on the case study, the second part of this diamond, the Final Design of the DSS, will be delivered.

2.2. Overview

To complete the design process, several methodologies will be used. Figure 2.2 provides an overview of the method used in each diamond in the design process. In the divergent parts, information is gathered through desk research and observational research. Expert interviews have a diverging nature in diamond 2 since information is gathered here; moreover, in diamond 3 an expert interview is used as an evaluation method and has a converging nature. Conceptual modelling is employed in the converging phases to limit the information to the essential aspects. The case study contains both divergent and converging components.

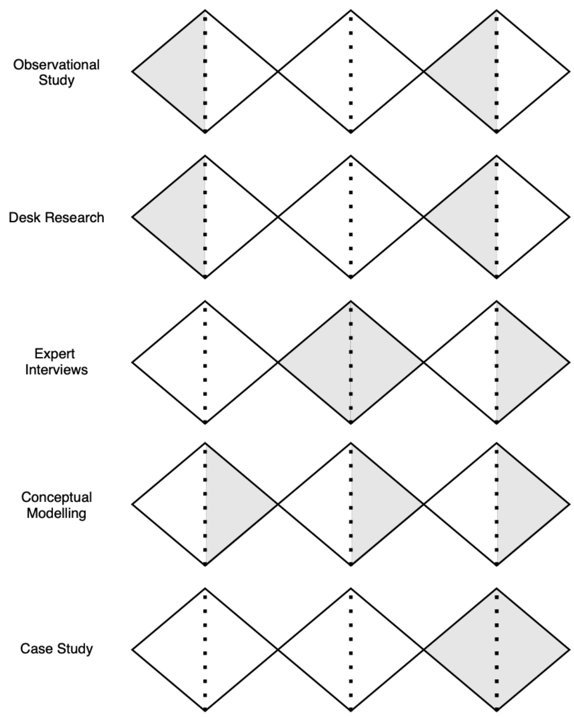

Figure 2.2: Methodologies used in each part of the 'Triple Diamond Approach'

2.3. Observational Study

A significant part of the information is collected through observational studies. This includes informal personal conversations with Witteveen+Bos colleagues and the Municipality of Amsterdam. Meetings at the company and phone calls that revealed interesting information are examples of these informal personal conversations. This was used to get current information that can not be found online. A visit to the case study area, specifically the bridges currently under construction, is also included. This is an enrichment in addition to the desk research to define the relevant impacts of construction work and bridge closure.

2.4. Desk Research

For the first diamond (Chapter 3), desk research will be used in various ways. Since this Chapter's purpose is to design the DMF + SD, this requires gathering the necessary information. In addition to researching the state-of-the-art of DSS, information will be collected on the impacts of bridge maintenance, and the current situation in Amsterdam will be investigated. Moreover, it also examines which steps need to be taken in a decision-making process. Desk research was also applied in the third diamond (Chapter 5) for looking up the information needed to develop the DSS. Scopus, Google (Scholar), and internal documents are search engines for this (grey) literature.

2.5. Expert Interviews

Interviews with various experts were conducted, as expert expertise is required to validate Conceptual Design (DMF + SD). Because it is critical to consider each expert's point of view, expert interviews were chosen over focus groups because each expert may freely express his or her point of view. Furthermore, scheduling an expert interview is less difficult than organizing a focus group. Six experts were interviewed; two from the Municipality of Amsterdam, one from the Municipality of Delft, and three from Witteveen+Bos. The interview with the Municipality of Delft would reveal differences across the cities and, as a result, provide insights that might eventually be applied to developing a general Decision Support System. All interviews will be semi-structured; the first reason for this approach is that a good conversation could offer new perspectives. Second, because many fields of expertise are involved, not every respondent can accurately respond to every question. As a result, specific questions are directed at all respondents, while others are tailored to each respondent. The interview results are compared in various tables and utilized to redesign the DMF + SD. They also offer helpful information that should be considered when designing the DSS. Ultimately, one expert interview is held to evaluate the developed Decision Support System (DSS). In addition to this brief explanation, a more detailed explanation can be found in Chapter 4.

2.6. Conceptual Modelling

Conceptual modelling is the process of creating a graphical representation (or model) of the real world. It also requires making assumptions about the issue at hand. The conceptual modeller must decide which parts of the real world to include and exclude from the model and the level of detail with which to model each aspect. Conceptual models offer a variety of applications in decision-making, including Decision Support Systems (Learning for Sustainability, n.d.). Conceptual modelling will be used to design the 'Conceptual Design' and the 'Final Design,' consisting of the DMF and SD. Furthermore, Conceptual modelling will be used at the end of the process during the design process of the Decision Support System.

2.7. Case Study

A case study will be used to develop the Decision Support System. Amsterdam is chosen as the case study area, but only partially taken into account because taking into account the entire city would be too complex and time-consuming. This is also unnecessary because the focus is on testing the method rather than the final result. This area of the city was chosen because it considers ongoing municipal projects; some of the area's bridges are currently under construction, while others will be soon. Since Witteveen+Bos is currently working for the Municipality of Amsterdam, information can be accessed relatively easily. More information on the case study will be explained in Chapter 5.

3 Set-up

The goal of this Chapter is to design the Conceptual Design, consisting of the Decision-making Framework (DMF) and the System Diagram (SD). The first diamond of the 'Triple Diamond Approach' will be run through to achieve this.

As shown in Figure 3.1, this first diamond consists of two parts. Namely, 'understand' and 'explore & define.' What will be covered in the 'understand' part can be found in Figure 3.2; this part consists of a 'theoretical' part and an 'in practice' part. In the theoretical part, the literature review about the state of the art of decision support systems for the programming of bridge maintenance will be presented, as shown in Section 3.1. After this, desk research and observational studies will be used to research the impact of bridge maintenance, as shown in Section 3.2. Finally, in Section 3.3 will look into the 'in practice' part, where the current programming approach used in Amsterdam will be discussed. These three Subsections contain stand-alone information but are all needed to arrive at the Conceptual Design (DMF + SD).

All findings from the 'understand' part will be used in the 'explore & define' part; here, the relevant components will emerge and the Conceptual Design (DMF + SD) will be designed, using conceptual modelling. The DMF considers the entire decision-making process, and the System Diagram (SD) considers the decision-making of one bridge regarding choosing a strategy.

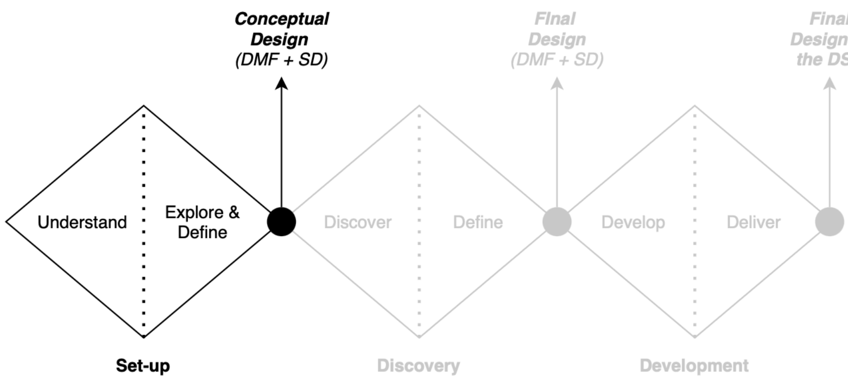

Figure 3.1: Diamond 1 of the 'Triple Diamond Approach'

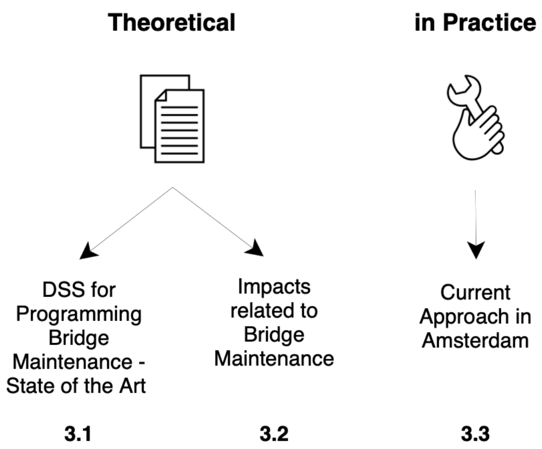

Figure 3.2: Sections related to the 'theoretical' and the 'in practice' part

3.1. Theoretical: DSS for Programming Bridge Maintenance - State of the Art

This Section relates to the first theoretical part as shown in Figure 3.2. The research aims to design a Decision Support System to provide insight into the decision-making for programming bridge maintenance for Dutch Municipalities. This literature review summarizes and compares the research on this topic. The methodology of finding the literature is presented first. Second, the literature is presented and compared in the analysis Section. Following that, an overview of the literature and a conclusion and discussion are offered.

3.1.1. Methodology

The purpose of this Chapter is to explore to what extent Decision Support Systems exist, what the content of these existing systems looks like, and to what extent Dutch municipalities can use them to make decisions in large-scale renovation assignments where several bridges need to be addressed simultaneously. To research the state-of-the-art on Decision Support Systems for planning bridge maintenance, scientific papers have been studied using Scopus and Google Scholar. The following Boolean operators were used for finding literature for investigating the state-of-the-art:

- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND (planning OR programming) AND bridge AND maintenance
- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND planning AND multiple AND bridge

Since planning other types of maintenance projects (e.g., road closures) are relatively similar to planning bridge maintenance, Decision Support Systems on these were also examined. The following Boolean operators were used to look into this comparable research. Nevertheless, this did not lead to any other valuable results:

- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND planning AND multiple AND ('construction work' OR road)
- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND planning AND multiple AND infrastructure AND projects
- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND planning AND simultaneously AND projects
- ('decision support' OR decision-support OR 'decision making') AND (system OR tool OR framework OR method) AND planning AND simultaneously AND bridge

Many papers were discovered as a result of this. There were too many to read all of them, and they were not all relevant to the scope of this project. For these reasons, the discovered papers were assessed on the following criteria:

1. The paper is preferably no older than 5 years.
2. The terms 'decision', 'planning', 'bridge' and 'maintenance' are preferably mentioned in the title.
3. The relevance of the paper was evaluated by checking the number of citations and peer reviews.
4. If the paper appeared to be sufficiently relevant, the abstract and conclusions were read first to assess its substantive contribution.

When an interesting paper was found forward and backward 'snowballing' was used to find more relevant papers. Eventually, all relevant papers regarding the current state-of-the-art of Decision Support Systems for planning bridge maintenance will be discussed.

3.1.2. Analysis

According to Jeong et al. (2018), bridges are vital aspects of transportation systems and the economic process. Therefore, bridges should be kept in good condition by transportation agencies to provide a desirable degree of service to the public on a restricted budget. Furthermore, the number of bridges in these four countries are fast deteriorating. Fortunately, because some nations have had bridges fail due to aging, the countries studied in this study have already created comprehensive bridge management systems (BMS) and inspection processes. As a result, this paper aims to look out and combine important information on BMS and bridge inspection processes in the four nations.

Jeong et al. (2018) looks into how different countries have different bridge management systems to inspect their bridges in order to determine the maintenance they need. Other papers designed a mathematical tool to support the decision to what extent a bridge needs to be maintained. Sabatino et al. (2016) and Samadi et al. (2021) both designed a mathematical model to support the decision-making process of bridge maintenance.

Sabatino et al. (2016) created a mathematical decision support framework to find the optimum maintenance techniques for structures with aging components, which are defined by lifetime functions such as survivor, availability, and hazard at the component and system levels, as well as correlation effects.

According to Samadi et al. (2021), it is critical to developing the ideal bridge maintenance plan (i.e., the best time and type of repair actions performed to bridge elements) while keeping financial constraints in mind. As a result, a framework based on Bridge Information Modelling (BrIM) is created to support maintenance managers in making decisions.

Next to Sabatino et al. (2016) and Samadi et al. (2021), various other researchers have made mathematical models for planning maintenance. Alikhani and Alvanchi (2019) and Lerique et al. (2020) both designed a slightly different tool to plan maintenance.

Alikhani and Alvanchi (2019) designed a method that is mainly used for planning maintenance for different kinds of bridges (differences in age, types and conditions). To test the applicability and efficiency of the model, it was applied to a network of 100 bridges in one of the southwestern provinces of Iran.

Lerique et al. (2020) developed a method that takes into account long-term maintenance planning for a large number of bridges. However, since these bridges are dispersed across the nation, they are unaffected by one another.

The already mentioned researches mainly focus on the technical characteristics. Furthermore, the research by Allah Bukhsh et al. (2019), Pramesti et al. (2021) and Karaaslan et al. (2021) also takes into account nontechnical aspects, including societal and economic elements.

According to Allah Bukhsh et al. (2019), because of their extensive social integration, transportation infrastructures must not only comply with technical standards but also adapt to societal and economic changes. Therefore, planning for bridge maintenance should consider several performance requirements that need to be measured by different performance indicators. The performance requirements that are considered are to improve assets' reliability, minimize agency costs (economy), minimize environmental impact, minimize the impact on users (society), and keep the network safe. In this study, a case study of bridges from the Netherlands road network illustrates how Multi-Attribute Utility Theory (MAUT) might be used for planning bridge maintenance. By recommending a trade-off between them, MAUT aims to optimize several objectives. It then ranks the bridges that it has taken into consideration.

Pramesti et al. (2021) has set a priority for managing restoration and keeping a bridge in place requires paying attention to the right factors, which have a direct impact on the system of treatment priority ratings. Therefore, a model is created to examine the interaction and impact of these criteria in bridges and the ranking of bridge maintenance priorities. This model adapts 13 sub-criteria from the technical (structural), technical (functional), and non-technical maintenance priority criteria. Technical (structural) factors include i.e. condition value, age of the structure, and load. The technical (functional) factors include, among other things, the average daily traffic and the number of lanes. The non-technical factors include the historical importance of the bridge, social, economic, and political factors.

Karaaslan et al. (2021) provides a novel decision support system that takes into account several aspects of bridge management. To develop optimal maintenance strategy with many choice alternatives, the decision ranking considers a wide variety of elements such as structural safety, serviceability, rehabilitation cost, life cycle cost, and societal and political issues. However, the method is not very user-friendly for governments because it uses advanced prediction models, decision trees, and incremental machine learning algorithms. Moreover, this method is not suitable for determining which bridges should be addressed at the same time.

All previously mentioned research focuses on planning bridge maintenance. For the Netherlands, where many bridges currently lack maintenance, there is the question of what bridges should be renewed simultaneously. This question can not be answered with the tools mentioned above. These tools are helpful when the specific state of maintenance needs to be determined, but this is often not needed or can not be done. Therefore there should be looked into research that plans for maintaining multiple bridges at the same time. The only research found covering this was by Liang and Parlikad (2020). In this research, there was stated that in recent years, preventive maintenance has gained a lot of popularity. However, the literature has not given significant attention to the use of predictive maintenance at the network level. This study proposes a predictive group maintenance model for networks with multiple systems and many components (MSMCN). These networks are made up of various systems, which are made up of various components.

3.1.3. Discussion & Conclusion

In this literature review, a substantial body exists concerning systems to support bridge maintenance. All mentioned studies investigated the bridge's state to provide insight into when they need to be maintained to make a prioritization using mathematical models. However, differences in these systems arise concerning whether they only focus on the technical aspects or whether societal, economic, and political elements are taken into consideration.

The bridges' ranking and deciding when they need to be maintained is crucial in the planning of bridge maintenance. Nevertheless, the problem in Amsterdam and other dutch cities is that many bridges within a city lack maintenance, leading to the need to maintain multiple bridges simultaneously. When this is planned only considering their technical prioritization, this could lead to network problems in the city since all bridges are essential connectors in the same network.

A scientific gap exists regarding a decision support system for planning multiple bridges. Only one mentioned research looked into the planning of group maintenance. The existing research about ranking the bridges on their current state is an important input to consider in planning them since ensuring that the most urgent bridges are maintained soon is essential.

All maintenance planning tools used a mathematical methodology. One significant disadvantage of mathematical models is that they are not user-friendly for municipalities and require a great amount of data. In the context of a decision support system for municipalities, not all data and experience with models are widely available. Another disadvantage is that bridge programming is not entirely rational, and hence cannot be expressed in a mathematical model. As a result, the decision-support system should provide insight into decision-making while considering all variables. The Decision Support System should support the decision rather than make the actual decision because it is crucial to motivate the decision-maker to think critically.

It can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities, leading to a scientific gap.

3.2. Theoretical: Impacts related to Bridge Maintenance

This Section will provide information about the impacts related to bridge maintenance and relates to the second theoretical part, as shown in Figure 3.2.

Bridge maintenance includes the impacts related to closing the bridge and the impacts related to the construction work. First, the definitions of the terms ’impact’ and ’effect’ will be discussed. Secondly, different categorizations of the impacts will be discussed. Thirdly, research will be done regarding the impacts of bridge maintenance, both using scientific- and desk research. Furthermore, there will be looked into the impacts of building new infrastructure since there can be assumed that the impacts of building new infrastructure are opposite to closing infrastructure. Looking into this will provide new insights and is therefore researched. Finally, a conclusion will be drawn.

3.2.1. Definition

The terms ’impact’ and ’effect’ are closely related. Both words are often used in literature. The definition of impact is formulated as follows: ’a powerful effect that something, especially something new, has on someone or something’ (Cambridge Dictionary, n.d.). The difference between ’impact’ and ’effect’ is formulated as follows by Pediaa (2016): ’The main difference between impact and effect is that impact is the influence of an action/phenomenon on something or someone whereas effect is the consequence or outcome of an action or a phenomenon.’ Since these words are closely related and appear in literature, both will be used in the search process. However, this thesis will mainly use the word ’impact’ for simplification.

3.2.2. Categorisations of Impacts

Very often, impacts and effects related to bridge maintenance are divided into three categories: societal, environmental, and economical. This will be investigated in Section 3.2.3, where existing scientific literature is discussed.

In Section 3.2.4, impacts related to building new infrastructure will be discussed using grey literature since this can be seen as the opposite and provides new information about the topic. According to Binsbergen (2021) effects can be subdivided between internal and external effects. Internal effects are ’(direct) effects on the system itself,’ and external effects are ’effects outside the system’. Furthermore, the following categorization can be used for indirect effects: environment, ecology, safety, land use, and social. Furthermore, the distinction between local, regional, and global effects will be elaborated on.

The categorization between accessibility, safety, and livability, which was already shortly mentioned in Chapter 1, will be mentioned in more detail in Section 3.2.4 and in the next Subsection (3.3) where the current approach of Amsterdam will be discussed.

3.2.3. Impacts of Bridge Maintenance

This Subsection will provide research that investigates the impacts of bridge maintenance. This includes the fact that the bridge is closed and the construction work. The impacts discussed are categorized between societal, environmental, and economical. Some studies include all three categories, but others only one or two. In the end, a small observational study will also be conducted about Amsterdam.

The following research took into account social, economic, and environmental impacts. Effects that were taken into account in the research of Wu et al. (2021) where workplace and traffic safety, mobility (both people and goods), economic growth on a regional scale, environments for dwellings and public services. The study of Ibrahim et al. (2018) took into account increased travel distance, relocation of residents, loss of business, closure of business, inconvenience of noise. The main impacts found in the study of Santos et al. (2021) were interdiction (partial or total) of vehicle traffic, noise, pavement damage, interruptions, and changes in pedestrian traffic. The study of Allah Bukhsh et al. (2019), which was also considered in the literature review, took into account social, environmental, economic, and safety. Various performance indicators were used to calculate those impacts. For example, the quantities of materials produced, travel distance, vehicle noise, and machine noise were considered to calculate the environmental impact. Impact on society was calculated by the user delay costs (taking into account the extra travel time, number of users affected, cost of an hour of a user, duration of the maintenance activity) and the user costs (vehicle operating costs, travel time costs, and accident costs). Finally, the impact on safety was calculated by the number of traffic accidents, fatalities, and injuries.

Furthermore, the impact of the closure of the Hammersmith bridge documented by Robinson and Zachary-Younger (2020) in London is researched; social, economic, and environmental impacts were taken into account. The wider perspective was considered, leading to the main impacts on residents, businesses, and traffic. Local retailers were asked about the impact on their business; their responses differed: 40% reported a decline, 41% businesses were the same, and 19% an improvement. From data from Mastercard, there was even found an increase. According to our analysis, businesses that experienced a trade loss rely on customers from the other side of the river. Customers are turned off by the extremely long travel times. Also, tourism has changed. The visitor numbers in central London have dropped, but have been balanced out by the increased tourism in other parts. Therefore the impacts have not been felt. Regarding the air quality, the pollution level did not increase and seemed to have decreased overall. The reason for this is due to the disappearing daily traffic jams. Traffic congestion in the wider area is increased; after a while, drivers have started to change their behaviour by either switching to another mode (modal shift) or not making their journey. This phenomenon, 'traffic evaporation,' happens when a major route is closed. In the case of the closure of the Hammersmith Bridge, the number of trips made decreased by about 38%. Nevertheless, some main routes and junctions in the area had an increase in the number of vehicles.

Some studies only took into account the social and environmental impacts. Four major effects were identified in the study of Xue et al. (2015); these were the travel of residents, transportation, environment, and daily life. Zou et al. (2018) took researched the impact on Quality of Life (QoL), taking into account safety, dust, noise, and peoples' response to emergencies.

The research of F. Wei et al. (2022) only focused on economic impacts. Hence, building losses, content losses, and business interruptions were taken into account.

Celik and Budayan (2016) studied nuisance in more detail. Some residents are more sensitive than others. Loss of peace and quiet in the neighbourhood, degradation of ambient conditions, and house cleanliness were the most irritating impacts.

The study of Casanovas-Rubio et al. (2020) only focused on how the travel routes of residents were impacted. Concluded can be that road closure can only lead to reduced traffic in cities when it leads to significant disruption.

Kattan et al. (2013): impact on travel behaviour changes resulting from a reduction in traffic capacity. A survey was used to get insight into the increased travel time, mode choice, alternate route choice, and selection of information sources by the travellers. It was found that a significant change in mode choice took place (less private vehicles and more public transport usage).

How different groups are impacted differently was researched by D. Wei et al. (2022). Disruptions in this area (he researched) lead to lower-to-middle groups being proportionally more impacted than middle-to-high-income groups.

During a visit to the city center of Amsterdam, it was discovered how construction work in the city might impact the historic trees and houseboats. Historic trees might need to be removed, and houseboats to be moved. Also, most earlier-mentioned impacts possibly play a role. There should also be taken into account that Amsterdam, like the Netherlands, has some specific characteristics, i.e., the large number of canals, and many cyclists and tourists.

3.2.4. Impacts/effect of Building New Infrastructure

This Section will discuss two different categories of impacts: direct - indirect and local - regional - global. Furthermore, a case study about the North-South Line in Amsterdam will be discussed, whereas the categorization of accessibility, livability, and safety is presented.

Binsbergen (2021) also recognized the distinction between economic, environmental and social, as mentioned in paragraph 3.2.3. Nevertheless, effects can also be divided into direct and indirect effects. In the case of transport projects in general, direct effects are, i.e., increased travel time and noise. Indirect effects can be divided into five categories: environment, ecology, safety, land use, and social. Environmental indirect effects are for example, air pollution and gas emissions (in this case during construction work). Safety external effects are, for example, production loss, property damage, and human costs (accidents might happen because other streets become more crowded). Ecology external effects are, for example, biodiversity and water pollution, and social effects include barrier effects, noise, visual quality, historical value, and health.
According to Binsbergen (2021) a distinction can also be made between local, regional, and global effects. Local effects are traffic safety, noise, air pollution, comfort, local accessibility, urban quality, barrier effects, visual impacts, and travel time. Regional to global effects are economic and job competitiveness, accessibility to activities, equity in accessibility, multi-modal connectivity, and long-term environmental impacts of emissions to the air (for instance, greenhouse gasses). Also, distributional effects should be considered: how are the total effects divided among the members of different community/socio-economic groups).

The research of Mottee et al. (2020) is about Amsterdam's North-South Metro Line (NZL), which is a mega-project from the starting phase in 1990 to its opening in 2018. Several problems have occurred during this project. The project never had a formal Environmental and Social Impact Assessment (ESIA); therefore, it is interesting how the social impacts are addressed without this. Using ESIA in urban and transportation planning would improve assessing and managing future mega-project infrastructure developments' social implications. The effects and impacts mentioned are noise, property impacts, loss of business, relocation of business, dust, vibration, road obstructions, and subsidence (geotechnical and groundwater risks). Landholders, businesses, and residents were affected by this project. Accessibility, livability, and safety need to be considered in the tendering phase of the project as a contractor. Just as communication, by writing a BVLC-plan (accessibility, safety, livability, and communication). Using SIA from project onset would have helped decision-makers understand the distribution of effects and identify which social indicators should be used to monitor social changes and impacts at different spatial scales. Scales are, for example, the project-scale and city-wide scale.

3.2.5. Conclusion

Section 3.2.3 showed that several studies had been executed, considering one or more categories (social, economic, and environmental). Since some studies consider all categories and others only one or two, the level of detail differs. In Section 3.2.4 also, other categorizations of impacts were presented. These included the distinction between direct and indirect effects and local, regional, and global impacts. In the research on the North-South Metro Line also, the impacts on accessibility, safety, and livability were discovered.

Table 3.1 shows an overview of the mentioned impacts. Many impacts are mentioned multiple times, i.e., safety, noise, loss of business, and transportation. The impacts in Table 3.1 are divided into four categories since they emerge naturally. The effects on livability, the environment, and society are related. Therefore, these have been combined into one category.

Moreover, consideration should be given to how to deal with different modes. Since different groups experience different impacts, a distinction may also have to be made within a mode between, for example, commuters, tourists, and residents.

Since all studies have been conducted abroad, it can be concluded from the observational study that Amsterdam has some specific characteristics that should also be considered. Elements that need to be taken into account are a large number of cyclists, tourists, historic trees, and houseboats.

The Conceptual Design (DMF+SD) will be designed at the end of this Chapter. When designing the Conceptual Design, a decision should be made on what (combination of) categorizations will be taken into account and what impacts are relevant to consider. To decide, this first information from the next Chapter needs to be considered.

	Safety	Accessibility	Economy	Livability / Environment / Social
Wu et al. (2021)	Safety (workplace and traffic)	Mobility people and goods	Economic growth	Environments dwellings and public services
Ibrahim et al. (2018)		Increased travel distance	Closure/Loss of Business, Relocation of residents	Noise
Santos et al. (2021)		Interdiction of vehicle traffic, Interruptions and changes in pedestrian traffic		Noise, Pavement damage
Allah Bukhsh et al. (2019)	Safety	Travel distance, Extra traveltime		Noise (vehicle and machine), Material usage
Zachary-Younger (2020)		Overall decrease of trips, Increased traffic volume, Travel distance, Behavior changes traffic, Modal shift	Loss of Business	
Xue et al. (2015)		Travel residents, Transportation		Daily life, Environment
Zou et al. (2018)	Safety			Noise, Dust, Peoples' response to emergencies
F. Wei et al. (2022)			Business interruptions, Building and content losses	
Celik and Budaya (2016)				Nuisance in general
Casanovas-Rubio et al. (2020)		Traffic routes		
Kattan et al. (2013)		Behavior changes traffic, Modal shift		
D. Wei et al. (2022)				Distributional effects (along socio-economic groups)
Binsbergen (2021)	Human costs, Traffic safety	Local accessibility, Traveltime, Accessibility to activities, Multi-modal connectivity	Property damage, Production loss, Economic and job competiveness	Air pollution, Gas emissions, Biodiversity, Water pollution, Barrier effects, Noise, Visual quality, Historic value, Health, Comfort, Urban quality, Equity in accessibility, Distributional effects (along socio-economic groups)
Mottee et al. (2020)	Safety	Road obstructions, General accessibility	Property impacts, Loss of Business, Relocation of business	Noise, Dust, Vibration, Subsidence , General livability

Table 3.1: Comparison between impacts found in literature

3.3. In Practice: Current Approach in Amsterdam

This Section relates to the ’in Practice’ part as shown in Figure 3.2 and will look into how programming is currently going in Amsterdam and what bridge renewal strategies are possible. After that, the policy of the Municipality of Amsterdam will be discussed, including the definitions of accessibility and livability, since there will be found that these are important to take into account by the municipality. Finally, an overall conclusion will be given. Amsterdam was chosen since the case study will be done here; hence, the process has already started in this city.

3.3.1. Programming

The guiding principle behind the current programming is to keep the city accessible and to function as well as possible. Not every route is equally essential in the city’s public transport/car network. For some routes, only one good alternative is available, leading to a vulnerability in the network. Therefore, there are several essential corridors throughout the city’s network. The works that have now started concern the public transport corridors, namely the tram tracks. The starting point here, therefore, is that a maximum of one tramway should be out at a time in order to maintain the city’s accessibility. The maintenance that has now started is for the public transport corridors. The first tramway to be tackled is that of the ’Oranje Loper .’All bridges on this tramway will be dealt with, even if they have a remaining lifespan of up to 30 years. For bridges with a remaining lifespan of between 30 and 50 years, consideration will be made (Gemeente Amsterdam, 2021). This early replacement is a huge drawback. Furthermore, this current programming causes the tram to be out of service for the entire period.

During a personal conversation with an expert from Witteveen+Bos, it was found that the Municipality of Amsterdam started to renew the bridges of the ’Oranje Loper.’ At the ’Oranje Loper,’ a temporary bridge has been built for cyclists and pedestrians next to each bridge. Which results in extremely high costs, leading to financial problems already. Furthermore, politics has made less money available, implying that just two bridges can be built per year rather than the initial eight to ten. As a result, the ’Oranje Loper’ process is already delayed enormously. Therefore, the work planned next, at the ’Leidse corridor,’ has to wait until the ’Oranje Loper’ is completed. This way of operating creates limited flexibility in the planning, delaying the entire project. Moreover, the condition is unknown for all bridges, as inspections into this take much time and are costly. This leads to bridges being replaced when they did not need replacement, as already happened with the ’Oranje Loper’ (J. de Leeuw, personal communication, October 17, 2022).

It can be concluded that the current bridge programming in Amsterdam has some significant drawbacks. In the following Subsection, there will be elaborated on what strategies were previously done in Amsterdam, which should be taken into consideration in the decision-making process.

3.3.2. Strategies

As mentioned, the municipality uses temporary bridges and closes the bridges entirely for trams and cars. Nevertheless, other strategies are common in bridge renewal, which have already been used in Amsterdam. Therefore, all strategies should be taken into consideration in the decision-making process. The possible strategies are temporary bridges, phased building process, and entire closure. This Section will elaborate on these strategies and show some previous projects that have used these strategies.

Currently, some temporary bridges are built for pedestrians and cyclists at the ’Oranje Loper.’ Temporary bridges can sometimes be built for the tram as well, but this is very expensive and often impossible given the turning circle of the tram. The Municipality of Amsterdam already spends much money on temporary bridges, which facilitate active modes to keep the city as accessible as possible, even when this might be too expensive and not feasible for the project in the long term. Temporary bridges were used in other projects as well, for example, for the Leidsebrug (WSP, n.d.), the Berlagebrug (M. Meulblok, personal communication, June 1, 2022), the Bullebakbrug and for the renovation of the Hogenstraat the temporary bridge was even accessible for the tram (E. Dirksen, personal communication, June 2, 2022).

Phased construction is another possible strategy. This allows partial access to the bridge during construction for cyclists, pedestrians, and/or trams. Generally, a tram can be moved from one side of the bridge to the other using a gauntlet track (J. de Leeuw, personal communication, June 15, 2022). Gauntlet tracks have often been used in Amsterdam, as mentioned by GVB 2022. Gauntlet tracks allow the tram to be moved to one side of the bridge and to allow construction work on the other side and afterward the other way around. Another huge advantage is that when the tram can use the bridge during construction work, it is also available for emergency services. A phased building process is often used in Amsterdam and other projects in the Netherlands, for example, the bridge in the Vijzelstraat in Amsterdam (E. Dirksen, personal communication, June 2, 2022). During the renovation of the Leidsebrug, the bridge was almost accessible the whole time for tram traffic due to a smart phasing building process (WSP, n.d.). Using phased building might make it possible to work at different public transport corridors simultaneously by taking into account that the tram should not be out of use in the same period.

Entire closure is the third possible strategy. This is the most common possibility in bridge maintenance.

3.3.3. Policy

From Gemeente Amsterdam (2021) was found that keeping the city accessible and functioning as well as possible has been chosen as the guiding principle in making the programming. Although efforts are made to minimize the impact on accessibility and livability of this task as much as possible, the measures and work will increasingly affect the daily functioning of the city. Furthermore, the fact that constructions might collapse significantly impacts safety. Also, ensuring safety might limit the possibilities for optimal programming. This makes the puzzle even more complex and challenging.

From various personal conversations with experts within Witteveen+Bos, it was discovered that the Municipality of Amsterdam is willing to give a lot to keep the city accessible and livable. For example, one expert from Project Management who worked on the North-South transit line in Amsterdam mentioned how the municipality badly wanted to keep the city as livable as possible by not wanting to temporarily close some terraces for the construction, which almost led to the termination of the project (E. Molier, personal communication, July 21, 2022).

This willingness to pay much money to keep the city accessible and livable can also be seen right now, as already mentioned, by providing temporary bridges for all bridges at the 'Oranje Loper,' as mentioned by another expert from the Project Management Department. Unfortunately, this expensive investment has resulted in the need to downscale the project due to high costs.

3.3.4. Definitions of 'Accessibility' and 'Livability'

The Municipality of Amsterdam aims to keep the city safe, accessible, and livable. The definitions of the terms livability and accessibility are not obvious. Moreover, since both terms have multiple definitions, an explanation of these will be given. The definitions will provide a good understanding of how these concepts are expressed in large-scale bridge maintenance in Dutch cities.

The definition of 'Accessibility' depends on the actor, scale level, and underlying intentions. It is a multidisciplinary issue involving infrastructure, spatial planning, and economics. Accessibility is an important prerequisite for economic growth and prosperity. Furthermore, time is seen as an important factor for accessibility (Kennisplatform CROW, 2022). Kennisplatform CROW (2022) also mentioned a definition defined by KiM: 'the amount of time, money and effort users of an activity must invest to reach the (destination) location of the activity from their area of origin.'

According to Platform31 (n.d.), the Van Dale dictionary defines 'liveable' as 'suitable to live in it and with it.' In the policy world, livability usually refers to the population, housing quality, facilities, and living environment. It thus encompasses various social and physical aspects in an area (usually a neighbourhood or district). Which aspects are included, from whose perspective livability is assessed, and by which metric varies from area to area. Moreover, the interpretation also depends on the goals and ambitions of interested parties. Taking the Van Dale definition into account, the most logical choice is to focus on the perspective of the residents and users of a neighbourhood (Platform31, (n.d.).

3.3.5. Conclusion

This Section revealed various shortcomings in Amsterdam's current programming approach. The three strategies for bridge renewal (temporary bridge, phased building, and entire closure) have all been performed in Amsterdam and are, therefore, plausible. The goal of the Municipality of Amsterdam is to ensure the city's accessibility and livability. Since other municipalities will likely have different ideas about handling this, this must be considered when creating the Conceptual Design.

3.4. Conceptual Design

All information from Figure 3.2, gathered in the 'Understand' part of the 'Triple Diamond Approach,' will be considered. In this converging part of the 'Triple Diamond Approach,' only the relevant findings will be used in this 'explore & define' part in order to design the Conceptual Design, as shown in Figure 3.1. This Conceptual Design consists of the Decision-making Framework (DMF) and System Diagram (SD). The results from the 'Understand' Section (diverging part) will be presented first, along with how they will be used, and then the emerging general issues will be presented. Thirdly, the DMF will be made in Section 3.4.3, and after this, the SD will be developed in Section 3.4.4. Both frameworks support decision-making for Dutch cities in general from a scientific perspective.

3.4.1. Results from Set-up

From the previous Section, it was discovered that different impact categories exist. Therefore, it is decided to distinguish between accessibility, livability, safety, and costs. This categorization is chosen since the relevant impacts to take into consideration can be linked easily to one of these four components. Furthermore, this categorization is often used in Amsterdam, which is beneficial. There is an overlap between this categorization, and the other often-used categorization, namely the distinction between environmental, economic, and societal impacts. Hence, there could be argued that environmental impacts are related to livability, economic impacts to loss of business, and accessibility. Economic impacts are also related to construction costs. The societal impacts are related to accessibility, (traffic) safety, and livability since this is a very broad concept.

The main effects should be considered during the decision-making process rather than going into too much detail. The major impacts can be considered as direct and a few indirect impacts, as well as impacts on a local to regional scale (not on a global scale). Minor impacts are challenging to measure and usually do not ultimately lead to other outcomes. Remember that one of the three strategies must eventually be used to maintain all bridges. Therefore, considering the impacts that vary depending on the strategy is crucial. Moreover, since several bridges are addressed simultaneously, it is necessary to consider which impacts differ for each scenario (group of bridges addressed simultaneously) as well.

The previous Subsection presented shortcomings in the current programming approach. These shortcomings are inspirations for the general problems as discussed in the next Section (3.4.2). There was also found that the three strategies have a high possibility of being feasible. Finally, the policy of the Municipality of Amsterdam was discussed. Since other municipalities will likely have different ideas about handling this, this must be considered when creating the Conceptual Design.

3.4.2. General Problems

Various problems have arisen that should be taken into mind during the decision-making process. Currently, all bridges on one route are considered simultaneously, but wouldn't it be better to spread out over the city? Moreover, this differs per mode: trams have a strong connection between the bridges, but this might not be needed for other areas with no trams. Furthermore, do you want to consider all bridges simultaneously that fit into the same strategy? What happens when all bridges on one route fit into the same strategy (for example, phased building) except for one? Do you want to use a temporary bridge for this bridge? What do you do if this is not possible? Do you only do a part of the route? Moreover, how do you deal with bridges with a remaining life span? Do you take them into account? Furthermore, you can use a phased building process for a bridge, but only temporary bridges are around it. Then do you have to use a temporary bridge too, even if it is more expensive because it is more advantageous in the bigger picture? All these questions will be elaborated on in the designed DMF.

3.4.3. Decision-making Framework (DMF)

The goal of the DMF is to show the decision-making process a municipality has to go through when deciding on planning bridge maintenance, given a city where many bridges should be maintained. However, only a small part can be taken into account simultaneously. For every bridge, a decision should be made about what strategy (temporary bridge, entire closure, phased building) fits best. The designed DMF will be shown in Figure 3.3, and all parts of the framework will be explained using italics in parentheses. Different blocks are used in the DMF to distinguish between general aspects, input/output, research elements, and where the decisions must be made. To develop the DMF, the outline of a generic decision-making method was used consisting of the following phases: identify a decision, gather information, identify alternatives, weigh the evidence, choose among alternatives, take action and review your decision (UMass Dartmouth, n.d.).

Most cities have a large number of bridges. Since there is necessary to know which bridges should be taken into account in the decision-making process, all bridges need to be researched (*investigating all bridges*). In the case of Amsterdam, this led to about 850 bridges that needed to be renewed. For other Dutch cities, this number is probably much lower.

To investigate the bridges, you need to have information about the bridges (*information bridges*). This includes, i.e., the structure's condition (urgent or has a remaining life span of x years).

Next, out of all the bridges in the city, x number of bridges are included in the decision-making process (*choosing bridges*). For example, bridges with a residual life of more than x years or an unknown state are excluded. There can be considered to only take into account bridges situated in a specific area or along specific routes. It can be argued that all bridges should be considered and penalty when a bridge has a remaining life span. Nevertheless, taking all bridges into account might make it too complicated. From an ethical and sustainable point of view, it can be argued that renewing bridges before they are needed is a waste.

Following that, it will be determined which strategy is feasible for each bridge and which strategy is the ideal fit for each bridge (*investigating possible strategies per bridge + choosing a strategy per bridge*). Next, there will be a ranking of all feasible bridge strategies. Which is the best option, which comes next, and which follows? Taking into account the effects on accessibility, livability, safety, and costs; a specific strategy is ideal for one bridge without considering the best/possible strategies for other bridges nearby. Adding a not initially chosen bridge (for example, due to a residual lifetime) may be advantageous during the scenario creation process. An initially not chosen bridge might also be added since it leads to better scenarios. The diagram depicts this using a feedbackloop.

What is included in the block *information bridges*, which is needed for the blocks *investigating possible strategies per bridge + choosing a strategy per bridge* are the characteristics of the bridge and its surroundings, since these influence the decision for choosing a strategy. Information about these characteristics can lead to a possible probability of whether a specific strategy is suitable. For example, when there are many historic trees around a bridge, the possibility that a temporary bridge is the best option might be slight since it will probably not fit, and cutting down historic trees is possibly not an option. Also, when a bridge is very narrow, phased building might not be very beneficial since there is not much space left for vehicles and people to cross. Therefore information is needed about which modes of transport use the bridge (tram, car, bicycle, pedestrian), street function, bridge width, presence of historic trees and houseboats, part of the main route, and whether there are suitable alternative routes available.

Information on the strategies is required to analyze the potential strategies for each bridge (*information strategies)*. Information on the strategies is needed to evaluate which methods are feasible for each bridge and which is most appropriate. First, what strategies might be possible in addition to the ones already discovered should be investigated (phased building, entire closure, or temporary bridge). Following that, the characteristics of each strategy should be examined in terms of their impact on safety, livability, accessibility, and costs. It is also essential to consider how long they take.

Of all the chosen bridges, a ranking is made of the best strategies. Since only x number of bridges can be addressed at a time, groups will be made of that x number (*defining scenarios*). Several scenarios will be made, which can then be tested. Combinations that can be made are, i.e., bridges with the same best-fit strategy, on the same route, in the same neighbourhood, spread out, and on the same tramway. Furthermore, a bridge may not require the best-fit strategy to be chosen, but it is better to go for option two or three because it fits better concerning the other bridges when the scenarios are created. A feedbackloop represents this (iterative) process.

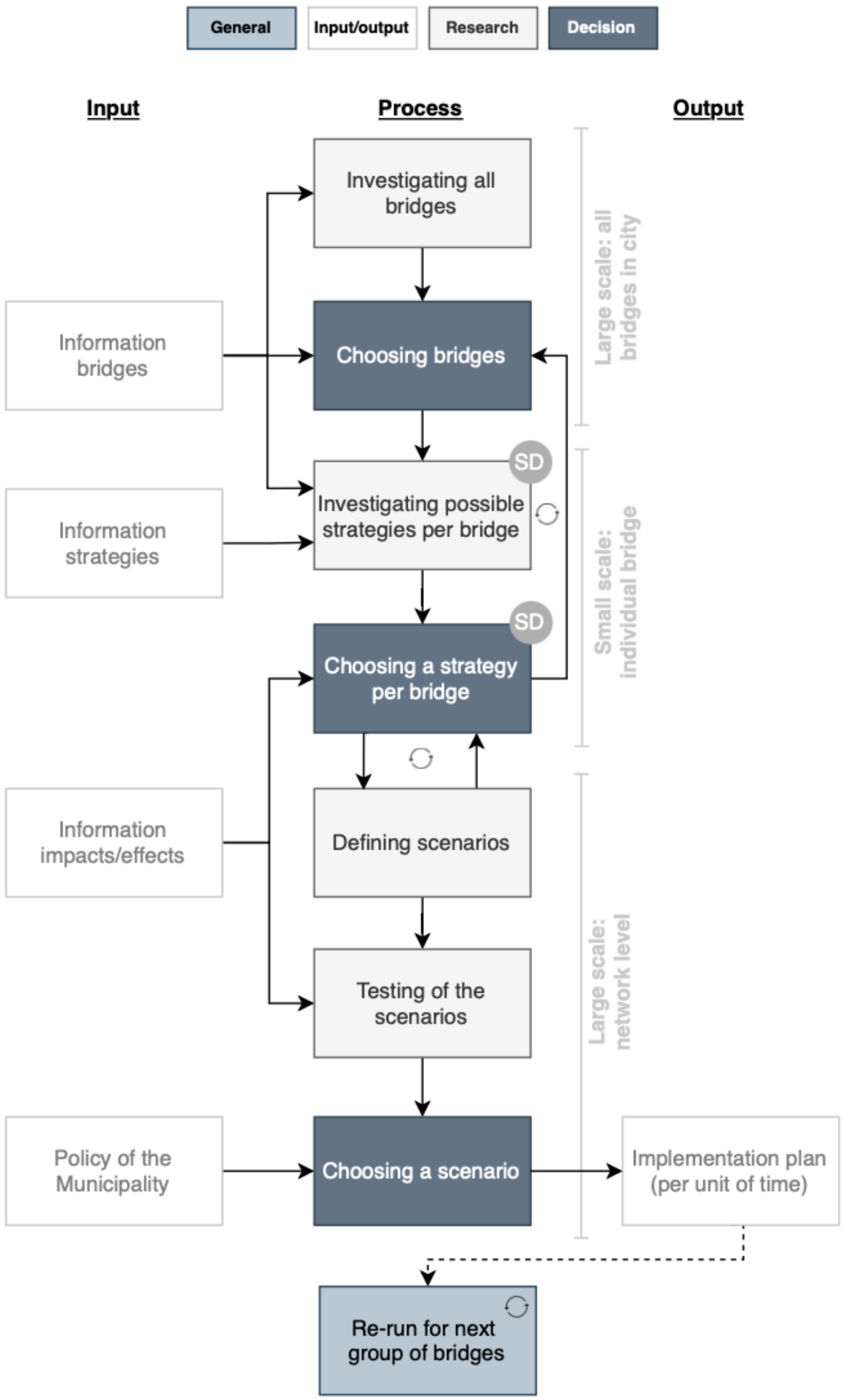

Figure 3.3: Conceptual Design: Decision-making Framework (DMF)

Information about the impacts/effects (*information impacts/effects*) is needed to know which strategy best fits per bridge and test the scenarios. For example, we need to look at the impacts of accessibility, safety, and livability. Information about the impacts/effects is also needed for testing the scenarios since other impacts might play a role when bridges are maintained simultaneously.

To determine which scenario fits best, these need to be tested (*testing of the scenarios*). Therefore, each scenario will be scored on the different impacts: livability, safety, accessibility, and costs. This requires information on the impacts/effects as already discussed.

Choosing the best scenario (*choosing a scenario*) might be challenging. Therefore the scores on the impacts (livability, safety, accessibility, costs) must be compared using, i.e., a CBA or MCDM. Furthermore, when choosing a scenario, a trade-off between, e.g., costs and accessibility probably have to be made. Deciding on this might differ per municipality; therefore, the *Policy of the Municipality* is needed as input.

Each municipality may have a different vision of handling the scoring of different impacts on the scenarios (*policy of the municipality*). For example, some may want to pay more money to keep a city accessible to others. Characteristics of a city can also play a role in this, for instance, if a city has much tourism like Amsterdam. Attitudes as a city towards cars can also be taken into account.

An implementation plan is created when the framework is completed (*implementation plan*). This states which bridges should be addressed simultaneously and with what strategy.

To eventually schedule all bridges, this framework has to be gone through several rounds (*re-run for next group of bridges*). During the first rounds, a solid implementation plan might emerge. But as the process progresses, the remaining bridges might cause no good implementation plans. Therefore it must be ensured that the entire decision-making is a solid choice.

The DMF relates to various scales. First, the upper two blocks relate to the 'large scale: all bridges in the city.' After this, two blocks relate to the 'small scale: individual bridge,' and the final blocks again refer to the large scale; nevertheless, this is the large scale on the network level. The decision-making for this individual bridge on a small scale will be elaborated on in the System Diagram (SD) in the next Section. Therefore, the DMF considers the entire decision-making process, whereas the System Diagram considers the decision-making of an individual bridge. Hence, the SD is related to the blocks 'investigating possible strategies per bridge' and 'choosing a strategy per bridge' as indicated by the grey circle with 'SD' at the top right of these two blocks.

3.4.4. System Diagram (SD)

In the SD, as shown in figure 3.4, the decision-making of an individual bridge will be shown by looking into the impacts of choosing a specific strategy: temporary bridge, phased building, and entire closure. First, the DMF and SD relationship will be discussed, along with the relation between the decision for an individual bridge and the larger scale. Furthermore, the methodology used for designing the SD will be explained. Finally, the SD will be described.

The 'small scale: individual bridge' Section of the DMF is linked to the System Diagram, making it an extension of that Section of the framework. The first two blocks in the DMF correspond to the 'large scale: all bridges in the city,' the following two blocks to the 'small scale: individual bridge,' and the remaining blocks to the 'large scale: network level.' Additionally, there are feedbackloops between the large and small scales. The feedbackloops illustrate the connection between a small-scale decision and a large-scale decision. The System Diagram offers a theoretical understanding of the effects of selecting a particular strategy. When deciding the strategy to apply in the 'small scale: individual bridge' Section of the DMF, it is helpful to bear this in mind.

To show which factors play a role in the decision-making of an individual bridge, a System Diagram (figure 3.4) was used. On the edges of the system diagram are the *means*, *external factors*, and *criteria*.

This method is mentioned in the work of Enserink et al. (2022), where these edges are explained. The *criteria* are the factors that indicate to what extent a specific strategy has an impact. The *external factors* are the factors that can not be influenced by the client (municipality) but do affect one or more criteria. The *means* can be influenced by the client (municipality) and affect one or more criteria. The elements within the boundaries are the *internal factors*; these are all factors that play a role and affect the criteria.

The System Diagram, as shown in Figure 3.4, conceptualizes a potential strategy's primary effects. Choosing a potential strategy per bridge leads to different outcomes in terms of criteria. Therefore, the SD is executed again for each potential strategy. For example, if a bridge qualifies for all three possible strategies, it is run through three times, and the score of each strategy on the criteria is examined. The information in the system diagram was obtained by examining the relevant impacts from the previous Section and putting together the elements that came along during the design process of the DMF. Since all bridges need to be renewed in the end, only the major impacts that (possibly) differ per strategy are considered. The goal of the SD is to provide insight into the impacts of different strategies in general to guide the decision-making process.

Which impacts from the previous Section should be taken into account in the SD (as *internal factors* and *criteria*) are indicated in bold in Table 3.2. These impacts are selected since these probably vary depending on a strategy. The often-used categorization of criteria in Amsterdam, namely safety, accessibility, and livability, resulted from these relevant impacts and is therefore chosen in the design of the SD. Since the only economic factor is 'Loss of Business,' it is included in the SD in another way. Historic trees and houseboats, along with other aspects, were discovered during the visit to the location of the case study. These will be included in the SD as well. Construction costs have been included as a criterion for choosing a strategy; nevertheless, this is not related to the impacts.
The means of the SD are 'available money' and '(clear) communication about detours.' As the diagram indicates, '(clear) communication about detours' influences 'travel behaviour changes.' 'Available money' influences 'choosing a specific strategy.' For example, when more money is available, municipalities might choose a temporary bridge since this is more expensive over entire closure. The external factors are 'characteristics bridge + surroundings,' 'technical feasibility of a strategy,' and 'relation bridge to other bridges' as already mentioned, the municipality can not influence these, but all influence the decision of choosing a specific strategy. 'Characteristics bridge + surroundings' also influences the 'technical feasibility of a strategy'; for example, a phased building process might not be possible when a bridge is too narrow. The criteria are accessibility, (traffic) safety, livability, and costs; this categorization of impacts was already discovered.

The *internal factors* are categorized into three categories, as indicated by the different colours: transportation (turquoise), space (green), and temporary construction (blue).

First, the internal factors regarding transportation will be discussed. Choosing a specific strategy influences whether the tram is available. This impacts the travel time (which can differ per mode) and modal shift. As discussed in Chapter 3.2, the DSS design requires possible distinctions between modes and groups within modes, e.g., residents, tourists, and commuters. As indicated by the arrows, changes in travel time lead to changes in travel behaviour. Changes in mode choice (modal shift) lead to changes and reductions in traffic flows and increased traffic volume at some places for specific modes. Which, in the end, leads to an impact on accessibility and (traffic) safety. If the accessibility changes, this impacts the loss of business, which leads to changes or reductions in traffic flows. Changes in accessibility also lead to traffic behaviour changes.

Choosing a specific strategy also impacts the use of space. E.g., when a temporary bridge needs to be built, more space near the bridge is needed compared to phased building or entire closure. When more space is needed, this leads to changes in infrastructure, which leads to increased traffic volume at some places for specific modes and impacts the (traffic) safety. When more space is needed, for example, for a temporary bridge, this may lead to moving houseboats and cutting historic trees (leading to loss of historical value), ultimately impacting livability. Also, choosing a specific strategy, use of space, and cutting historic trees impacts the visual quality, which can also be connected to livability.

A specific strategy also leads to a construction method. A specific construction method leads to the time needed for construction, dust, and noise, which all impact livability.

Finally, choosing a specific strategy leads to construction costs. For example, a temporary bridge is expensive, whereas the entire closure is the cheapest option.

	Safety	Accessibility	Economy	Livability / Environment / Social
Wu et al. (2021)	**Safety** (workplace and traffic)	**Mobility people and goods**	Economic growth	Environments dwellings and public services
Ibrahim et al. (2018)		**Increased travel distance**	Closure/**Loss of Business**, Relocation of residents	**Noise**
Santos et al. (2021)		**Interdiction of vehicle traffic, Interruptions and changes in pedestrian traffic**		**Noise**, Pavement damage
Allah Bukhsh et al. (2019)	**Safety**	**Travel distance, Extra traveltime**		**Noise** (vehicle and machine), Material usage
Zachary-Younger (2020)		**Changing number of trips/flows, Increased traffic volume, Travel distance, Behavior changes traffic, Modal shift**	**Loss of Business**	
Xue et al. (2015)		**Travel residents, Transportation**		Daily life, **Environment**
Zou et al. (2018)	**Safety**			**Noise, Dust,** Peoples' response to emergencies
F. Wei et al. (2022)			**Business interruptions,** Building and content losses	
Celik and Budaya (2016)				Nuisance in general
Casanovas-Rubio et al. (2020)		**Traffic routes**		
Kattan et al. (2013)		**Behavior changes traffic, Modal shift**		
D. Wei et al. (2022)				Distributional effects (along socio-economic groups)
Binsbergen (2021)	Human costs, **Traffic safety**	Local accessibilty, **Traveltime,** Accessibility to activities, Multi-modal connectivity	Property damage, Production loss, Economic and job competiveness	Air pollution, Gas emissions, Biodiversity, Water pollution, Barrier effects, **Noise, Visual quality, Historic value,** Health, Comfort, Urban quality, Equity in accessibility, Distributional effects (along socio-economic groups)
Mottee et al. (2020)	Safety	Road obstructions, **General accessibilty**	Property impacts, **Loss of Business,** Relocation of business	**Noise, Dust,** Vibration, Subsidence , **General livability**

Table 3.2: Impacts used in the SD

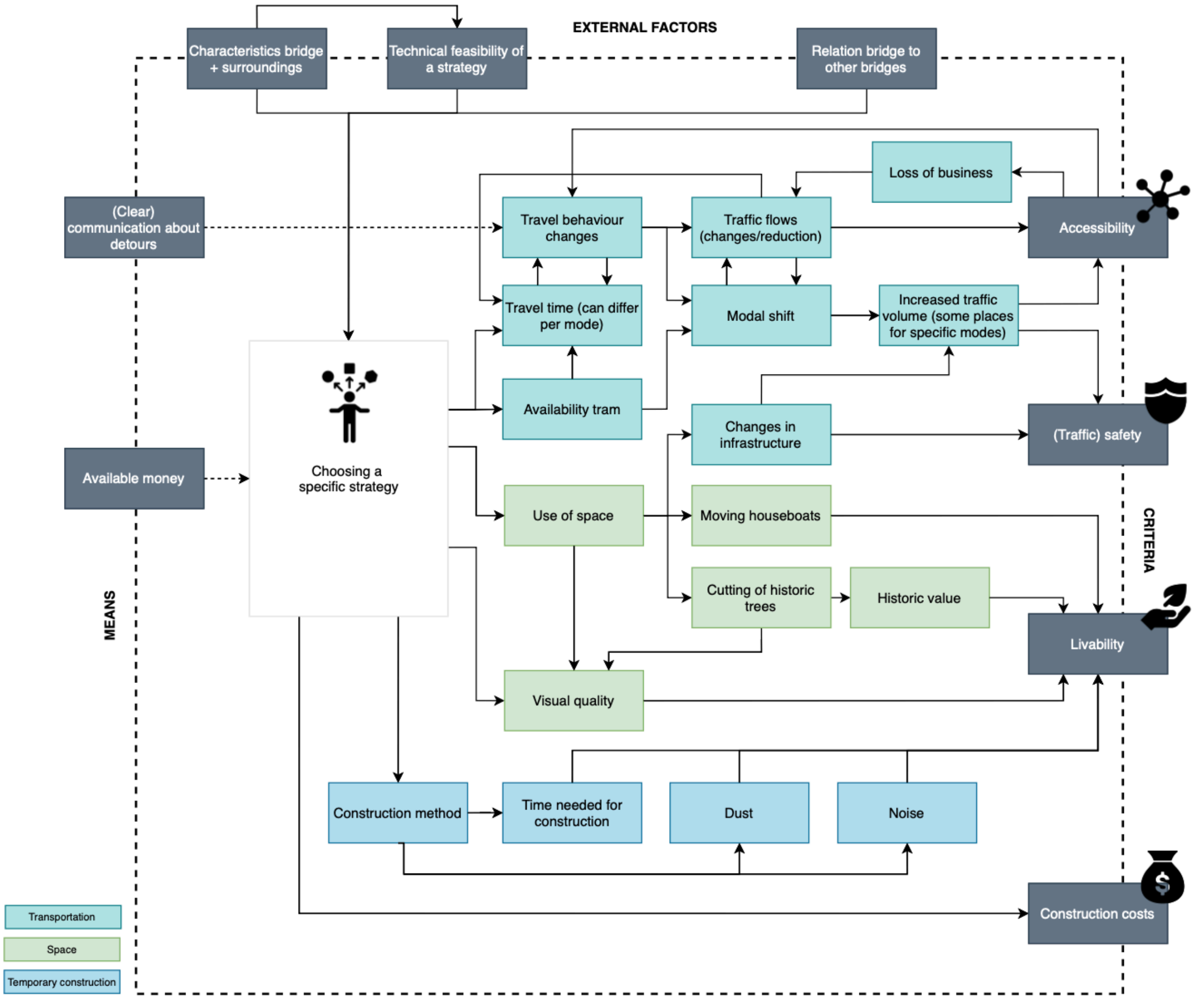

Figure 3.4: Conceptual Design: System Diagram (SD)

4
Discovery

This Chapter covers the second diamond of the 'Triple Diamond Approach.' After the Conceptual Design (DMF + SD) development in the previous Chapter, validation of the Conceptual Design will be done using expert interviews. The first part of this Chapter relates to the 'discover' part of the second diamond, as shown in Figure 4.1. Due to the divergent nature, new findings are emerging here. These new findings arise through expert interviews. Concerning the expert interviews, the set-up will be discussed in Section 4.1. After this, the main results of the interviews are addressed in Section 4.2. Using the results from the expert interviews, conceptual modelling will be used to redesign the DMF and SD to a Final Design (DMF + SD) in Section 4.4. Due to the converging nature (using only the relevant findings to create a product), this part relates to the 'define' part of the second diamond.

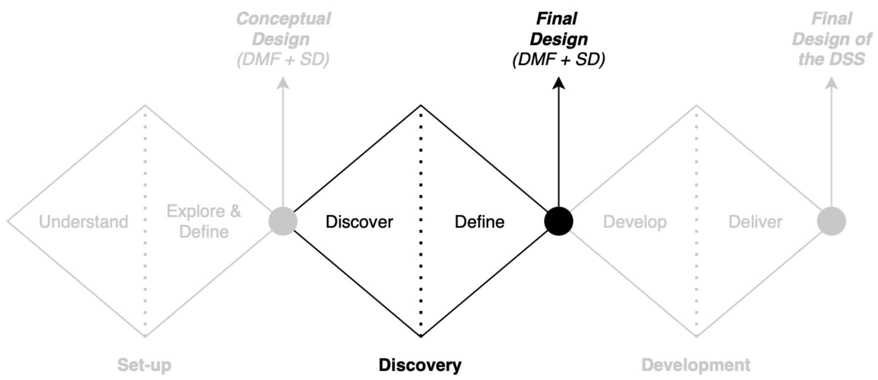

Figure 4.1: Diamond 2 of the 'Triple Diamond Approach'

4.1. Interview Set-up

In this Section, the interview set-up will be discussed. First, there will be an elaboration on the expert selection in Subsection 4.1.1. After that, the interview guide will be presented in Subsection 4.1.2. In Appendix B, the guide used during the interviews can be found. In Appendix C, the summaries of the individual interviews are shown. All interviews took place in Dutch. For this reason, the interview guide and interview summaries are in Dutch.

4.1.1. Expert Selection

Six experts have been interviewed. Two experts from the Municipality of Amsterdam, three experts from within Witteveen+Bos, and one expert from the Municipality of Delft have been selected. It is decided to have experts with different expertise in order to get various points of view. Moreover, experts from the Engineering Firm and municipalities were interviewed to highlight the difference between theory and practice. Different municipalities were also selected to determine the differences per city, which is helpful for the eventual generalization of the DSS. After these six interviews, sufficient information became available for further development of the DMF + SD and input for the DSS to be designed. Therefore, for this reason, and limited time, it was decided not to conduct further interviews.

4.1.2. Interview Guide

During the semi-structured interviews, the experts' knowledge was used to validate the DMF and SD and gain insights into the various components (methods, strategies, impacts/effects, and policy of the municipality). During the interviews, which took around one hour, a PowerPoint presentation was used to structure the interviews and to explain the DMF and SD. The interview guide is shown in Appendix B.

The interviews began with an introduction round, in which a person was asked about their experience, current position, and if the interview could be recorded. After this, the expert was told what the interview would look like. After the introduction, the research was briefly explained. Then the purpose of the interview was discussed, and after that, the first questions (part 1 or 3) and an explanation of the DMF. Afterwards, more questions were asked (part 2 of 3), and an explanation SD was given. Finally, after explaining the SD, there were some final questions (part 3 of 3) and the closure of the interview.

The interview aims to validate the DMF + SD and discuss more detailed DMF topics. Additionally, interview discoveries are used for designing the DSS. For each expert, several questions were chosen to match that person's expertise. After this, the first question was asked prior to showing a framework. No documents were sent prior to the interviews either. This was because often only some interviewees would prepare and some would not, so it was decided not to send anyone anything in advance to keep everyone's prior knowledge equal. The DMF was then discussed with several questions later. These questions varied from expert to expert, as each expert has different expertise. After that, SD was discussed, with some questions afterward as well. Finally, the interview was rounded off by asking what is available regarding data and models and what kind of framework is helpful for the municipality. Finally, there was asked to the expert whether he/she was open to a second interview, whether he/she knew anyone else who would be interested in having an interview as well, and if there were any general tips.

4.2. Interview Results

Many insights resulted from the expert interviews. To use these findings, these are compared per question. From these, the most important findings for further research were then filtered. These findings are presented in this Chapter by several diagrams. Only the relevant results are presented in this Chapter. All results can be found in the summaries (Appendix C). A summary was written for each interview and was sent to the respective expert for approval after the interview.

In this Section, the function and expertise of each expert will be discussed first. A general comparison of the findings will be given later. Then, each part of the comparison table will be discussed and begins with a conclusion. Hereafter a comparison of the different strategies will be revealed. Subsequently, a conclusion and a discussion will be given. The findings related to DMF + SD will be covered in the next Section (4.4), where both frameworks will be redesigned. Findings from the interviews regarding this redesign have only been mentioned in the next Section, as they would otherwise be duplicated.

The interviewees can be divided into three groups, and different expertise is represented within each group. A and B are from the Municipality of Amsterdam, and F is from the Municipality of Delft. Experts C, D, and E are all from Witteveen+Bos. Interviews will be referred to as done during general literature research. The following letters have been used to refer to the interviews:

A = Environment Manager at the Municipality of Amsterdam
B = Lead Programming at the Municipality of Amsterdam
C = Planning and Process Management Department at Witteveen+Bos
D = Head Traffic and Roads Department at Witteveen+Bos
E = Public Goods Economist at Witteveen+Bos
F = Civil Engineering Consultant at the Municipality of Delft

		Amsterdam (A+B)	Delft (F)	W+B (C+D+E)
Current programming:	*Satisfaction*	+	+	N/A
	Stable political situation	-	+	N/A
	Stable funding	-	+	N/A
	Tendancy to use entire budget	+	+ / -	+ / -
	Long-term planning	+ / -	+	+ / -
Programmering principles:	*Function bridge in network*	+	-	+ / -
	State bridge	+ / -	+	+
	Area-oriented	+	+	+ / -
Characteristics of the city:	*Overdue maintenance*	+	-	N/A
	Cables and pipes in bridge	+ / -	-	N/A
	Tram in city centre	+	-	N/A
	Information state bridges	-	-	N/A
Policy of the Municipality:	*Short and intense*	+	+ / -	+ / -
	Long and less intense	-	+ / -	+ / -
	Accessibility emergancy services	+	+ / -	N/A
	Small pedestrian detour time	+	+ / -	N/A
	Small cyclist detour time	+ / -	+ / -	N/A
	Combining other projects	+ / -	+ / -	+ / -

Table 4.1: Comparison between Municipality of Amsterdam, Municipality of Delft and W+B

4.2.1. Function and Expertise

All interviewees hold different positions at different companies. Because of this different expertise, the subject was discussed from different angles. However, it also leads to different views on the topics. Therefore, this Subsection will explain per person their function and expertise.

Expert A has been with the Municipality of Amsterdam since 2007 as environment manager (in Dutch: 'omgevingsmanager'), for which she has done several projects. She currently works two days a week at PBKA on the Weteringcircuit. Furthermore, the person responsible for the PBKA's current programming was interviewed (Expert B), official position: 'task-field lead programming' (in Dutch: 'taakveld trekker programmering'). He is responsible for deciding when which bridge and which quay wall will be dealt with.

The first expert within Witteveen+Bos to be interviewed is Expert C, who works in the 'planning studies and process management' group (in Dutch: 'planstudies & procesmanagement'), which focuses on making choices in projects. Often for explorations in dyke reinforcement or highway projects. She mainly develops MCBAs and environmental impact assessments. In addition to Expert C, Expert D was also interviewed. Expert D is the Head of the Traffic & Roads department (in Dutch: 'verkeer & wegen'). This department deals with the engineering of roads (especially provincial and state roads) from variant and feasibility studies to determining asphalt thickness. The third person within Witteveen+Bos was Expert E, a public goods economist (in Dutch: 'publieke groederen econoom') who is an expert or the field of impact assessment (in Dutch: 'effectbepaling').

Finally, Expert F of the Municipality of Delft was interviewed. He works here as a civil engineering consultant (in Dutch: 'civieltechnisch adviseur'), and envisaged infrastructure manager. He has three tasks he performs: advisor cables and pipes, advisor roads (management and replacement), primary task management, and maintenance civil engineering objects (bridges, locks, quay walls, noise barriers); he makes the planning for maintenance or makes sure it gets into the planning for replacement.

4.2.2. General Comparison

Table 4.1 compares the Municipality of Amsterdam, the Municipality of Delft, and the experts of Witteveen+Bos about some topics. Each topic will be discussed. Table 4.2 shows another comparison between interviewees, which will be elaborated on later.

Current programming

From this first part it can be concluded that both cities are satisfied with their current programming approach, although they differ a lot. In Amsterdam, there is no stable political situation, which is related to

	Corridor (per route)	**Scattered**	**Area-oriented**	**Category**	**Other**
A	x		x		
B	x		x		
C	*corridor or scattered*				
D	*combination*			x	
E					x
F			x	x	

Table 4.2: Logical scenarios to make according to the experts

no stable funding of the project. This is probably the reason for the tendency to use the entire budget. In comparison, Delft has a stable political situation that leads to stable funding of the projects. Due to the different budgets, there is no tendency to use the entire budget, but to spend it responsibly. Since there is a politically stable situation and funding there is a budget for the long term (around 50 years).

Expert B, from the Municipality of Amsterdam, explains that the current programming is designed according to what we, as the municipality, consider most important: namely, the accessibility of the city by trams, i.e., the public transport corridors. Of these, only one can be out of use at the same time. Hence, the bridges are addressed one corridor at a time. Expert B believes that the current way of programming, i.e., from the point of view of tram accessibility, is the best. A drawback of the current programming is that there is too much focus on small bridges with little impact, and less budget should go here. Besides that, the municipality is currently having problems with the budget. In Amsterdam, the initial plan intended to tackle eight to ten bridges in a year; however, this had to be scaled back to two. The reason for this is probably that it is not well organized politically in Amsterdam. We need to move towards a model of long-term stable funding (Expert B); if there is stable funding, maintaining bridges can also be done correctly. Expert A, like Expert B, explains that there is currently less available budget. Expert A says the municipality just started investigating other solutions, like life extension. The idea behind the programming, namely keeping the city accessible, is logical, according to Expert A.

The procedure is significantly different in Delft. Expert F describes how CROW standards, which are the maintenance levels, are used in Delft (A is the highest quality level). The inner city and a single park outside the inner city should meet level B, and the rest of the city meet level C. Economically, restoring something and bringing it back to level A is always advantageous. Managing lower than level C is capital destruction. Of course, there is only a limited budget that must be considered in planning. There are two budgets, one annual one that 'runs out' every year and a larger one for big projects. On the annual budget, you have more than enough one year and a deficit the other. In the 1960s/70s, everything was maintained, so no maintenance is really overdue. Here it is under control compared to Amsterdam because of the increase in scale and the fact that everything is well-maintained here. Contractors treat an area each year, and each bridge is maintained. Expert F also explained that their project funding, like in other cities, depends on politics.

Expert B explains that the entire budget will be used in Amsterdam, something Expert E calls a problem. According to Expert E, money can only be spent once. If you choose the more expensive alternative that costs two million extra, which only leads to a small favor for five shopkeepers, you can ask yourself whether you should have spent the money elsewhere. Deciding on this can also be done without expressing it in euros, e.g., price in minutes in terms of turnaround time. It is essential first to count how many people it affects to make a good choice. The experts from Witteveen+Bos explained that the entire budget should be handled responsibly not just be used for the sake of using it.

Expert A explains that in Amsterdam, planning is done far ahead in broad outlines and then adjusted. The best possible information about the bridge's state is desired, but this changes over time. For Amsterdam, the decision was made to plan 20 years, with blocks of two years in detail. The planning until 2040 was all set, but now some changes will be made. Planning for 20 years is not yet completely definite and will be updated annually. Expert F explains that Delft works with three plans: An annual planning requires timely communication with the contractor about the capacity needed for the projects in the following year. There is also a planning for four to five years ahead, including major projects besides the usual maintenance. Moreover, there is a 50-year plan which gives an insight into which long-term projects need to be pushed forward and backward to suit the available budgets. If this is not planned correctly, problems with politics arise. Expert C says it seems logical to her to make a detailed plan for about five years ahead, also considering the other city projects, e.g., the intersections. Furthermore, make a rough plan for 10 and 50 years to keep track of the urgent bridges. Expert D indicates that it is helpful to plan for ten years. Furthermore, according to Expert D, it may be that at some point, the realization speeds up or the function of the bridge in the network changes. According to Expert E, long-term planning should be done immediately, i.e., the optimal ranking for your complete portfolio. This does promote by looking at the total damage, calculating the social costs by expressing all effects in euros, and choosing the scenario with the lowest costs.

Programming Principles

In this part, the different programming principles when comparing the municipalities and experts from Witteveen+Bos, as indicated in Table 4.1, will be shown. From this, there will be found that the Municipality of Amsterdam mainly focuses on the function of the bridge in the network (i.e., in the public transport network). In contrast, the Municipality of Delft and the experts from Witteveen+Bos argue that the bridge's state should be used as a starting point. From Table 4.1 is discoverd how both municipalities use an area-oriented approach, whereas the experts from Witteveen+Bos do not specifically mention this. This area-oriented approach is also shown in Table 4.2. This Table provides more detail about defining the scenarios; it was found that the experts from Witteveen+Bos would combine a corridor and scattered or choose one of these two. Also, one expert has another opinion, which will be elaborated on in this Section.

Expert D is familiar with the project in Amsterdam and would prioritize based on the constructive importance of a bridge. Also, taking into consideration the function of the bridge in the transport network and taking only a few bridges with an essential function at the same time; otherwise, this would lead to network problems. Therefore he would make a mix of an important bridge and then x number of less essential bridges. Technical complexity per bridge should be taken into account as well. Expert E, like Expert D, would look at which bridge is the first to collapse and see the consequence of each bridge if it is not addressed and how many people are affected. Expert E explains that the bridge with the greatest social damage (if you do nothing) should be done first. Expert E also explains that relating this to costs is unnecessary since all bridges should be addressed. Therefore, Expert D and Expert E would choose the state of the bridge as the starting point for programming. This is a different main starting point' from the one the Municipality of Amsterdam chose, namely the tram lines. The bridge's state is a logical starting point, but in Amsterdam's case, this is a problem, as many bridges' states are unknown. The corridor method (as done by the Municipality of Amsterdam) does result in early replacement; however, the approach indicated by Expert D and Expert E does not. Furthermore, Expert D also argues that one should look at the function of the bridge in the network in order to avoid problems. D argues that, in addition to the bridge's state, accessibility should also be taken into account, which corresponds to the main principle of the Municipality of Amsterdam. The approach of the Municipality of Delft, Expert F, is approximately similar to how the experts approach this problem. However, experts were presented with the scenario of overdue maintenance, which is different in Delft. However, they all agreed that the first thing to consider was the condition, which is irrelevant for Delft since Delft does not have overdue maintenance. However, both have the state of the bridge as the main starting point. According to Expert E, everything should be translated to costs; therefore, the most beneficial option (lowest total costs) should be chosen.

The differences between the programming principles regarding 'function bridge in network' and 'state bridge' are already discussed. This part will elaborate on the different approaches regarding defining scenarios, as represented by Table 4.2.

Expert A indicated that there are different impacts per scenario. A variants study was first supposed to be done by the Municipality of Amsterdam, but unfortunately, the plug was pulled. The effects of a corridor are different from closing bridges that do not have much to do with each other. If you address one bridge in a cluster causing people to make a slight detour by bike. However, this detour time can become too long when a corridor is closed. Expert B agrees that there are significant differences in whether bridges are replaced per corridor and area or spread out/scattered. The scenario of scattering through the city was never actually explored in Amsterdam due to the choice of a corridor and area approach. The corridor approach has a much larger spot effect. The scenario of spreading through the city is a ways off because we have the 'short and heavy' principle, even though it might be revisited according to Expert A. Furthermore, combining multiple projects in the city is advantageous, but everything is waiting for everything, making it very complicated. Right now, there is a discussion about whether it is worth putting much effort into combining bridge maintenance with a rail project of only 3 tonnes. Furthermore, Experts C, D, E, and F also agree that each scenario has different impacts. Expert D indicates that both scenarios should be converted to vehicle loss hours to compare them.

Expert C recommends studying what happens when maintaining bridges scattered throughout the city because this might spread the effects. However, it might also be more expensive. Furthermore, you might prefer to have one year of more trouble over ten years of a little bit ('short and intense' or 'long and less intense'). For the framework, choosing the scenarios broadly as you go through them to test these extremes is wise. That a resident might prefer short and heavy rather than long and less heavy is something the Amsterdam municipality adheres to, as discussed earlier in the interviews with Expert A and B. Expert D says that a combination of the scenarios mentioned by Expert C. Namely, combining one route with several bridges spread throughout the city. If you can do several bridges on one route at the same time, that is useful, but you should not tackle two major routes at the same time. Expert F does not mention the bridges on one route but mentions addressing bridges in the same area. This saves the cost of moving the construction site. However, the bridges should be able to accommodate each other, so the alternative route should not be tackled simultaneously, i.e., by a different kind of project. According to Expert E, the only thing to consider while bundling bridges is the cumulative social effect, as this is the only criterion (which should be kept as small as possible).

Expert F explains that you can frame urgency differently, implying that bridges are only urgent to tackle if they are used. Choosing which bridges can be done simultaneously can be categorized according to the same length (beneficial if a mold has to be made for the bridges, saves many costs if this only has to be done once, and width is more easily adjusted). Categories can also be made by the type of stone or whether the bridge is movable. Furthermore, the decision-making depends on the situation in the city. In Delft, the most urgent bridges had already been done using an area-oriented approach. An area-oriented approach in Delft has as benefit that the contractor only has to set up the construction site once and can handle several bridges (about eight) from that location, saving costs. Further, it is recommended to maintain a bridge completely than go for a quicker and cheaper renovation option. Expert B explains that he would make groups of bridges, for example, by the same tramway, important cycle route, standing mast shipping route, or a main street. This linking of bridges was also mentioned earlier by Expert F, for example, in terms of length when pre-fabricated or the same type of stone. Expert D also says that it is mainly about the interplay of the bridges, and in this, a distinction must be made between the local function of the bridge and its function in the network. Expert C indicates that identifying which strategies are possible per bridge is helpful. If necessary, the second or third best strategy per bridge is chosen if this fits better in the scenario.

Characteristics of the City

There are many differences between the city of Amsterdam and Delft. Firstly, there is substantial overdue maintenance in Amsterdam, whereas in Delft, this is not the issue. Secondly, some bridges in Amsterdam have cables and pipes inside, which is not the problem in Delft. Furthermore, Amsterdam has a tram in the city center, whereas Delft only has a tram outside the city center. Finally, both cities do not know much about the state of the bridges.

As mentioned, in the 1960s/70s, everything in the city center of Delft was replaced, and there is no great maintenance backlog. Of course, the bridges need to be maintained, but these are relatively minor interventions done on an area-specific basis. During the interview with Expert B, there was talked about the substantial amount of cables and pipes that have to go through the bridges of the 'Oranje Loper.' During maintenance, these cables and pipes are put in the temporary bridge. However, according to an expert from Witteveen+Bos, these cables and pipes can also be put on a much cheaper construction (J. de Leeuw, personal communication, December 19, 2022). In Delft, there are barely any cables and pipes in bridges (Expert F).

Furthermore, it should be taken into account that Delft does not have a tram running through the city center, which can be assumed to result in a simplification in programming.

Expert B indicates that little information is known about the state of the bridges in Amsterdam. Much of the information from the archives was lost when they were moved. The municipality is busy researching the bridges, but this is expensive and takes time. In Delft, information from the archives is lost, mainly when they were digitized, Expert F explains. This concerns information gathered between 1850 and 2000. Furthermore, F explains that many historic bridges do not have building plans. Furthermore, research is complicated. For example, the bridge can be in bad condition and not have any cracks. However, a bridge can have cracks and falling stones and being in good condition.

Policy of the Municipality

This part discusses the different policies of the municipalities. The Municipality of Amsterdam aims to have construction work in the city rather 'short and intense' than 'long and less intense'. In contrast, the Municipality of Delft and the experts of Witteveen+Bos do not have a preference. Both municipalities need to have good accessibility to emergency services; nevertheless, the Municipality of Amsterdam handles it in another way compared to the Municipality of Delft. In Amsterdam, the detour times for pedestrians should be short, whereas slightly longer distances are allowed in Delft. Regarding cyclists, both cities agree that it is okay to have a detour time for cyclists. Finally, both cities aim to combine the maintenance of bridges with other projects in the city.

Expert A claims that even though it might be reconsidered, spreading projects throughout the city is not an option due to the concept of 'short and heavy.' Combining projects has benefits but is also tricky because projects have to wait for each other. Expert B confirms that the preference for 'short and intense' over 'long and less intense' is where the idea to combine several projects (called 'creating work with work') originates. Expert B further mentioned that a 'short' period has another definition for the citizens than for the municipality.

According to Expert A, the accessibility of emergency and rescue services is non-negotiable. Expert B agrees, mentioning that the emergency and rescue services are the most important to consider, specifically the ambulance and rescue vehicle, because they are often wider than, i.e., a fire brigade and police. Expert A says that the basic principle is to close a bridge entirely during maintenance, but this is often impossible since it should be accessible for emergency and rescue vehicles. Furthermore, like Expert A and B, Expert F says that accessibility for emergency and rescue services is most important. However, it was decided in Delft that emergency and rescue services should use the detour if a bridge is closed. However, it should be clearly communicated that a particular bridge is closed.

Amsterdam and Delft have different opinions on the allowed detour times for pedestrians. Expert F explains that in Delft, pedestrians have to walk to the other bridge; the only time a temporary bridge was used was somewhere outside the city center, where otherwise, people had to walk a few kilometers to the next bridge. On the other hand, expert A explains how a detour for pedestrians is not an option in Amsterdam; therefore, a temporary bridge should be built. Although this is less of an issue for cyclists, Expert B explains.

According to Expert E, combining projects with each other is often beneficial. Everything in the city has its replacement rhythm (sewerage, drinking water extraction, and gas lines). If the road is already open for one of these, it is cheaper if others can also do their replacement. This is cheaper in terms of implementation costs and is also beneficial in terms of traffic congestion and inconvenience for residents. Expert F explains that most municipalities manage problems incidentally; they see where things are going wrong and then tackle them there. In Delft, asset management is used. With asset management, there is tried to get an overview of the entire area and plan accordingly. For example, opening a road is not recommended if it has to be reopened two years later.

4.2.3. Comparison of the Strategies

In Figure 4.2 and Figure 4.3, the strategies are compared. In Figure 4.2, for every strategy, the impact on accessibility, safety, construction costs, and lead time is shown. The strategies are compared on only these four aspects. Many more elements are shown in the SD, but this figure only shows these four aspects because they were mentioned most often in the expert interviews. Furthermore, Figure 4.3 shows for each municipality the strategy/strategies they prefer.

Figure 4.2: Comparison of the strategies

According to Expert B, which of the strategies is possible depends on the situation, but they have all been done in Amsterdam. Indeed, according to Expert D, you only have these three choices in terms of strategies: temporary bridge, phased building, and entire closure. The latter two are a choice of principle; 'short and heavy' or 'long and less intense.'

Expert B says that health and safety are often the problems with phased building. Therefore it is often difficult to keep the bridge accessible for trams. In contrast, Expert E says that phased building is usually possible for bridges with a tram due to a bridge's robust construction. Furthermore, Expert F says that phased construction has been done in Delft, but the feasibility depends on the location; there is often no specific preference. Finally, according to Expert D, phased building is less safe than complete closure, which is the safest option.

Expert A states that the temporary bridge would rather not be chosen because it is very narrow and is two to three million euros. Expert A also says that entire closure is preferred unless there is no other option, as entire closure is the quickest and safest. However, entire closure is sometimes not possible as emergency and rescue services need to be able to cross the bridge. According to Expert B, it is helpful to have a temporary bridge when there are a lot of cables and pipes in a bridge since these can be stored safely here. Expert F says that a temporary bridge was only used once in Delft because the detour time was too long for pedestrians.

It can be concluded, as shown in Table 4.2, that entire closure is the safest option and phased building most risky. Nevertheless, when a bridge is entirely closed, no accidents happen on that bridge, but other parts of the city can become too crowded, leading to accidents. As discovered earlier entire closure is the cheapest option and a temporary bridge the most expensive. The lead time is the shortest for entire closure and is longer for both phased building and a temporary bridge. A temporary bridge is best for the accessibility of the city (this may differ per mode since it might only be used for some

	Amsterdam (A+B)		**Delft** (F)	
Preferred:	Entire Closure		Phased Building Process	Entire Closure
Otherwise:	Phased Building Process	Temporary Bridge	(Temporary Bridge)	

Table 4.3: Comparison of the preferred strategies per Municipality

modes), and entire closure is the worst (closed for all modes). When phased building is used, it can differ for which modes the bridge remains available. Furthermore, it is also likely that the bridge has to be entirely out of use for a short period when using phased building.

Table 4.3 shows how in Amsterdam, entire closure is preferred, and there is no clear preference for a phased building process over a temporary bridge. In Delft, entire closure and phased building are possible with no clear preference. A temporary bridge was only used once and is, therefore, usually not an option.

4.3. Conclusion and Discussion

In this Section different opinions when comparing the municipalities and experts within Witteveen+Bos will be presented. Therefore the DSS needs to consider these different views. Therefore, the block 'policy of the municipality' plays a role in the decision-making, as shown in the DMF. The adapted versions of the DMF and SD will be presented in Section 4.4.

Remarkable from the interviews are the different opinions of the experts and how different cities have different policies. One explanation for the different expert opinions is that everyone reasoned from his/her expertise and experiences. Moreover, everyone may have had a different view of the city, especially regarding experts at Witteveen+Bos, some of whom are very familiar with Amsterdam and others who are not. Another reason might be familiarity with the subject. It was noticed that some respondents quickly understood the DMF and SD (which will be discussed in the next Section) because they work with frameworks more often. In contrast, others indicated that they found it complicated. Therefore, this may also influence the answers given.

There are many new (contrasting) findings per interview; the different expertise and companies can explain this. Hence no saturation took place. Since there is no saturation, it might be helpful to have more interviews. Since the interview with the Municipality of Delft provided many new findings, conducting interviews with other municipalities may provide even more insights. Whether this is useful will be discussed in more detail in Chapter 6.

4.4. Final Design

In this Section, the findings from the expert interviews will be used in this 'Define' part to arrive at a Final Design of the DMF and SD, as shown in Figure 4.1. Various feedback came from the interviews, some of which contradicted each other. Therefore, only the elements that were implemented or relevant to the design of the DSS are shown. The modified DMF and SD are shown below, and the changes are explained. Further explanations and other comments from the interviewees can be found in Appendix C.

4.4.1. Adapted Decision-making Framework

Figure 4.3 shows the adapted Decision-Making Framework. A few minor adjustments were made as the experts, in general, agreed with the Decision-making Framework. Below, the changes are mentioned, along with some important remarks.

The first change is the edge of the 'investigating all bridges' block, which is dotted. This is because, in practice, not all bridges are investigated. Interviews with Experts A, B and F revealed that information about the bridges is often missing. Furthermore, researching bridges is extremely expensive and time-consuming. According to Expert C, ideally, the block 'choosing bridges' does not exist, and all the city's bridges are included in the decision, even if they have residual life. That it is not possible to include all bridges is a capacity issue (Expert C).

The 'choosing a strategy per bridge' block was removed, as was the feedbackloop from this block to the 'choosing bridges' block. It was found from the interview with Expert C that feedbackloops are not desirable as the process should be linear since time is linear as well.

According to Expert D, the bridges should not be considered individually but collectively as a batch from the first moment. For this reason, the blocks 'investigating possible strategies per bridge' and 'defining scenarios' has been positioned next to each other, and both are directly linked to 'choosing bridges.' Because defining the scenarios can be partly dependent on what the possible strategies are per bridge. However, this can be done 'quick-and-dirty' to estimate in advance what strategies might be a good option per bridge to delimit the possible choices further. Therefore, a dotted arrow has been drawn from 'choosing bridges' to 'investigating possible strategies per bridge.' However, it takes a lot of time and money to investigate every bridge to what extent the strategies are applicable. By creating the scenarios first, the bridges covered in this scenario can be investigated in more detail. The leftward pointing arrow of the feedbackloop indicates this. The right-pointing arrow shows the feasibility of the strategy for an individual bridge, which might be helpful in making scenarios, since it is helpful to know to some extent per bridge which strategies are theoretically possible to arrive at good scenarios. The feedbackloop ends relatively quickly, since for each group of bridges there are only a limited number of logical strategies.

Moreover, the 'policy of the municipality' block has been linked to more blocks than initially. It is also linked to the block 'choosing bridges' since it differs per municipality whether, i.e., bridges are included with a remaining life or not. The preferred strategy varies a lot from one municipality to another, as was also revealed in the interview results. The block 'policy of the municipality' is also linked to this.

Besides making changes to the DMF, some critical observations should be considered in using the DMF and designing the DSS.

According to Expert B, describing the selection criteria well for choosing bridges is important. Criteria that can be focused on are, for example, urgency, construction, and accessibility

In the interview with Expert F was found that scenarios can also be made regarding the equal stone type, length (if not brick), and material.

Expert D mentions that impacts depend on the availability of an alternative route, the amount of traffic, the function in the network, and how long the bridge is out. This can be converted into the vehicle loss hours = extra detour time x number of vehicles.

Expert C indicates that using an MCA is a good option for the 'choosing bridges' block and testing the scenarios. For testing the scenarios, it is best to use an MCA without weights or the same weights everywhere to represent the alternatives objectively. Noise and traffic models can be used to determine impacts and effects (Expert D). According to Expert D, linear programming is preferred, but an MCA can also be beneficial, allowing for other factors. Experts C and D indicate that trade-offs can be compared well using an MCA in which the different scenarios are objectively presented. Therefore the weights of the criteria should not be determined. Expert C indicates that the weights can be determined in a working session with the municipality.

Expert C mentioned that the level of detail needed (e.g., for the models to determine impacts) should be considered, which depends on the municipality's capacity. Moreover, a distinction could be made between the ideal situation and practice.

4.4.2. Adapted System Diagram

Besides the adapted DMF, the SD has also been modified due to the expert interviews, as shown in Figure 4.4. The adapted framework can is shown below, and the modifications will be explained. First, the changes at the edges will be discussed, followed by the changes in the internal factors.

First, the changes at the edges will be discussed. The mean 'other projects' has been added since choosing a particular strategy, as mentioned in the interviews with Experts A, C, and E. 'Other projects' also refers to long-term projects, i.e., raising the bridges on a particular shipping route, as discussed in the interview with Expert A. Furthermore, 'other projects' also influence 'increased travel time (differs per mode)' (Expert C) and 'additional public space needed.' Furthermore, the mean 'Policy of the Municipality' was added, as explicitly mentioned in the interview with Expert B. As found from the interviews, it differs per municipality what their vision is regarding an acceptable turnaround time, 'short and intense' or 'long and less intense', and the accessibility for emergency and rescue services. All these aspects influence the choice of a particular strategy.

The external factor 'characteristics bridge + surroundings' should also include whether a bridge is movable or not and what needs to be replaced; does the entire bridge need to be removed or does only part of it need to be renovated, as this affects how long it will take and how complex it will be, and the demolition work should not be forgotten (Expert E). Furthermore, 'characteristics bridge and surroundings' should include the following aspects, as mentioned in the interview with Expert A: parking spaces, disabled spaces, bad quays (quays need to be strong to have a temporary bridge attached to them), bats, transformer stations and the state of the buildings in the area. This is because the condition of the properties can affect the construction method.

All interviewees agree that the criteria used (accessibility, livability, safety, and costs) are logical and widely used. Regarding criteria, 'economy' was added, as mentioned in the interview with Expert C. Furthermore, '(traffic) safety' was changed to 'safety' to make it more generic (Expert D). Finally, 'sustainability' has been added, as mentioned in the interviews with Experts C and D, to which material use and CO2 emissions are linked; material use also includes not making full use of the material by, i.e., replacing bridges with a remaining life span. It also includes additional material use, e.g., for a temporary bridge. Furthermore, it includes whether certain parts of the bridge can be reused.

Also, several changes are made regarding internal factors. First, the blocks of the transportation category have been simplified. As it was discovered in the interview with Expert E that too much detail was given here by showing the entire system while only limiting it to the main effects is sufficient. The block 'increased travel time (differs per mode)' also includes the modes of transport over water (Experts C and E), and the block 'availability tram' is included in this block.

The 'loss of business' block did not change. However, different interviewees have contrasting opinions about whether this plays a role. Experts A and C have mentioned the accessibility of businesses, as fewer visitors in the street can lead to economic consequences. According to Expert E, however, this loss of turnover for shopkeepers plays no role since people do not spend less money; therefore, it only leads to an unequal distribution. Suffering for customers of shops and pedestrians are comfort issues that are difficult to quantify. It is often helpful to know how many people are affected by counting this (Expert E).

The block 'reduced accessibility to facilities' is added, as discussed in the interview with Expert C. This includes i.e., accessibility to hospitals and schools. The block 'changes in infrastructure' has been renamed to 'changes in access routes,' as this concerns access routes on a small scale, e.g., if a temporary bridge requires traffic to make a different turn, creating a new intersection (Expert E). In the 'space' category, the 'use of space' block has been renamed to 'additional public space needed' (Expert E). Furthermore, in the block 'cutting of historic trees,' 'loss of green' has also been added, as it is essential to preserve green in general (Expert A and D). The block 'historic value' has been removed as this is too much detail. Finally, the blocks 'visual quality,' 'dust,' and 'noise' have all been merged into the block 'disturbance to neighbourhood', which also includes vibration nuisance, walking over planks, passing construction traffic, narrow routes, and inconvenience to terraces (Expert E).

In the 'construction' category, multiple changes have been made. The block 'construction method' is linked to safety, as a specific construction method may lead to a higher risk of falling over or other accidents (Expert E). Furthermore, the block 'time needed for construction' was changed to 'lead time,' which is linked to 'reduced accessibility of facilities' and 'loss of business' since a longer lead time mainly leads to a greater loss of business and inconvenience of certain facilities being poorly accessible for a more extended period. This link also includes the time element, as mentioned in the interview with Expert D. Expert D also indicated that the time element should be linked to livability. Moreover, Expert D indicated that it should be investigated whether there is a preference for 'short and intense' or 'long and less intense'.

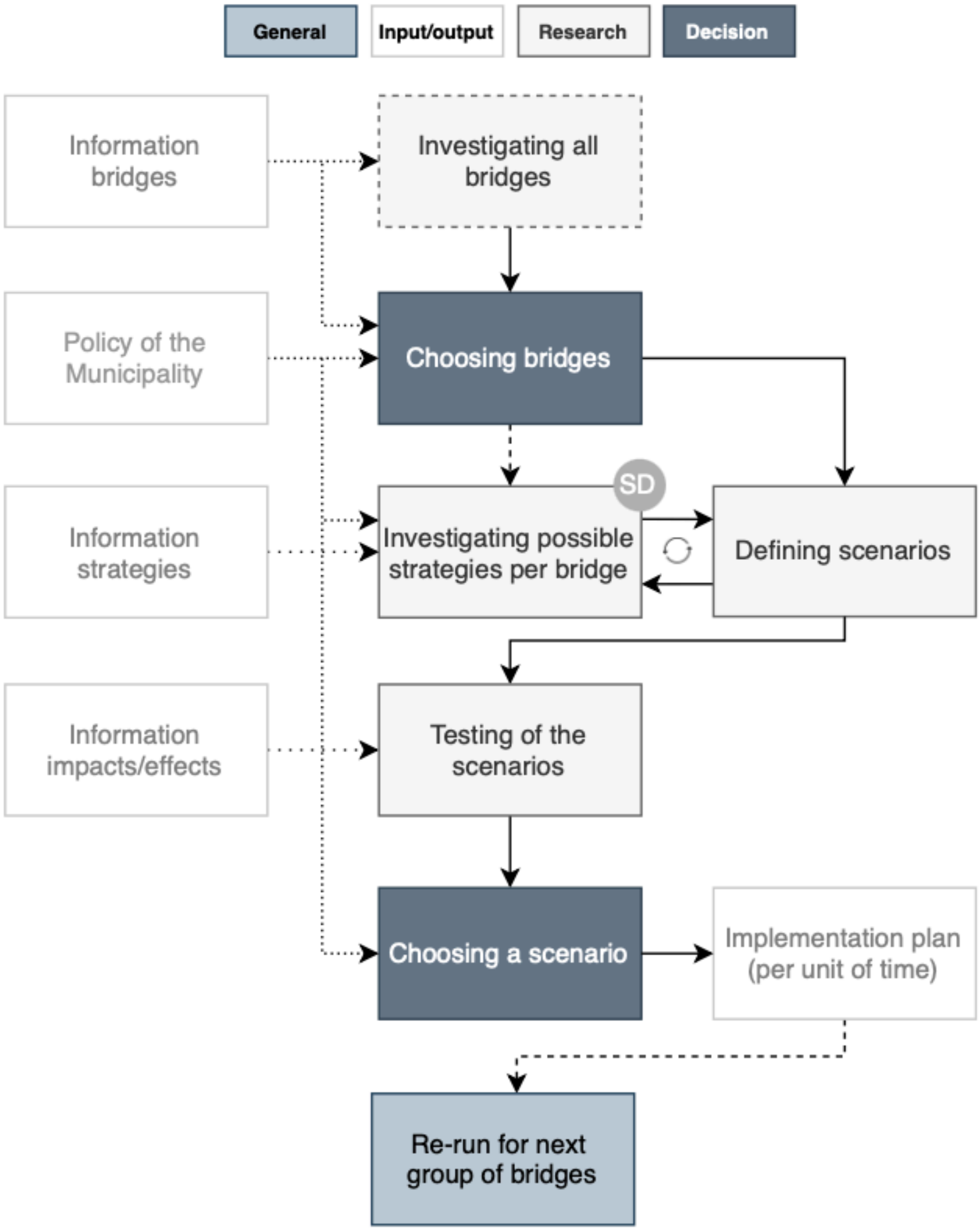

Figure 4.3: Final Design: Decision-making Framework (DMF)

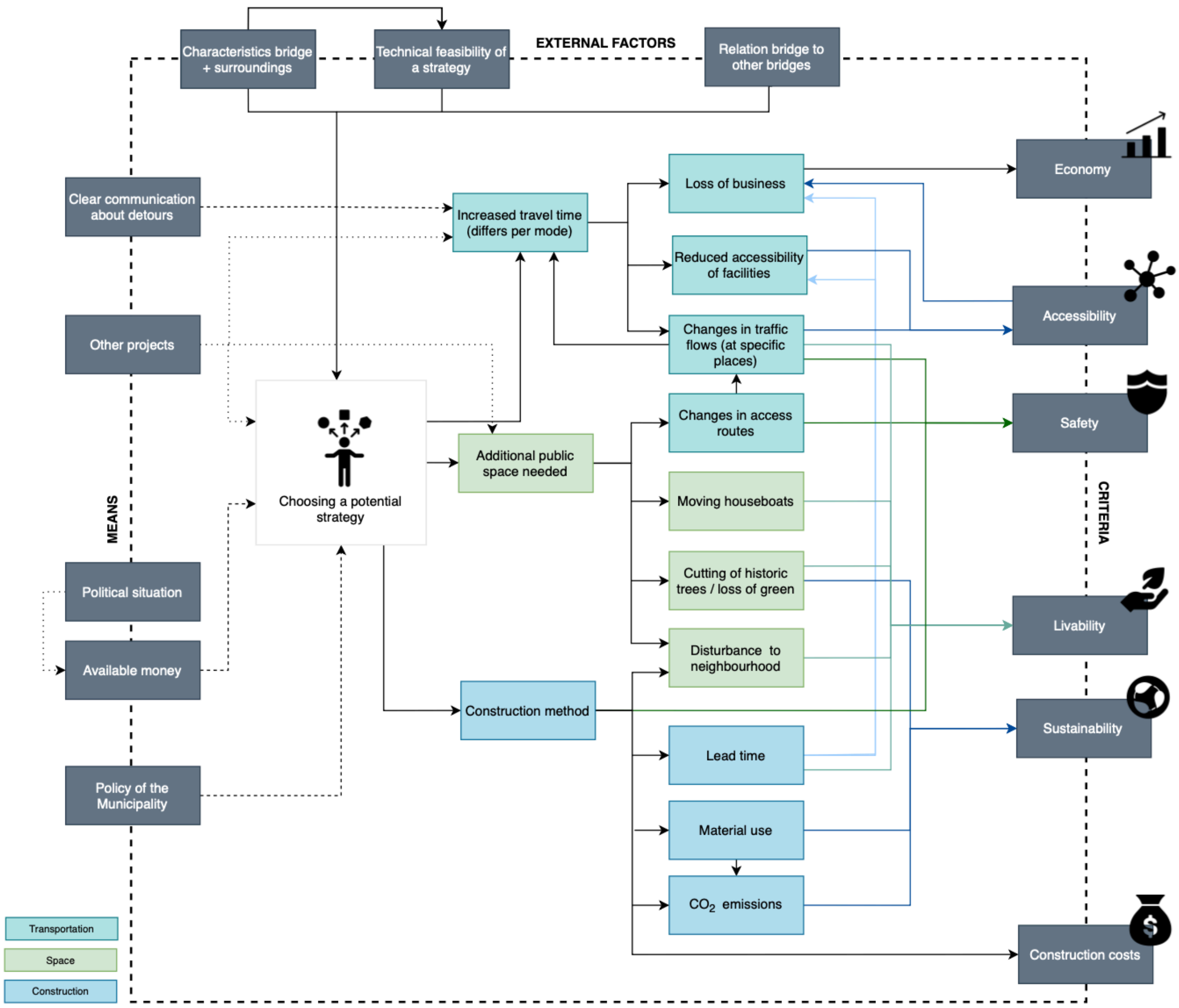

Figure 4.4: Final Design: System Diagram (SD)

5 Development

In this Chapter, the developed Decision Support System will be presented. The Final Design (DMF + SD) is used as theoretical input to develop this. The DSS is made in Microsoft Excel since this is an easily accessible, widely known tool for civil servants and is, therefore, user-friendly. The DSS aims to support the decision of municipalities by showing the consequences of choosing a particular scenario. Therefore, the DSS does not decide which scenario to choose. Moreover, the DSS aims to provide insight into the various scenarios and their differences to find the trade-off that should be made. This will provide insight into which factors play a role in making a decision and their importance. Finally, the DSS aims to provide insight into what effects are involved when a particular scenario is chosen, allowing the municipality to take additional measures.

A case study is used to develop the Decision Support System. Amsterdam is chosen as a case study but only partially considered because the entire city would be too complex and time-consuming. As a result, the best scenario from the DSS is not necessarily the best option in practice because only part of the city is included. Also, not all aspects from the DMF and SD are included for simplification purposes. This is also unnecessary because the focus is on testing the method rather than the final result. This city area was chosen because it considers ongoing municipal projects; some bridges are currently under construction, while others will be soon. Since Witteveen+Bos is currently working for the Municipality of Amsterdam, information can be easily accessed.

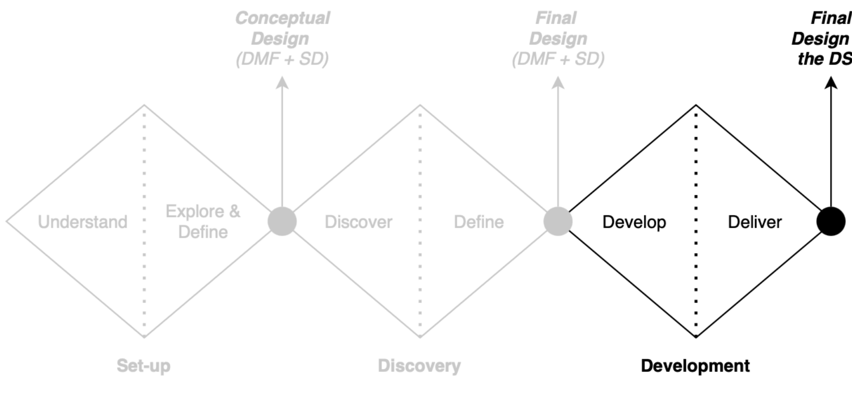

Figure 5.1: Diamond 3 of the ’Triple Diamond Approach’

This Chapter refers to the third diamond of the ’Triple Diamond Approach,’ as shown in Figure 5.1. The divergent nature will be shown in Sections 5.1, 5.2, 5.3, and 5.4, where the DSS is applied to the case study. Sections 5.5 and 5.6 relate to the convergent part, combining the key findings of the previous Sections.

First, this Chapter will discuss the outline of the DSS, explaining how the DSS is related to the Final Design (DMF + SD) and the Excel sheet of the DSS (Section 5.1). Next, the chosen case study area, namely the southwest of Amsterdam, will be explained in further detail in Subsection 5.2. Moreover, the designed DSS will be explained in Subsection 5.3. Next, five scenarios will be created, and these results will be discussed in Subsection 5.4. After that, in Subsection 5.5, recommendations for practical implementation will be provided. Finally, an expert evaluation will be given in Subsection 5.6.

5.1. Overview DSS

Figure 5.2 shows the steps involved in the DSS. This 'Overview DSS' shows how it is related to the DMF (blue), the SD (green), and the Excel sheet containing the DSS (turquoise). All steps are indicated with grey blocks. The light grey blocks show which information from the case study was included for each step. Consequently, this overview of the DSS (Figure 5.2) reveals how it relates to the theoretical part, as seen in the DMF and SD. As a result, the applicability of the DMF and SD in practice is presented.

Step 1 of Figure 5.2 involves deciding which bridges to include in the DSS. After step 1, the process splits off in two directions. In the first split-off, information is collected on a small scale per individual bridge, and an estimate is made per bridge as to which strategy might be a good option. In split 2, the relationship between the different bridges is looked at on a large scale (network level) instead of looking at each individual bridge. Next, these two splits come together while creating the scenarios, which are tested and compared in the final step.

Figure 5.3 shows the already designed DMF with the numbers indicating which parts are included in the 'Overview DSS' (Figure 5.2). Several blocks have not been given a number here. For example, the block 'policy of the municipality' of the DMF does not play a role at the moment, as a municipality does not currently run through it; however, the DSS does take into account that municipalities have different values for parameters, which will be explained further later. Furthermore, the 'choosing a scenario' block has not been implemented. As can be seen, scenarios are tested (block 8), but no choice is made in this. This is because the DSS is only used to support the decision and not to make it. However, these blocks should be considered in practice.

Which elements of the SD are included in the DSS is shown in Figure 5.4. The means of the SD are not explicitly included in the DSS but should be kept in mind when used. The means 'available money' and 'policy of the municipality' can be included since the values (e.g., the available budget and the Value of Time) can be adjusted in the DSS. Furthermore, all external factors and most criteria are included. The criteria 'livability' and 'sustainability' are not included because this is difficult with the available data. However, they are indirectly included. As shown in light grey under the dark grey block 'testing the scenarios,' the top four elements are related to the SD, i.e., to the strategy chosen for an individual bridge. The bottom three (early replacement, late replacement, and flexibility) are unrelated to the choice of an individual bridge regarding a strategy. These values come from classifying which bridge is addressed in which phase. However, an early and late replacement can be related to the criteria 'sustainability,' and flexibility can be linked to 'livability,' since flexibility is mainly about not overrunning the project, since the longer the project takes, the more extended inconvenience is experienced, which affects livability.

Figure 5.5 shows the DSS Excel spreadsheet, as will be explained in more detail in Section 5.3. This is a large excel sheet showing all the steps from Figure 5.2. These steps are indicated in Figure with a dashed black outline. For each frame, a turquoise arrow indicates which step of the 'Overview DSS' (Figure 5.2) it relates.

5.2. Case Study

Amsterdam is chosen as the case study, from which the information for designing the DSS will be derived. Since considering the whole city makes it unnecessarily complex, it was decided to focus only on the southwest. The aim is to design a DSS, not to decide for the Municipality of Amsterdam what decision they should make. The chosen case study area contains enough complexity, i.e., because several bridges are each other's alternative bridge, part of it is a shopping area, and multiple tram tracks are present. This complexity is desirable because it results in more findings.

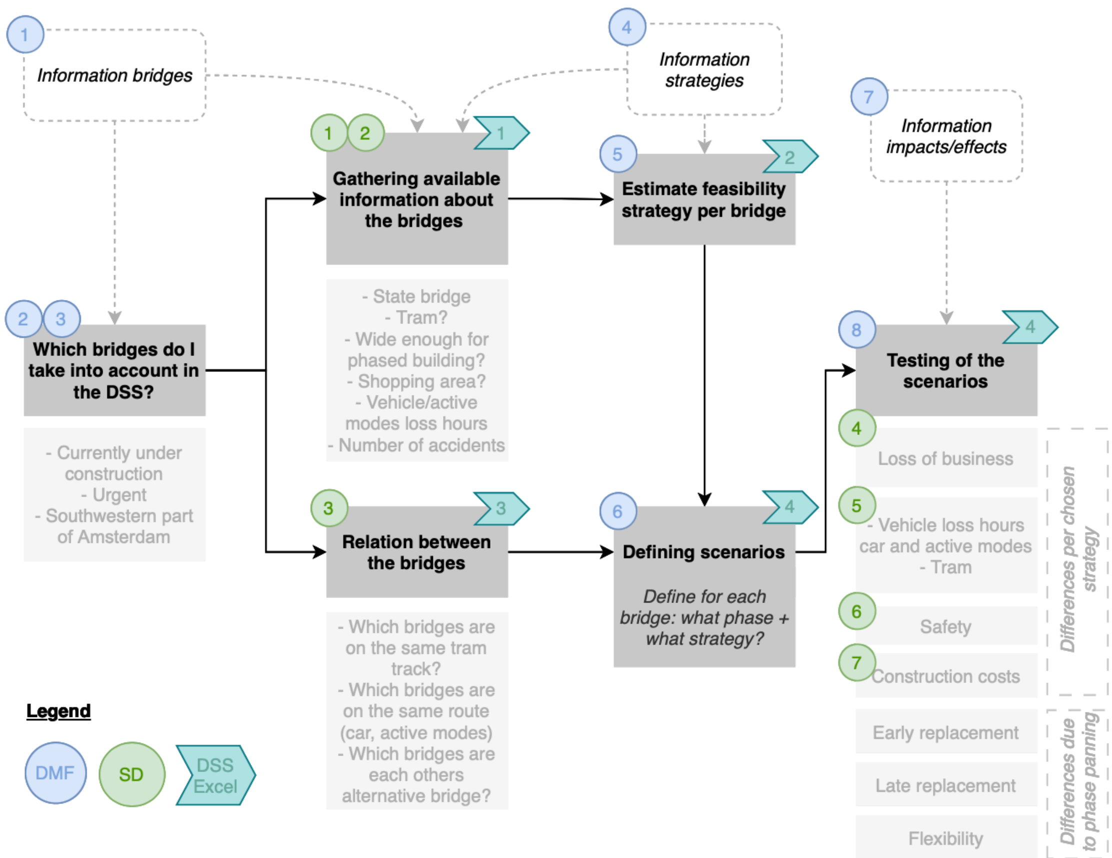

Figure 5.2: Overview DSS: relation with DMF, SD and Excel DSS

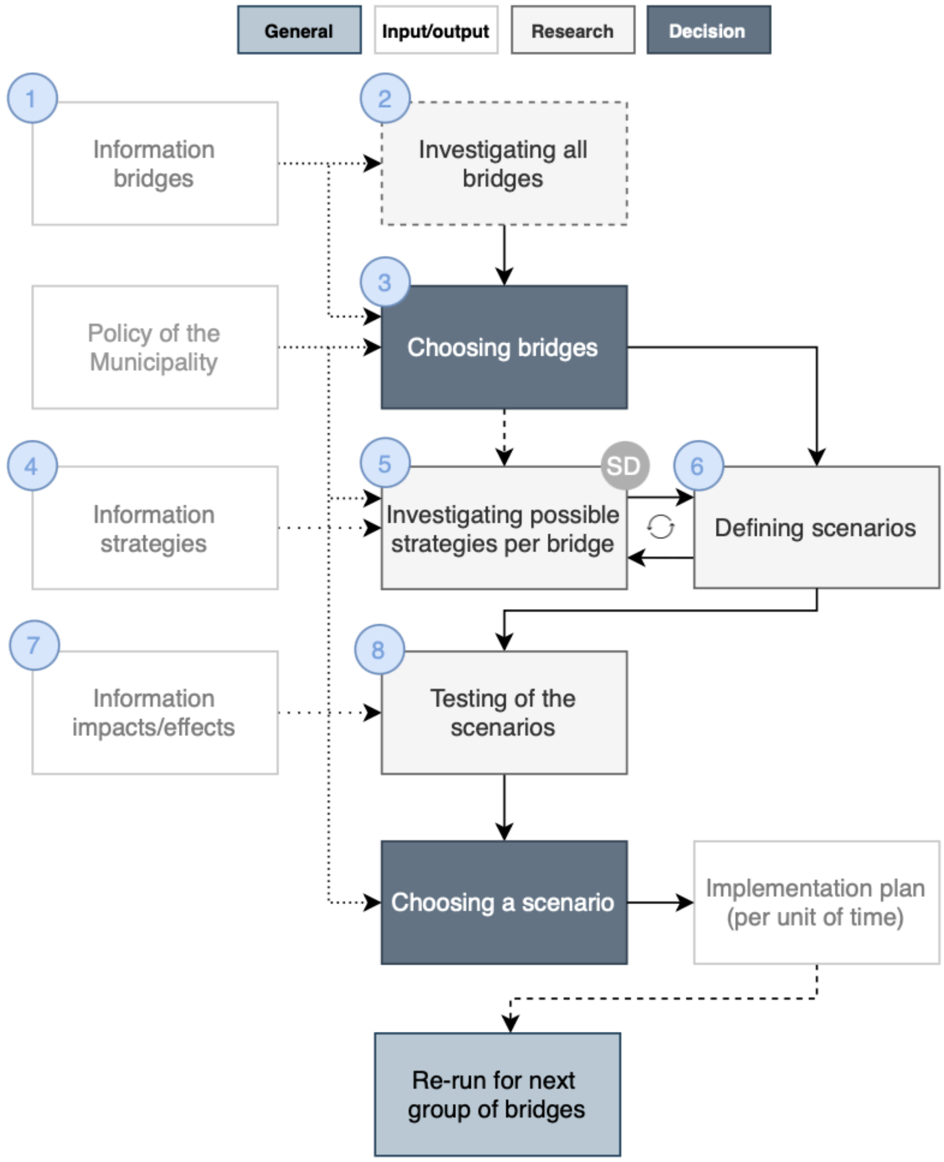

Figure 5.3: Parts of the DMF that are included in the 'Overview DSS'

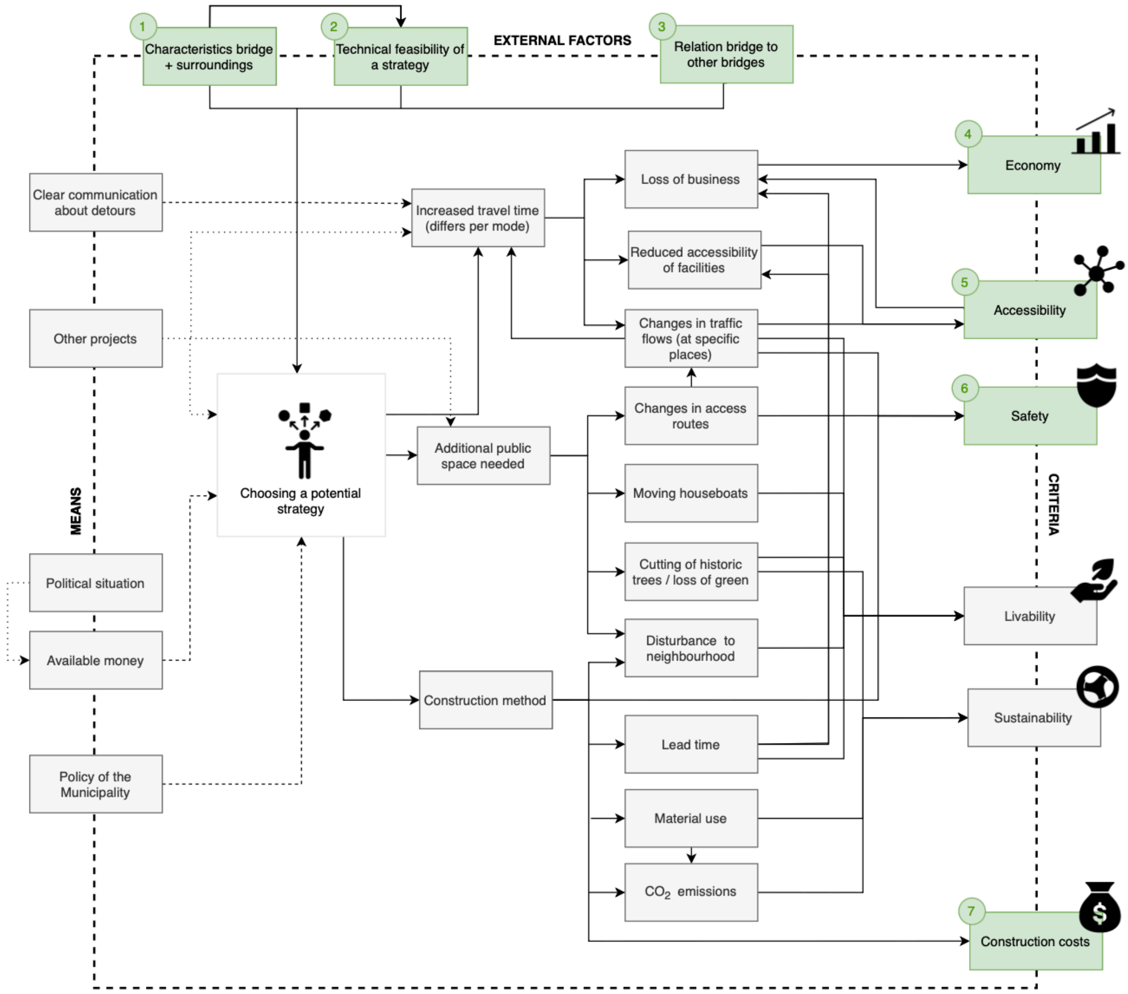

Figure 5.4: Parts of the SD that are included in the 'Overview DSS'

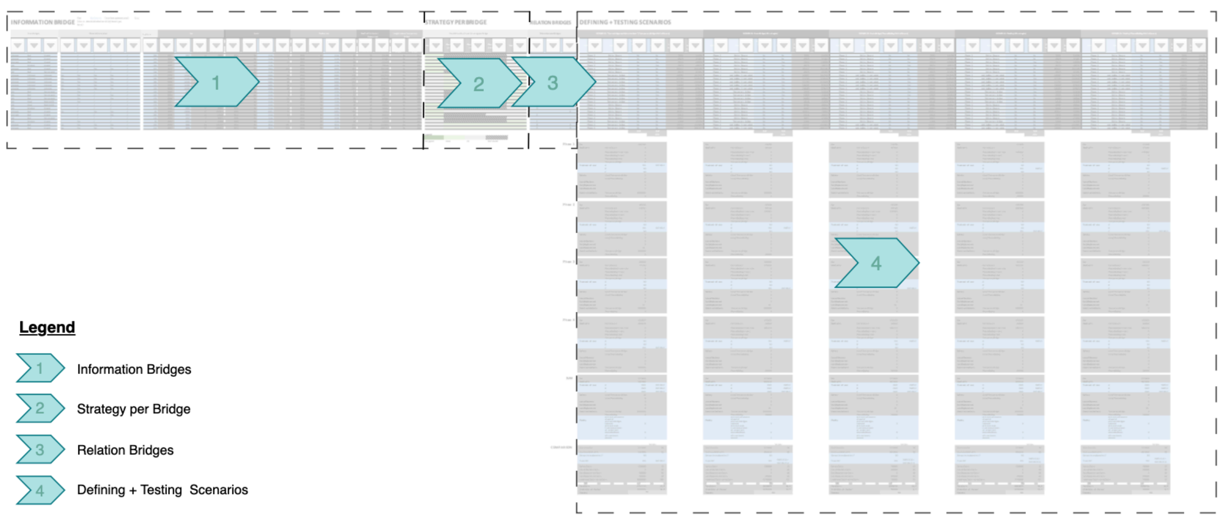

Figure 5.5: Parts of the DSS Excel that are included in the 'Overview DSS'

Figure 5.6: Case study area (background from Gemeente Amsterdam (2022a))

Figure 5.6 presents the area of the city that will be included in the case study. The 'Oranje Loper' and the 'Leidse Corridor' are present in this area. The 'Oranje Loper' is currently under construction, and the 'Leidse Corridor' is waiting for the work at the 'Oranje Loper' to be completed before work can begin here. Therefore, when looking at the area the municipality is currently working on, practical findings may be relevant to the municipality. Besides the bridges of the 'Oranje Loper,' only urgent bridges have been included, because it was discovered during the expert interviews that it is not convenient to replace non-urgent bridges.

In Figure 5.6, all bridges taken into account in the Project Bridges and Quay Walls (PBKA) are indicated with blue dots (Gemeente Amsterdam, 2022a). For all blue bridges within the case study area, urgent bridges were selected to be included in the decision-making. These bridges had received at least one critical rating (of the two ratings) according to the PBK Catalogue (Gemeente Amsterdam, 2022a). Highly critical bridges are indicated with red (two critical ratings), and slightly less urgent bridges (one critical rating) are marked with pink and grey. Furthermore, 'Oranje Loper' bridges are indicated in black; the condition of these bridges is unknown.

Furthermore, Figure 5.6 shows where the tram tracks run, which bridges are the alternative bridges of each other, and which bridges are on one route. It was discovered during the expert interviews that it could be helpful to use this to make intelligent choices in decision-making. In addition, it is indicated where the shopping area is located, which is necessary to determine the 'loss of business'.

5.3. Explanation DSS

Figure 5.2 shows the steps in the DSS. In this, the turquoise arrows indicate which parts of this are related to the DSS Excel spreadsheet in Figure 5.5. The Excel spreadsheet shown here is one of the four tabs that form the overall DSS Excel. Screenshots of the entire Excel file can be found in Appendix D. The DSS Excel consists of the following four tabs:

1. Introduction
2. DSS
3. Values of Parameters
4. Sensitivity Analysis

The first spreadsheet of the DSS is the introduction. In the introduction, an explanation is given about the use of the DSS. The introduction mentions, among other things, that all blue columns must be filled in using the drop-down menu. All grey columns are automatically calculated. This Section will first discuss the DSS (second spreadsheet), as shown in Figure 5.5. Then the values of the parameters will be discussed (third spreadsheet); these are the parameters used in the DSS and can be easily modified here. Next, spreadsheet four shows how changing these parameters affects the different scenarios' outcomes; this will be discussed in Section 5.4.

As shown in Figure 5.5 the DSS (spreadsheet 2) consists of several parts. First, information per bridge will be looked up in the 'information bridges' part (turquoise arrow 1). Then, using this information per bridge, an estimate will be made of which strategy might be a good option in the 'strategy per bridge' section (turquoise arrow 2). The 'relation bridges' Section (turquoise arrow 3) will show which bridges are each other's alternative bridges, are on the same route or the same tramway, as shown in Figure 5.6. Next, different scenarios will be created and tested in the 'defining + testing scenarios' section (turquoise arrow 4). When creating a scenario, each bridge will be assigned to a phase, and the strategy used will be indicated, for which the heading 'strategy per bridge' is helpful. All these parts will be explained in more detail below.

5.3.1. Information Bridges

The 'information bridges' part (turquoise arrow 1 in Figure 5.5) is split into three parts which will be discussed below. For every bridge included in the case study, information regarding the state, general information, and traffic will be presented.

State Bridges

As indicated earlier, only the bridges currently under construction ('Oranje Loper,' numbers 7-11) and the bridges with at least one critical rating (general high-risk rating and/or have 'bad' as the outcome of the dive inspection) were included. This overall risk assessment and dive inspection drew a conclusion for each bridge regarding its condition. All 'Oranje Loper' bridges have for both criteria state 'unknown' and therefore have 'unknown' as a conclusion. All other bridges have at least a general high-risk rating or a bad dive inspection. The bridge is 'very urgent' when both are high/bad.' When one of the ratings is 'medium' or 'average,' the bridge is 'urgent.' When, in addition to the high/bad risk rating, the bridge is rated 'good' in the other assessment, the conclusion about the bridge's state is 'Relatively OK.'

General Information

Furthermore, for each bridge, it is indicated with 'Yes' or '/' (No) whether the following elements are present. For every bridge, it is indicated whether a tram passes over it and whether it is an access route in/to a shopping area, using information from Gemeente Amsterdam (2022b). Furthermore, an estimate is made of whether the bridge is wide enough for phased building (tram and/or active modes); this was done by looking at Google Streetview to see how wide the bridge is and making a rough estimate on this. Furthermore, VIA Traffic Solutions Software (2022) was used to estimate the danger of the current traffic situation by looking at the number of accidents in the past; however, this did not reveal that any bridge was above average dangerous. To assess this, one should consider how busy a street is and whether there is a tram since both lead to a higher probability of accidents.

Traffic

As there was no access to suitable models, the costs related to loss hours of car and active modes were calculated manually per bridge, assuming the bridge would be entirely out of use. For calculating this, the detour time per bridge was multiplied by the intensity and the Value of Time.

This detour time was calculated using the distance to the alternative bridge and the mode speed. It was assumed that the distance to the alternative bridge should be traveled on average once. Suppose that there is good communication about which bridges are closed. In that case, a person can take a different route immediately, meaning the additional travel time is often short. It will rarely be necessary for someone to take the alternative bridge and then, after crossing the bridge, to be precisely on the other side of the closed bridge and thus cover the distance twice. Some people do not travel extra distances, and some double the distance to the alternative bridge. It has been assumed that thus on average 1/2*the maximum distance is traveled, which equals the distance to the alternative bridge once. Google Maps was used to determine the distance to the alternative bridge. However, congestion effects for car traffic occur in other places, but these have not been considered since a traffic model is necessary to determine this.

Determining the intensities for each bridge was done using BASEC (2022). However, data were only available for some bridges for cars and cyclists. The measurements of weekday and weekend days were available; the weighted average was taken from these. Data was taken from the most comparable bridge for bridges without data available. Also, there were no data on pedestrians. However, other places with pedestrian data were analyzed to see the ratio compared to the number of cyclists. As these corresponded fairly 1:1, it was assumed for the case study area that the intensity of pedestrians was equal to that of cyclists.

The value of time is used to translate the loss hours for car and active modes (cyclist + pedestrian) into costs. As shown in Rijkswaterstaat (n.d.), the Value of Time varies by mode and type of traveler. Additionally, the value of time increases over the next few years. Since only total passenger numbers are available and not per type of traveler, the Value of Time is assumed to be 15 euros per hour (in the default settings of the DSS). The consequences of a higher value of time, namely 30 euros, will also be discussed during the sensitivity analysis.

The right-hand columns show whether the costs related to costs of loss hours of active modes are higher than the costs of the temporary bridge, indicated with 'Yes' or 'No.' This column provides preliminary insight into whether a temporary bridge might be a good option. For example, when the costs of a temporary bridge are 3 million (as stated in Expert Interview A), the costs of a temporary bridge are higher than the costs related to loss hours of active modes.

5.3.2. Strategy per Bridge

In the 'Strategy per Bridge' section in the Excel, as indicated by the turquoise arrow 2 in Figure 5.5, which strategy might be a good option was estimated for each bridge. This was done using three criteria: whether the bridge is part of an access route to/from a shopping area, substantially more accidents compared to other bridges, and whether detour times are acceptable (detour time cyclist or pedestrian above the limit or 'costs Active Modes Loss Hours per Year > Costs Temporary Bridge?'). Points are awarded per bridge if it meets criteria linked to a strategy; from this, an estimation can be made for each bridge as to which strategy might be a good option. For example: When a bridge has no tram (/), is not an (access) route to/from a shopping area (/), has a low number of loss hours and detour time, and has substantially more accidents, choosing for entire closure might be a good option. The importance of the criteria can be changed and set by default to 1 (of equal importance). When a strategy is not possible, for example, because a bridge is too narrow for phased building or because a tram does not cross it (because then phased construction is not an option for the tram, as there is no tram) is also shown.

5.3.3. Relation Bridges

This 'Relation bridges' part relates to the turquoise arrow 3 in Figure 5.5. This part of the excel shows which bridges are alternative bridges of each other, which are on the same route, and which are on the same tramway, as shown in Figure 5.6. However, this is displayed again because it is essential to consider while creating the scenarios, as mentioned by the experts. For example, you do not want to tackle two bridges that are each other's alternative bridge at the same time, and preferably not the phase immediately after each other either, because when the first bridge runs out, the other has to wait.

Furthermore, tackling bridges on the same route in the same phase is advantageous. Closing an additional bridge only leads to a few more additional loss hours. Therefore, if bridges on the same route are addressed simultaneously, the costs related to the loss hours are multiplied by the discount factor (default at 0.8). This discount factor is determined as follows: when two bridges are closed one after the other, it can be argued that the car/active mode loss hours are halved (discount factor 0.5). However, closing two bridges, one after the other, will probably (depending on the situation) have a slightly greater impact on the detour times and traffic situation than a discount factor of 0.5. Therefore, the average between these two options is taken; option 1 is no discount (discount factor with value 1), and option 2 is a discount factor of 0.5. The average of these is 0.75, rounded to 0.8.

Bridges on the same tramway should preferably be maintained simultaneously, leading to the tram being out of use once. Moreover, using an intelligent phased building process, the tram can be out-of-use several times without too much inconvenience, but this requires complex planning.

5.3.4. Defining + Testing Scenarios

This Subsection is related to the fourth turquoise arrow in Figure 5.5. In this part of the excel the scenarios are created; every bridge is classified in which phase they will be tackled with which strategy. Creating the scenarios is preferably done by hand by first creating a map as shown in Figure 5.6.

As shown in the excel, in the ’alternative bridge chosen in same phase’ column, ’No’ must be entered for each bridge. If this is not the case, ’Not Valid’ will appear at the bottom, as this should not be the case anywhere. In addition, the ’discount’ column indicates which bridges are planned in the same phase on the same route, as these will receive the discount. Furthermore, for each scenario, the consequences regarding effects on cars, active modes, tram out-of-use, safety, early and late replacement, construction costs, and flexibility are calculated. All of these elements will be explained in this Section. The expert interview with Expert E revealed that everything should be put to costs to choose the best scenario. The quantification of these impacts was done roughly since this is about testing the methodology of the DSS rather than the exact outcome. However, recommendations will be made on how the final user (the municipality), should deal with this.

Car

The costs related to car traffic are determined by multiplying the vehicle loss hours by the Value of Time. In this DSS, all strategies are not accessible to cars; this was decided since it is probably not feasible for the bridges included in the case study and for simplifying the DSS. In the end, all bridges are entirely closed to car traffic once. Therefore, the only advantage that can be achieved is the simultaneous closure of bridges on the same route to take advantage of the previously mentioned ’discount.’

Active Modes

When calculating the costs related to the active modes loss hours, the costs are shown separately for each strategy. Showing this separately for each strategy minimizes the risk of error. For each phase, the strategy used to replace the respective bridges has been determined. For example, when ’entire closure’ is used for a bridge, the loss hours of this bridge are multiplied by the factor (factors are shown in spreadsheet 3) that indicates how many percent of the time the bridge is out of service (in the case of entire closure, this factor is one because it is out of service the entire time) and by the factor for ’additional time’ (in the case of entire closure, this is also one because this takes approximately one year).

When ’phased building (tram+active modes)’ and ’phased building (active modes)’ are chosen, the bridge is still accessible to active modes. Therefore, the loss hours per bridge are multiplied by a factor of 0.25 (since it is assumed that the bridge is not accessible only 25% of the time). However, ’phased building’ usually takes longer than entire closure. Therefore, the ’additional time’ factor of 1.25 is applied (factor 1 indicates 1 year, and hence 1.25 is 15 months).

Furthermore, for ’phased building (tram),’ a factor of 1 is applied, referring to the time the bridge is not accessible, which is the entire time since the bridge is only accessible for tram and not for active modes. Furthermore, the factor of additional time is also 1.25.

Concerning the ’temporary bridge’ strategy, the factor for what percentage of the time the bridge is not accessible is 0 (the bridge remains accessible to active modes throughout the period). The factor of additional time of 1.25 was applied. Since multiplication by 0 occurred, the costs related to active modes are set to 0. All these factors can easily be adjusted in their values in the 'Values of Parameters' spreadsheet in Excel, which will be explained later.

Tram out-of-use
Eventually, all bridges must be addressed, including those on tram tracks. When tackling all bridges on one tramway at once, a tramway only needs to be out of service once. If 'entire closure' is chosen for these tramway bridges, the tramway will be entirely out of service. However, if 'phased building (tram or tram+active modes)' is chosen for all bridges, the tramway is only partly out, which is more advantageous. As discussed later when creating the scenarios, assigning all bridges to one tramway at a time was quite feasible. However, in practice, this may not be feasible. Therefore, it might be preferable to choose phased construction, as this allows for smart phasing that minimizes disruption to the tram. Each phase indicates which tram is out and whether it is entirely or partially out. Finally, the 'sum' at the bottom shows how often a tram is out of service and whether it is entirely or partly out. This is not cost-related, as it is difficult to estimate. However, when comparing the scenarios, differences should be considered.

Safety
Expert interviews revealed that 'entire closure' is considered the safest option and that using phased building or a temporary bridge increases the risk of accidents. Therefore, this reasoning has been applied in the DSS. However, entire closure may not be the safest option in practice, as it may result in other areas of the city becoming very crowded and accidents occurring there. A 'point' is given for every bridge within a scenario where one of these relatively more dangerous strategies (phased building or temporary bridge) is used. The costs per point are set to 100,000.00 euros by default but can be changed in the third spreadsheet ('values of parameters').

Loss of Business
The interviews revealed different opinions on how 'loss of business' should be considered. In the DSS, this is included when a bridge in/to a shopping area has 'entire closure' as a strategy, putting the retailers in this area at a disadvantage. How often this occurs in a scenario is indicated with 'points,' as in the case of safety, to which costs are attached per 'point.'

Early Replacement + Late Replacement
Eventually, all 23 bridges should be classified. However, it is desirable to replace bridges in critical condition ('very urgent' and 'urgent') as soon as possible and those in relatively OK or unknown condition as late as possible. Costs are involved when a critical bridge is classified late since this potentially leads to accidents. There are also costs associated with renewing a 'relatively OK' bridge too early because it has a residual lifespan which is a waste. Moreover, bridges with unknown conditions should be postponed as long as possible until more is known about them; otherwise, they might be replaced too early. When bridges with state 'relatively OK' or 'unknown' are addressed in one of the first phases, there is no capacity for the (very) urgent bridges, leading to postponing these (very) urgent bridges.

In the spreadsheet 'Values for Parameters,' the punishment for addressing a bridge in a particular phase is given. The resulting number is multiplied by the cost, also presented in this spreadsheet.

Construction Costs
Ultimately, all bridges must be addressed with a strategy. However, specific strategies are more expensive than 'entire closure.' These additional costs required for phased building and a temporary bridge are presented here. In the default settings of the DSS, this additional cost of using phased building (gauntlet track) amounts to approximately 100,000.00 euros (J. de Leeuw, personal communication, December 19, 2022). The cost of using a temporary bridge is 2 to 3 million, as discussed in the interview with Expert A.

Flexibility
The 'sum' and 'comparison' headings are shown at the bottom for each scenario. In the 'sum' section, the above elements for the four phases are added together. Then, in the 'comparison' section, this is converted into the costs to make the different scenarios easily comparable. The heading 'sum' contains a new element: flexibility. Costs related to flexibility refer to the entire scenario instead of the phases

individually. The overall scenario gets points when it contains difficulties regarding flexibility. These points are translated to costs in the comparison part. A scenario scoring many points on flexibility increases the likelihood of higher costs and more time needed for the project.

Regarding flexibility in the planning, it is not desirable that the alternative bridges are scheduled the phase after each other immediately. For example, bridges 5 and 7 are each other's alternative bridges. When bridge 5 is assigned to phase 1 and bridge 7 to phase 2, this causes the bridges to depend on each other. When bridge 5 is delayed, bridge 7 also delays because work here can start once bridge 5 is completed, as both cannot be closed simultaneously. Moreover, it is advantageous for 'loss of business' not to have poor accessibility two years in a row (one phase is assumed to last one year).

Another aspect that should be taken care of is scheduling maintenance on bridges of different tramways. Although it is possible with phased building to ensure that multiple trams are not out simultaneously, it does add complexity to the planning, leading to potentially high costs and project delays.

Similarly to replacing the alternative bridge, one phase after another is not desirable; this is not desired for trams either. If tram line A is tackled in phase 1 and tram line B in phase 2, there is a possibility that they will have to wait for each other. Therefore, it is desirable to have at least one phase in between; tram A in phase 1 and tram B in phase 3 or 4. As there are three tram tracks and 4 phases in this case study, this can only be avoided partially, but it can be minimized by choosing, i.e., phases 1, 3, and 4 instead of 1, 2, and 3.

5.3.5. Values of Parameters

The parameters' values are easily adjustable in the 'Values of Parameters' spreadsheet. This makes the DSS adaptable to the respective municipality. In addition, parameters can be changed to see if different values lead to different best scenarios. Examples of parameters that can be adjusted are, i.e. the Value of Time, available budget, costs of a temporary bridge, costs of phased building, and the discount factor.

5.4. Results

Five scenarios will be created to determine whether the DSS works appropriately. This part will first discuss the five scenarios as created in Subsection 5.4.1. Then, these five scenarios will be tested against the criteria and the outcomes compared to each other in Subsection 5.4.2. Next, the sensitivity analysis will be presented in Subsection 5.4.3. This Subsection will reveal how the outcome of the DSS differs when other parameter values are used. Finally, these results will be discussed in Subsection 5.4.4.

5.4.1. Defining Scenarios

A total of 23 bridges were included in the case study. It was decided to divide them into four phases. Therefore, the number of bridges per phase corresponds approximately to the number of bridges that can be done in practice simultaneously, as revealed in the Expert interviews. Dividing 23 bridges into four phases resulted in five being classified in phase 1 and six in all other phases. Furthermore, it was discovered during the interviews that it is essential to make the optimal ranking for the entire portfolio; therefore, all bridges in this area within the scope are classified.

As presented in the expert interviews, an area-based approach was adopted, as only one area of the city was chosen. As further revealed in the expert interviews, when creating the scenarios, it was considered to opt for a combination of bridges on one main route with some 'single bridges.' After all, two main routes are not out of use simultaneously.

There are millions of possibilities for dividing 23 bridges into four phases. If all possible strategies for each bridge were included, this would lead to many more options. However, the constraints on scenario creation significantly reduce this number. In addition, the 'strategy per bridge' estimates per bridge which strategy might be a good option, further reducing the number of options.

Scenario 1 is the reference scenario; this scenario is relatively similar to the current programming in Amsterdam. The remaining four scenarios are good options considering the criteria being assessed. In drafting these, various (mandatory) constraints are taken into account, i.e., the replacement of bridges located on one route or tramway. Moreover, it has been taken care of which bridges are each other's

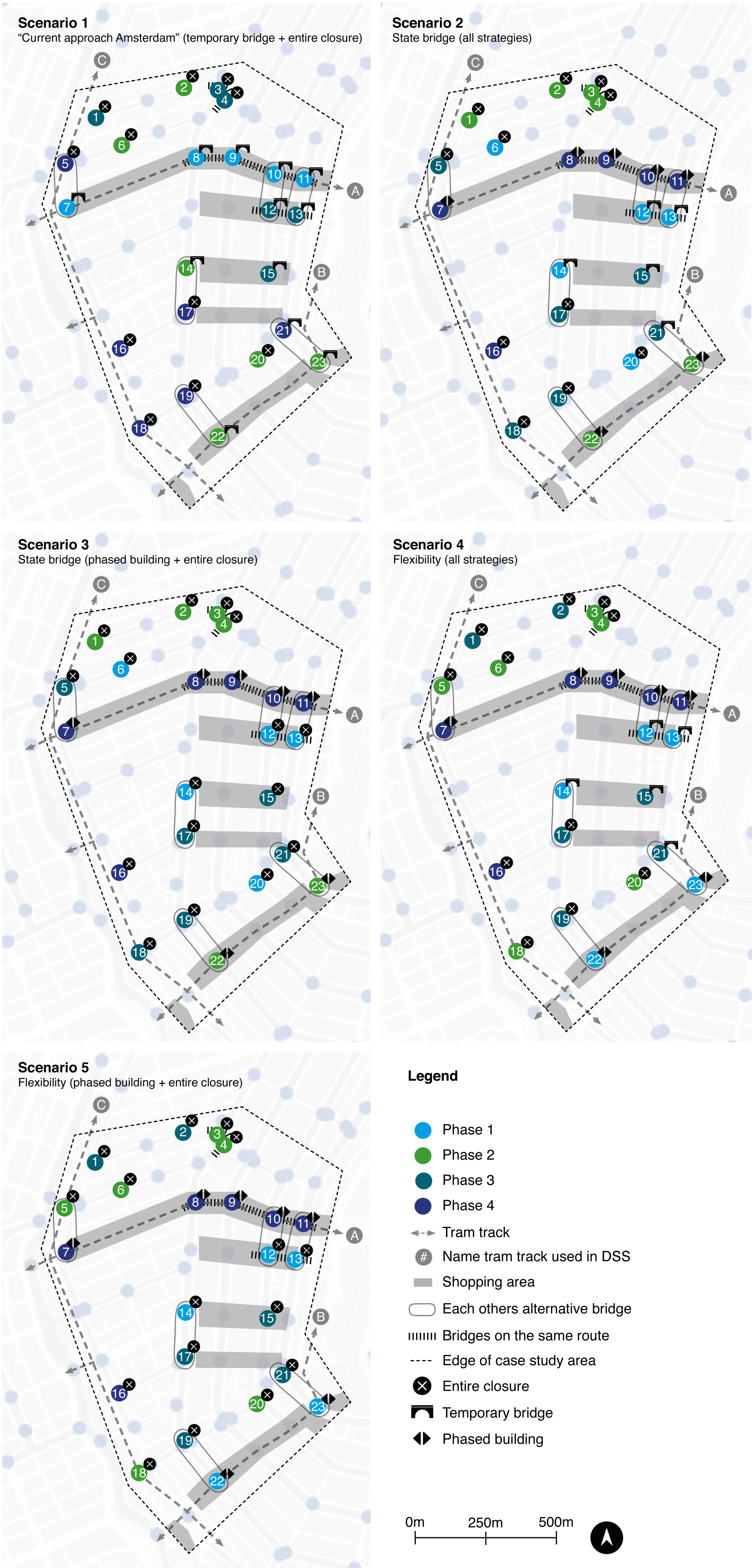

Figure 5.7: The five scenarios (background from Gemeente Amsterdam (2022a))

alternative bridges by addressing them, at least not at the same time (required) and preferably with a phase in between. Moreover, the bridge's urgency is considered; 'very urgent' bridges are prioritized in phase 1 and otherwise in phase 2. 'Urgent' bridges, preferably in phase 1 or 2 as well. Figure 5.7 shows which bridge in which phase will be addressed with what strategy.

Scenario 1

The first scenario is relatively similar to how Amsterdam is currently proceeding and can therefore be seen as the reference scenario. First, the 'Oranje Loper' (bridges 7-11) was scheduled, whose bridges have an unknown condition, whereafter the bridges of the 'Leidse Corridor' (bridges 22+23). Furthermore, in terms of strategies; temporary bridges, and entire closure have been used a lot in practice by the municipality and are therefore chosen in this scenario. The expert interviews revealed that entire closure is a preferred option and that temporary bridges are frequently used in this part of the city.

Scenario 2 + 3

While creating scenarios 2 to 5, a trade-off must be made between scheduling the bridges with the best possible consideration of residual life or the most flexible planning; considering both in one scenario is impossible in this case study. Scenario 2 has the bridge's state as its main principle, putting planning flexibility in second place. Indeed, expert interviews revealed that the bridge's state is a logical starting point. All strategies are applied in scenario 2. However, the excel revealed earlier that the cost of the temporary bridge does not outweigh the cost related to active modes loss hours. For this reason, in scenario 3, only entire closure and phased building are applied. The results of the 'strategy per bridge' part are used to decide which of these two strategies fits best. The decision about in which phase a bridge is assessed is identical to scenario 2.

Scenario 4 + 5

For scenario 4, the flexibility of the planning is the main principle, placing the state of the bridges second. For scenario 4, the same strategy was chosen per bridge as in scenario 2 (i.e., all different strategies are used). In scenario 5, only entire closure and phased building are applied, which are the same per bridge as in scenario 3. For scenarios 4 and 5, the decision concerning which phase a bridge is assessed is the same.

5.4.2. Testing and Comparison of the Scenarios

The comparison (at the bottom of the 'Defining and Testing' section, turquoise arrow 4) shows a scenario's total costs, which also explicitly indicates the out-of-pocket costs. The municipality must be aware that choosing the cheapest scenario in terms of total costs may have high out-of-pocket costs, which must comply with the available budget. The set available budget from the municipality in the spreadsheet 'values of parameters' indicates whether the scenario is feasible. The feasibility of the scenario is shown with 'Yes' or 'No'. Figure 5.1 shows the results per scenario when the scenarios are created using the 'default' settings. First, general findings will be discussed. Moreover, the scenarios will be compared.

General

The costs related to car loss hours are equal for every scenario. The reason for this is that no scenario is accessible by car. The only advantage for minimizing the car loss hours is replacing bridges on the same route, which is done in every scenario. Furthermore, it was discovered that scenario 5 has the lowest total and out-of-pocket costs. Scenario 3 emerges as second-best with hardly any difference. Both have the highest costs for loss hours of active modes, but this difference is minor compared to scenarios 2 and 4.

Scenario 1 <> 2 + 3 + 4 + 5

There is a significant difference between scenario 1 and the remaining scenarios regarding the cost of loss hours of active modes. It is the lowest in scenario 1 due to the high use of temporary bridges. However, the total costs, as are the out-of-pocket costs, are ultimately the highest. Indeed, as previously seen in the DSS excel, the costs for a temporary bridge do not outweigh the costs for the active modes' loss hours. Because all other scenarios score better on almost all other criteria and total cost, adding the constraints leads to better outcomes.

Legend → Worst *(highest value)* | Medium | Best *(lowest value)* — *Note: all values are in millions of euros*

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Costs Loss Car	3.8	3.8	3.8	3.8	3.8
Cost Loss Active Modes	5.4	8.9	9.9	8.9	9.9
Detour times above Limit?	NO	NO	NO	NO	NO
Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
Safety Costs	1.2	1.2	0.7	1.2	0.7
Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
(Additional) Construction Costs	36.0	15.7	0.7	15.7	0.7
Flexibility Costs	0.1	0.4	0.4	0.1	0.1
Total costs:	47.9	30.2	16.2	30.0	16.0
Of which 'Out-of-Pocket'	36.0	15.7	0.7	15.7	0.7
Feasibility	NO	YES	YES	YES	YES

Table 5.1: Comparison of the five scenarios

Scenario 2 <> 3
Scenarios 2 and 3 differ only in terms of the strategies chosen; for both, all bridges were assigned to the same phase. When classifying the bridges into a phase, the residual life of the bridges was used as the main principle. Using temporary bridges in scenario 2 leads to the lowest costs for active modes. However, the safety costs are higher, as are the construction costs. In scenario 3, however, the loss of business costs are slightly higher because there is a complete closure in a shopping area since, in this scenario, temporary bridges are no longer used. All other elements are equal between these two scenarios. In the end, the total costs for scenario 2 are slightly higher. Nevertheless, since this difference is relatively small, a trade-off can be made between the criteria, for example, whether it is worth having higher total costs and increased accessibility for active modes.

Scenario 4 <> 5
Scenarios 4 and 5 differ only in chosen strategies. In both scenarios, all bridges are classified into the same phase. For this classification, flexibility in planning was used as a starting point. As mentioned for scenarios 2 + 3, the only difference between 4 + 5 is temporary bridges. This leads to lower active modes costs but higher safety costs for scenario 4. In scenario 5, however, the loss of business costs is slightly higher due to the strategy entire closure in a shopping area. Ultimately, this leads to the lowest costs in scenario 5. Similar to scenarios 2 + 3, a trade-off can be made on whether higher total costs are worth having better accessibility for active modes.

Scenario 2 + 3 <> 4 + 5
When scenarios 2 + 3 are compared to scenarios 4 + 5, the differences are minimal. Indeed, scenario 4 + 5 includes late replacement costs, resulting from not considering the bridge condition as the main starting point. Moreover, for scenarios 2 + 3, the flexibility costs are higher since the condition of the bridges was the starting point. Therefore, given these default settings, scenario 5 appears superior. However, the difference with scenario 3 is minimal. Therefore, it is not possible to conclude which starting point (flexibility planning or state of the bridge) is more advantageous.

5.4.3. Sensitivity Analysis

The purpose of this sensitivity analysis (spreadsheet 4) is to examine the effect of different parameter values on the outcome of the DSS. As shown in Figure D.15 and D.16 of Appendix D, a total of five different analyses were performed. The first analysis contains the default settings whose results have just been discussed. The remaining four analyses will be discussed.

The parameters in analysis 2 have been modified so that a temporary bridge is more favorable. The value of time has been increased (which may be the case in Amsterdam), and the costs of the temporary bridge have been decreased to 2 million instead of 3 million (costs are, in fact, 2 to 3 million). Furthermore, the costs of phased building are increased. However, these changes still lead to scenarios 5 and 3 as the best options, although the outcomes of the scenarios are slightly closer to each other.

When the costs for flexibility increase in analysis 3, Scenario 5 is still the most favourable. However, regarding the second-best scenario, which is the best is debatable. When considering the total costs, scenarios 1 and 4 score well, but the total costs of scenario 3 are close to these and have much lower out-of-pocket costs. Therefore, a trade-off needs to be made.

In analysis 4, the default settings are applied along with a few changes. Sine livability is considered the priority; this leads to high safety and 'loss of business' costs. Therefore, both criteria (safety and 'loss of business') are set at 2 million. Scenario 5 is found best again, followed by scenario 3.

In analysis 5, the costs for early and late replacement are increased. This is investigated since it can be argued that early and late replacements are undesirable. Furthermore, the costs for the temporary bridge are set at 1 million. The costs of a temporary bridge are lower since the costs might be lower due to re-use. This leads to scenario 3 as best and scenario 5 as second best. This is explained by the fact that scenario 3 has the bridge's condition as the main starting point, which is considered very important in this analysis. The total costs of scenarios 2 and 4 are only slightly higher compared to scenarios 3 and 5. Furthermore, the out-of-pocket costs are relatively low compared to the other analysis since using a temporary bridge has become cheaper.

From this sensitivity analysis, it can be concluded that changing the parameters does not lead to a completely different outcome. In the case of these scenarios, scenarios 3 and 5 are close to each other and always the best options considering total and out-of-pocket costs. That these two scenarios consistently outperform means that these are stable solutions. Depending on the parameter values, which of these two is best varies. Another scenario may be better when more scenarios are created, additional criteria are added, and/or the parameter values are changed.

5.4.4. Discussion Results

In this case study, the Decision Support System (DSS) found scenario 5 to be the best option considering the total and out-of-pocket costs, based on the boundaries, criteria, and assumptions set forth. However, if the active mode costs are deemed particularly important, a different scenario may be chosen since scenario 5 scores worst on this criteria. Therefore, the DSS also highlights the trade-offs.

When creating scenarios 2 to 5, a trade-off between flexibility and residual life had to be made. If even more scenarios were created, other trade-offs might emerge, i.e., replacing bridges on one route versus the residual life of another bridge.

Several impacts have been included in the DSS to show the consequences of choosing a particular scenario. However, not all criteria from the SD are included. Likewise, the included criteria differ in detail and reliability, depending on available data on these and the ability to quantify them. Some criteria are difficult to quantify; therefore, their values are estimated (e.g., safety, loss of business, early and late replacement, and flexibility). These values may be adjusted by the municipality when further research is conducted. In addition, the only constructional criteria included are whether a bridge is wide enough, although other requirements should be considered as well.

Since many more factors play a role in practice, estimating which strategy is possible per bridge takes longer. Moreover, this will lead to fewer possible strategies per bridge, reducing the number of possible scenarios. In addition, when the DSS is applied, other essential elements such as cables and pipes, other projects, and accessibility for emergency services should be considered, which are currently excluded for simplification reasons.

The costs related to the loss hours of car and active modes were calculated using the intensities, distance to the alternative bridge, and the Value of Time. The distance to the alternative bridge was taken once. However, this may still lead to an overestimation in the loss hours. After all, one may not make a trip anymore, make the trip less often, chooses a different destination or a completely different route. This leads to little or no additional travel time due to the bridge closure. Since it is not feasible to calculate the loss hours accurately by hand, it is recommended to use a traffic model. Overestimation of the loss hours leads to the temporary bridges being less feasible.

Furthermore, the active modes intensities may not be entirely accurate, and when they turn out to be higher in practice, temporary bridges may be a good option for some bridges. However, despite these limitations, the DSS still provides insight into the consequences of choosing a scenario and comparing the scenarios.

Moreover, the discount of multiple bridges on a route is set at 0.8 but may be lower in practice. However, this does not lead to other best scenarios. In practice, municipalities often have a model that can be used to determine loss hours, eliminating the need for this discount factor. From a personal conversation with K. Zantema (personal communication, November 16, 2022) and R. Verweij (personal communication, November 16, 2022), two experts of the Municipality of Amsterdam from the traffic department, it was discovered that the Municipality of Amsterdam has two traffic models. The use of the simplified variant, namely the Urban Strategy Tool, was tried for this thesis, but there were many technical problems, and it was only for car traffic. Therefore, it was chosen to do the calculations manually. When a municipality starts using the DSS, it is recommended to determine the loss hours of all modes with a good model, in which, for example, congestion effects and disappearing traffic are also taken into account. Other places in the city could become very busy, possibly leading to safety risks, which should be considered as well. Furthermore, additional vehicle loss hours might increase or decrease when multiple bridges are closed simultaneously. A model in which several bridges can be closed simultaneously is therefore desirable. Despite its high run times, the municipality's other model (besides the Urban Strategy Tool) may be more suitable.

Moreover, a 'point' of flexibility is linked to costs. In practice, this is likely a percentage of the total costs. Additionally, flexibility costs are a probability of having to spend money.

In the DSS, all tramways are equal. However, they could be implemented more accurately in the DSS by examining which ones are more frequently utilized (considering the intensity of people using the trams and the number of trams per hour). This can be examined using a public transport model. Indeed, it is more desirable for a busier tram to apply phased construction than for a quieter one. Furthermore, it can be investigated whether running a tram up to a closed bridge and using this as a transfer is beneficial.

Currently, there is no strategy in the DSS with car and truck accessibility. Car accessibility does not necessarily need to be added as most Dutch cities want to move towards a car-free city. Nevertheless, accessibility for trucks could be investigated. Another strategy that could be considered is the combination of a temporary bridge and a phased building process.

5.5. Recommendation on Practical Implementation

From this case study, the output of the DSS consists of the following elements: a picture with the different scenarios, a table with a score on the criteria for each scenario, and then a sensitivity analysis. The municipality is recommended to realize these deliverables as well. Since the municipality is recommended to proceed slightly differently, the differences between this case study and the practical implementation are shown in Table 5.2.

		Case Study	**In Practice**
Scope		Part of the city	Entire city
#scenarios		5	10+
SD	*Means*	/	Taken into consideration
	External Factors	Simplified	Well researched
	Criteria	4 of 6	6 of 6
DMF		Not all steps	All steps
#sensitivity analysis		5	10+

Table 5.2: Comparison of the DSS in the 'case study' and 'in practice'

Table 5.2 shows that the entire city has to be included when the DSS is applied in practice. This leads to at least ten scenarios being created depending on the situation. Creating more scenarios is recommended due to the larger number of bridges included. When more bridges are included, the number of possible scenarios increases.

Table 5.2 also presents the relation between the edges of the SD and the DSS. As shown in Figure 5.4, the means of the SD (left-side edge) are not explicitly included in the case study, but should be considered when using the DSS. The external factors of the SD have all been included but in a simplified way. In practice, these need to be investigated further (e.g., the constructive feasibility of the strategies). Regarding the criteria of the SD (right-side edge), only four out of six were included in the case study. In practice, all criteria should be included. Because more aspects need to be considered in practice, it can be challenging to arrive at ten good scenarios. However, looking as broadly as possible and exploring as many different scenarios as possible is recommended, to ensure all options are considered.

Moreover, the DSS incorporates the main steps of the DMF, as shown in Figure 5.3. Therefore, the remaining steps (e.g., 'choosing a scenario') must also be considered when applying the DSS in practice.

Five different sensitivity analyses were made in the case study. In each analysis, the values of different parameters were tested. In practice, more criteria are taken into account, and at least ten scenarios need to be made. Therefore, performing at least ten sensitivity analyses is recommended. Nevertheless, this depends on the situation and the certainty about the values of the parameters. Furthermore, it is recommended to conduct further research on the values being part of the trade-off, especially when these values are uncertain and/or have a high share in the total costs.

5.6. Evaluation by Expert

With an expert working as Process & Contracts Manager in the scope of Witteveen+Bos at the PBK (J. de Leeuw, personal communication, January 23, 2023), the DSS was evaluated in a short expert interview. This evaluation considered whether the DSS is correct and the feasibility of usage in practice. There is no summary of this in the Appendix. However, an approved summary concerning the main elements can be found in this Subsection.

During this discussion, it was discovered that the DSS reflects well what the decision should look like from a rational perspective. Apart from some minor content comments regarding usability (which have been adjusted), the DSS proved to be a suitable tool. J. de Leeuw noticed that it is essential that in the sensitivity analysis, changes in parameters do not suddenly change the advice. It is also valuable that conclusions can be drawn from the DSS; this leads to valuable insights, for example, about the detour time being too short for the wise use of a temporary bridge.

As a recommendation for future Decision Support Systems, J. de Leeuw indicated that it would be helpful to investigate further the costs related to a point of 'safety,' 'loss of business,' 'early replacement,' 'late replacement,' and 'flexibility,' which entire studies in terms of complexity. Looking at the 'sum' part instead of the 'comparison,' these can also be weighed appropriately without being converted into euros. Furthermore, the content of the DSS can be further improved, i.e., by incorporating automatic checks to prevent the possibility of errors. Especially with many bridges, the DSS can otherwise become very error-sensitive.

J. de Leeuw mentioned that the DSS is a rational approach to decision-making. Nevertheless, some other factors in Amsterdam play a role in the decision-making that are not captured in this model, which is why this model is presumably not applied in Amsterdam. For example, the municipality considers accessibility for cyclists and pedestrians enormously important; during the construction of the North-South line, a 3-minute detour time for cyclists was already unmentionable. Because the municipality prioritizes bicycles, it would be a better investment to make the city bike-friendly, i.e., by providing short wait times for cyclists at traffic lights. Waiting at a traffic light is acceptable, but detouring when a bridge is closed is, for some reason, problematic. Furthermore, providing a bike-friendly city is a better long-term investment.

Moreover, the Municipality of Amsterdam is taking everyone involved in the project seriously, therefore, everyone's opinion is included. However, this leads to expensive decisions with little added value.

6 Conclusion, Discussion and Recommendations

In this thesis, a Decision Support System (DSS) was designed. This was achieved by using the 'Triple Diamond Approach.' First, a Conceptual Design was created through literature research and observational studies, consisting of a Decision-making Framework (DMF) and a System Diagram (SD). The findings of expert interviews were used to modify the DMF and SD, resulting in a Final Design. Additionally, expert interviews provided the information needed to design the DSS. After this, the Decision Support System was developed using the theoretical basis of DMF and SD. Finally, the DSS was designed using a case study, namely the southwest part of Amsterdam. In the end, the DSS has been evaluated by one expert.

In this Chapter, a conclusion and discussion will be presented. Finally, recommendations will be given.

6.1. Conclusion

The unstructured decision-making approach currently used in Amsterdam has not considered multiple options. Additionally, in the current programming, only several factors have been taken into account. Consequently, this programming has resulted in massive costs and project delays. Furthermore, from the literature review, it can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities. Besides Amsterdam, this decision is also an issue in other Dutch cities. If no support is provided, every municipality has to make its own decisions. Since it is essential to make an informed decision, there is a need to develop a method to look at decision-making in an integral and systematic sense. Therefore the aim of the study was:

" Designing a Decision Support System to provide insight into the decision-making for bridge programming for Dutch Municipalities "

This study designed a DMF, SD, and DSS, solving the gaps as stated in Section 1.2. First, the DMF solves the theoretical gap about how decision-making should be done. The DMF highlights the crucial steps that need to be taken to make a good decision and what is required as input. The DMF also shows how the large scale of the entire city relates to the small scale of the individual bridge. In addition, the SD solves the second theoretical gap by providing a clear overview of what effects play a role in choosing a potential strategy for an individual bridge and the interactions between these effects. Finally, the design of the DSS partly solves the methodological gap by measuring these effects.

The designed DSS can support a municipality in making decisions. It also provides insights into decision-making as it presents a broad picture of the whole situation in the city and how the many elements involved in the decision-making are related. Current decision-making in Amsterdam only considers a few factors (e.g., tram accessibility and active modes), while the DSS considers more factors (e.g., costs, safety, and residual life of bridges). The designed DSS provides a broader view than the current decision-making; however, some aspects of the DMF + SD still need to be implemented to arrive at a complete view. Moreover, the DSS has some simplifications and limitations, as further explained in the discussion. However, the DSS clearly shows how this method works and offers insights. Finally, the DSS provides a systematic and user-friendly approach for municipalities to think about their decision-making. The DSS supports the decision for municipalities by showing the consequences of each scenario. Note that the DSS does not decide which scenario should be chosen. Instead, the DSS investigates various scenarios and their differences to provide insight into what factors play a role in the decision-making and the trade-off in criteria that should be made. In the most complex decisions, trade-offs must be made between criteria, such as accessibility and cost. By identifying these trade-offs, the municipality's policy can be evaluated according to the criteria between which there is a trade-off. This shows the municipality which criteria play a critical role and need to be considered. For instance, a municipality has to determine which criteria they consider most important and how much they are willing to spend on this. By showing the costs related to the criteria, the DSS reveals between which parts the trade-off should be made and how difficult this decision is. For example, in this case, the difference between scenarios 1 and 5 in active mode costs is only a few million. In contrast, the difference in total costs is several tens of millions. Therefore, making this choice would be relatively easy. However, it is more complicated when the difference in total costs would also be only a few million. Moreover, creating multiple scenarios ensures the user looks broadly and considers multiple options. However, due to the user-friendly nature of the DSS, municipalities are motivated to take a critical look at their decision-making. The products created (DMF + SD + DSS) make municipalities aware of this problem and show how their current decision-making relates to theory. Therefore, the DSS translates theory (DMF + SD) into practice (DSS). Finally, the DSS provides insights into what effects are involved when a particular scenario is chosen, allowing the municipality to take additional measures.

The designed DSS is plausible and leads to meaningful insights into decision-making, as can be concluded from the expert evaluation. However, other choices are made in Amsterdam, which means that unobserved factors, not included in the model, play a role in the decision-making process in Amsterdam. Therefore, the Municipality of Amsterdam will probably not use the DSS. Moreover, the DSS might be used by other municipalities where it does match their decision-making.

6.2. Discussion

This Section will provide information on the limitations of the research and a reflection on the DSS.

6.2.1. Limitations of Research

In the previous Chapter (Subsection 5.4.4), there was an extensive discussion of the results and the simplifications in the DSS. Therefore, this research has been limited since not all elements from the DMF and SD were included in the design of the DSS. Furthermore, only a small part of the city was used in the case study. These choices were made because, otherwise, it would be too time-consuming. When the DSS is applied in practice, several steps need to be done differently from the case study, as discussed in Subsection 5.5 in the previous Chapter. Since no models were used and many assumptions were made for the calculations, these need to be further examined when the DSS is used to make a decision. For example, it is necessary to use a traffic model to calculate vehicle loss hours for closing an individual bridge and multiple bridges simultaneously.

In all expert interviews, new findings continued to emerge. Doing more interviews would have led to more information. To what extent this extra information would lead to other outcomes is questionable. The experts often had the same opinion about the DMF and SD. Therefore the design of these two frameworks would probably mostly stay the same when more interviews are conducted. Since the DMF and SD were used for the design of the DSS, it would probably not change to any great extent either.

Multiple expert interviews were conducted at the Municipality of Amsterdam. However, the Municipality of Amsterdam is quite exceptional compared to most other Dutch municipalities, as it is much larger, and other factors play a role. Thus, the difference with the Municipality of Delft was already evident in the expert interviews. Looking at other municipalities besides Delft, i.e., Gouda and Utrecht, could lead to a DSS where specific parameters are given a fixed value, and the preference for a specific strategy can be highlighted. Therefore, the fact that no interviews were conducted with more municipalities besides Amsterdam and Delft is not so much a limitation on the DMF and SD but mainly on the values of the parameters in the DSS.

The theoretical basis of the DMF + SD was used to design the DSS. In this SD, the consequence of choosing a particular strategy is represented as a linear process that has to be rerun per potential strategy per bridge. This is a limitation as, in practice, this process contains feedbackloops so that it is only run once per bridge. Furthermore, the SD criteria are shown as separate elements without interaction. However, in practice, the criteria also affect each other (i.e., accessibility affects livability), further complicating the process. Furthermore, some criteria are more overarching than others, while they appear to be equal in the SD. For example, accessibility affects the economy, which can be seen as a final criterion. For the designed DSS, this matters little, but it should be taken into account when it is further developed that criteria are only taken into account once.

6.2.2. Reflection on DSS

From the expert evaluation (Subsection 5.6), it was discovered that the DSS is unlikely to be applied in Amsterdam, as choices are made based on factors not considered in the DSS. Moreover, this decision is often made by instinct without considering multiple options. In addition, the expert interviews revealed that both the municipalities of Delft and Amsterdam are satisfied with their current decision-making, making it questionable whether they see the usefulness of a DSS.

As mentioned in Subsection 1.5, DSSs are often not or hardly used in practice because it is challenging to generate a good set of scenarios, and using a DSS takes a lot of effort (Uran and Janssen, 2003). Also, several limitations about DSSs were listed by Management Study Guide (n.d.) difficulties in finding and quantifying data, being aware of assumptions, and knowledge of decision-makers about technology. Moreover, the disadvantages were that a large amount of information makes it difficult for decision-makers to filter out useful information, decision-makers no longer think for themselves, and subjectivity can be lost. Furthermore, as is going to be discussed in more detail in Subsection 6.3, it is indeed challenging to arrive at good scenarios when a large number of bridges need to be included. Moreover, it can be difficult for the municipality to implement the still missing elements, as discussed in Subsection 5.5. Nevertheless, the designed DSS is as transparent and user-friendly as possible, minimizing these drawbacks and limitations as much as possible.

Despite the drawbacks, the DSS has the potential to help municipalities with their decision-making. The designed DSS can help to think carefully about creating and comparing different scenarios. When the municipality arrives at a good decision, it leads to a reasonable expenditure of public money, and the city is as enjoyable as possible during a maintenance project. By providing insight into the effects of choosing a scenario, appropriate measures can be taken.

When the DSS is applied in practice, it will lead to new insights. In this study, for example, personal conversations revealed that flexibility in planning is essential, something that did not emerge in theory. Therefore, applying the DSS in practice is essential, leading to new insights and improvements.

This thesis aimed to make the DSS generically applicable. Therefore, this DSS can be used for any city, but depending on the situation, the DSS should be adapted, making it more or less complex. When applied to a less complex city (e.g., no cables and pipes in bridges and no tram), fewer adjustments must be made. Since the DSS was created for a few bridges, it is easily adaptable to cities with a similar number of bridges, compared to making it adaptable for the entire city of Amsterdam.

This DSS can also be used for other city maintenance projects with some modifications. Including, for example, road closures or maintenance of quay walls. The main difference is that a bridge can be seen as an essential street, as it is one of the limited crossings over the water. Moreover, it has another transport flow under it, namely the waterway. Moreover, a bridge is more structurally complex than a street, and multiple strategies are possible for a bridge. In contrast, this is different for a street, leading to a simplified decision-making process.

6.3. Recommendations

In this Section, recommendations for municipalities and further research will be given.

6.3.1. Recommendations for Municipalities

The first recommendation to the municipalities is to gather data on the condition of the bridges, which in many cases has yet to be discovered. However, it is essential to know the bridge's condition before replacing it. This prevents unnecessary early replacement and helps identify high-risk bridges in time. As this information changes over time, it must be updated repeatedly in the DSS.

As more reliable data becomes available, the values of the criteria differ, leading to a different outcome of the DSS. As transport costs account for a large share of total costs, it is essential to use a transport model, given the availability of these and within the municipality's capacity (budget and time). The priority for figuring out detailed data for the criteria that play a small role is less critical since this would probably not lead to a different outcome of the DSS.

When using the DSS, the municipality should also take care of the values of the parameters since these are set to default. Furthermore, assumptions have been made regarding the values of the parameters used. These values can be easily adjusted as these may vary from practice and per municipality. Because these values can be changed, the DSS is generically applicable. It is also helpful within a municipality to play around with these values (sensitivity analysis) to discover if this leads to a different best scenario.

When the municipality uses the DSS, they have to consider that everything is converted into costs; however, some things are difficult to monetize, and there can be an ethical discussion about whether this allows compensation in some aspects. Therefore, the 'sum' section can also be used to compare the alternatives, as here, the differences between them are also shown, but not in monetary terms. Moreover, they should keep a close eye on the out-of-pocket costs to see if they are within budget and if it is worth the cost.

Furthermore, when the DSS is applied in a large city like Amsterdam, many more bridges than the current 23 must be included. When more bridges are included, making the scenarios by hand becomes challenging. Furthermore, when more bridges are included in the decision-making process, the number of possible scenarios increases exponentially. However, in practice, there are more criteria to consider, such as structural feasibility, cables, and pipes in the bridge, accessibility for emergency services, and other projects in the city. All this makes creating the scenarios by hand very complex. Therefore, developing a relatively simple linear programming model that arrives at several scenarios is recommended. After which, these scenarios can be critically examined manually. It would also be helpful to develop an interactive map where each bridge is given a phase and strategy, and the results for each scenario are shown immediately. Furthermore, as discovered in Subsection 5.6, the DSS can be improved further, for example, by incorporating automatic checks to prevent the possibility of errors. Especially with many bridges, the DSS can otherwise become very error-sensitive.

In this thesis, five scenarios were investigated. However, as previously discussed in Subsection 5.5, it is recommended to investigate more than five scenarios in practice, probably at least ten. The exact number depends on the situation (number of bridges, capacity of the municipality, availability of linear programming model). When the few best scenarios are found, additional research has to be done on the criteria where the most significant difference is between the scenarios. If, for example, there is primarily a difference in loss of business between two scenarios, it is advised to investigate this further. If this investigation shows that the consequences for loss of business are, in fact, much lower or higher, this will influence which of the two scenarios is chosen. In this way, it is possible to choose which criteria are helpful to explore further because exploring everything in more detail is often impossible.

Furthermore, municipalities are advised to be critical of their current decision-making and their assumptions in this regard. For example, it was discovered in the expert interviews that the Municipality of Amsterdam chooses that 'short and intense' is better than 'long and less intense.' For future research, it is also undoubtedly useful to investigate the preference from the citizen's perspective. It is then helpful to share these findings with other municipalities.

Cooperation between municipalities is also valuable for other types of studies. For example, in terms of which values of the parameters can be applied. For instance, flexibility is included in the planning, but it remains to be seen whether problems with flexibility occur in practice and the costs related to it. The same applies, for example, to the safety of the various strategies. It has been stated that entire closure is the safest strategy and phased building and a temporary bridge entail safety risks. However, this difference may not exist on a large scale because entire closure may lead to safety risks in other places due to congestion. Furthermore, it could be investigated whether clever use of temporary bridges can be made, for example, by reusing them and making them from cheap and sustainable materials. Moreover, obtaining more detailed data on the user groups is recommended to consider this in the DSS since different groups have different Values of Time.

6.3.2. Recommendations for Further Research

Not all components of the DMF + SD were included in the DSS; therefore, future research should focus on these. For the SD, i.e., livability, sustainability, and other projects in the city can be investigated. However, the bridge's construction, simplified in the DSS, can also be included in further detail. For the DMF, the main thing is to look at how the municipality can be supported in choosing a scenario. As a result, the 'Decision Support System' will be upgraded to a 'Decision-making Tool.' It is also recommended to do further research on quantifying the current impacts and to do it in a way that is easily applicable to municipalities.

It is also suggested to research what detour times are acceptable and the residents' views on whether they prefer 'short and intense' operations or 'longer and less intense' operations. Furthermore, since it was discovered in the expert interviews that there were significant differences between Delft and Amsterdam regarding their current approach and vision, it is also interesting to research other municipalities.

Finally, developing a Decision Support System for large groups of bridges using a linear programming model to arrive at several scenarios is advised. Indeed, this will ensure that the DSS can be easily applied in practice, helping cities get through these enormous renovation challenges in the best possible way.

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A
Scientific Paper

The paper can be found on the next pages.

Decision-making for Large-scale Bridge Maintenance: Designing a Decision Support System for determining which bridges should be renewed simultaneously and with what strategy, using Amsterdam as a case study

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Abstract

Delayed maintenance is a major issue in Europe, including the Netherlands. The city of Amsterdam recently started a large-scale maintenance project to renew (renovate or replace) many bridges: an issue that other cities will have to face soon. Decision-making for bridge programming (deciding which bridges should be renewed simultaneously using what strategy) is a contemporary issue. The current decision-making in Amsterdam is not structured; as a result, not all options have been considered, and only a few factors are taken into account. Consequently, this programming has resulted in massive costs and project delays. From the literature review, it can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities. Since it is essential to make an informed decision, there is a need to develop a method to look at decision-making in an integral and systematic sense. Therefore a DSS is designed in this study to support this bridge programming. The DSS will systematically show which main effects play a role, the options a municipality can choose, and their advantages and disadvantages. Moreover, it will reveal the trade-offs a municipality will have to weigh when making its choice. The DSS was designed using a case study, namely a part of Amsterdam. In the end, the expert evaluation showed that the DSS is plausible and leads to meaningful insights into decision-making.

Keywords: Decision-making, Decision Support System, Bridge, Programming, Maintenance, Municipality, Trade-off

1. Introduction

The world's densest infrastructural networks are found in Europe. However, social-economic reasons have led to a cutback in the budget for maintaining the ageing infrastructure for several decades. Postponing maintenance reduces internal market mobility, raises the possibility of accidents and increases CO_2 emissions in the transportation industry (European Construction Industry Federation, 2020). Stadszaken (2021) reports a backlog of maintenance in the Netherlands as well. This research examines the decision-making process for planning bridge maintenance in the Netherlands, specifically in Amsterdam. A large-scale renovation project is underway, involving the renovation or replacement of over 200 km of quay wall and 850 traffic bridges, with most located in the historical center of Amsterdam. The Municipality of Amsterdam is the client for this project, called "Program Bridges and Quay Walls," with Witteveen+ Bos and the Engineering Firm of the Municipality of Amsterdam in charge of project management and engineering.

Delayed maintenance is a major issue in the Netherlands, and Amsterdam recently started a large-scale maintenance project to renew many bridges: a challenge that other cities will soon face. The planning of the scheduling of bridge renewal is called "programming," and a decision should be made on which bridges to renew simultaneously. The programming in Amsterdam has several major drawbacks, including trams being out of service for a long time, early replacement of bridges, and high costs due to the use of temporary bridges. Many temporary bridges are currently in use, but other strategies, such as entire closure or a phased building process, could lead to better outcomes. Hence, the current decision-making is not structured, not all choices have been evaluated, and the decision is based on only a few aspects. As a result, this programming has led to enormous expenses and project delays (J. de Leeuw, personal communication, June 15, 2022).

Making the decision of which bridges to address simultaneously with which strategy can potentially be supported by a Decision Support System (DSS). The literature review shows that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities, leading to a scientific gap. From this, the theoretical gap about how decision-making should be done is lacking. Moreover, effects can be found in the literature. However, a clear overview of which ones are relevant to consider in decision-making is unknown, leading to a second theoretical gap. Finally, a methodical gap arises because it should be made sure that measuring these effects is feasible for the municipality. Ultimately, the DSS should be a user-friendly tool easily accessible to a municipality.

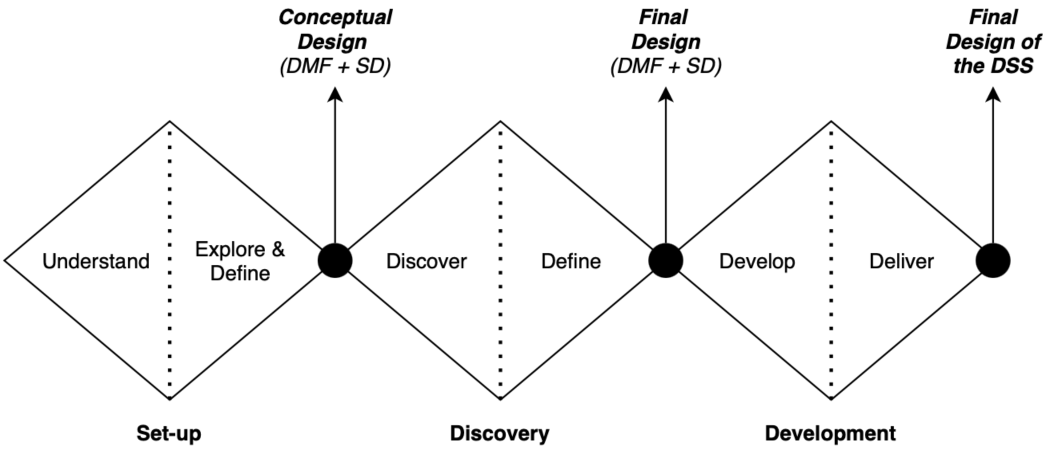

Figure 1: 'Triple Diamond Approach'

The current decision-making in Amsterdam is not structured; as a result, not all options have been considered, and only a few factors are taken into account. Consequently, this programming has resulted in massive costs and project delays. Since municipal money must be spent wisely, an informed decision must be made. From the literature review, it can be concluded that no DSS exists that considers all criteria, is suitable for simultaneously planning multiple bridges, and is user-friendly for municipalities. Besides Amsterdam, this decision is also an issue in other Dutch cities. If no support is provided, every municipality has to make its own decisions. Since it is essential to make an informed decision, there is a need to develop a method to look at decision-making in an integral and systematic sense. This leads to the following main objective of this study:

" Designing a Decision Support System to provide insight into the Decision-making for Bridge Programming for Dutch Municipalities "

The Decision Support System (DSS) is a tool that provides insight into the decision-making process for which bridges to renew simultaneously and what strategy to use (entire closure, phased building, or a temporary bridge). While this is a complex decision, the DSS does not make or optimize the decision, but rather supports it, creating a clear overview of the situation. The DSS will show the main effects at play, the available options and their advantages and disadvantages, and the trade-offs involved. Through the use of the DSS, municipalities can improve their decision-making and become aware of the issue at hand. The user-friendly design of the DSS provides practical guidance and encourages municipalities to take a critical look at their decision-making process. Once a DSS is developed, it can be used and improved collectively, allowing for cooperation between municipalities. The research will first be conducted at the theoretical level to arrive at a DSS that can be practically applied. Two frameworks (DMF + SD) will be designed, serving as theoretical input for the DSS and clarifying how municipalities' decision-making relates to both parts.

The DSS will support Dutch cities with a high number of bridges in making decisions about which bridges to renew simultaneously while taking capacity limitations (people or money) into account. The tool will serve as a planning tool that includes impacts and budgets and will primarily provide information on the consequences of different programming options. Ultimately, the municipality will make its own decision. The research will focus on designing the DSS for the city of Amsterdam, where a case study will be conducted. However, the DSS will be applicable to other Dutch cities as well. The research will approach the problem from a transport perspective, without going into detail about the construction of the bridges.

2. Methodology

A design process was applied to create a Decision Support System, using the 'Triple Diamond Approach' as the underlying theory. A combination of the approaches of Lyons-Grose (2017), Burton (2019) and Sensaco (2019) together with own input were used, as shown in Figure 1. This method was chosen because it helps to achieve a goal, with each diamond providing a specific output that brings the designer one step closer to their objective. Furthermore, the divergent and convergent nature of the approach forces the designer to think about the complete system and to extract only the relevant findings from it.

At each step of the 'Triple Diamond Approach,' various methods have been used, including desk research, observational studies, expert interviews, conceptual modelling, and a case study. The Conceptual Design, which includes the Decision-Making Framework (DMF) and the System Diagram (SD), was the output of the first diamond, designed using desk research and observational studies. The DMF describes the general

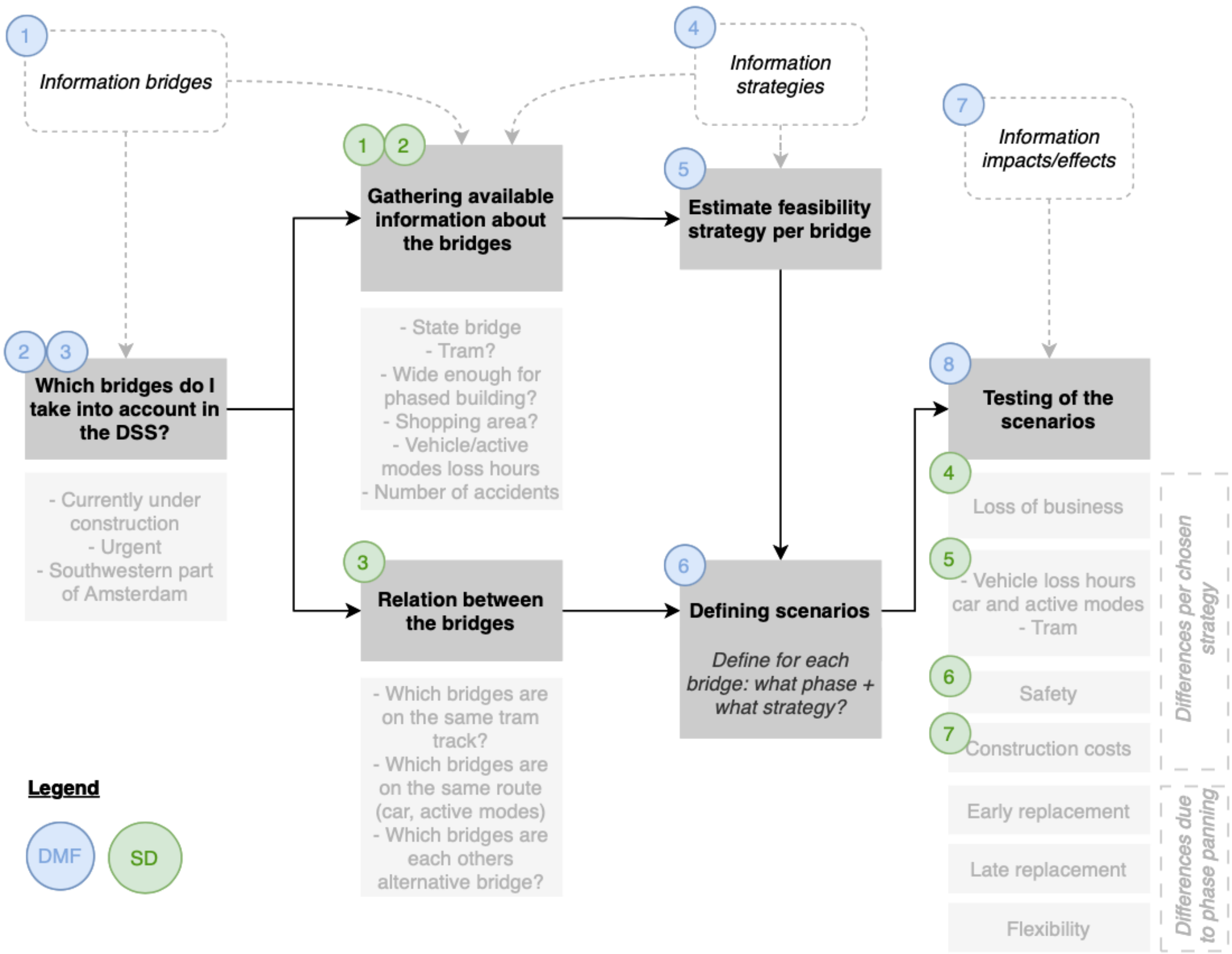

Figure 2: Overview DSS (in relation to DMF + SD)

decision-making process, including the steps necessary to develop a plan for the next few years. The SD will take individual bridges into account. The second diamond involved adapting the Conceptual Design (DMF + SD) based on expert interviews, resulting in a Final Design. Finally, the third diamond involved developing the Decision Support System based on the theoretical scientific input of the Final Design (DMF + SD), using the southwestern part of Amsterdam as a case study.

3. Results

The final result, the DSS, was achieved by going through the three diamonds. This Section will explain the findings from all three diamonds.

3.1. Diamond 1 — Set-Up

The first diamond has set up the Conceptual Design, consisting of the DMF + SD, by gathering information using desk research and observational studies and arriving at this Conceptual Design using conceptual modelling.

The Conceptual Design required two types of information: 'theoretical' and 'in practice.' In the 'theoretical' part, a literature review is conducted on the current state-of-the-art of DSS for programming bridge maintenance. Numerous studies have investigated the state of the bridge to provide insight into when they need to be maintained in order to make a prioritization using mathematical models. However, these systems differ in whether they only focus on the technical aspects or consider societal, economic, and political elements. It can be concluded that a scientific gap exists in terms of a decision support system for the planning of multiple bridges that need to be maintained. Moreover, the tool should be user-friendly for municipalities and include all effects. In addition, the 'theoretical' part discovered the impacts related to bridge maintenance and building new infrastructure. Researching this provided new insights. In the 'in practice' part, the current approach in Amsterdam was examined, exploring the current programming, possible strategies, and the policy of the municipality.

Ultimately, all this information is used to arrive at the Conceptual Design (DMF + SD). The goal of the DMF (Final Design of DMF is shown in Figure 5) is to show the decision-making process a municipality has to go through when deciding on planning bridge maintenance, given a city where many bridges should be maintained. However, only a small part can be taken into account simultaneously. The DMF considers the entire decision-making on a large scale but also considers the individual bridge (as indicated by the grey circle with 'SD'). A SD (Final Design of SD is shown in Figure 6) was used to clarify which factors play a role in the decision-making of an individual bridge. The means, external factors, and criteria are on the edges of the system diagram. This method is mentioned in the work of Enserink et al. (2022), where these edges are explained. The criteria indicate to what extent a specific strategy has an impact. The external factors are the factors that can not be influenced by the client (municipality) but do affect one or more criteria. The means can be influenced by the client (municipality) and affect one or more criteria. The elements within the boundaries are the internal factors; these are all factors that play a role and influence the criteria. The System Diagram conceptualizes the main effects of a potential strategy. Choosing a potential strategy per bridge leads to different outcomes of the criteria.

The Conceptual Design (DMF + SD) is not shown in this paper. Therefore, the Final Design of the DMF + SD is referred to, including the relation with the DSS. This relation will be described in the third diamond.

3.2. Diamond 2 — Discovery

Experts validated the Conceptual Design (DMF + SD) in the second diamond. The results from the expert interviews are used to redesign the DMF and SD to a Final Design (DMF + SD), as shown in Figure 5 and 6 using conceptual modelling.

Six experts are interviewed, including two from the Municipality of Amsterdam, three from Witteveen+Bos, and one from the Municipality of Delft. Experts with different areas of expertise were selected to obtain various viewpoints. Experts from an engineering firm and municipalities are selected to emphasize the difference between theory and practice. Additionally, different municipalities are chosen to discover the differences per city, which will be helpful for the generalization of the DSS. The information obtained from these interviews provides sufficient data for further development of the DMF + SD and input for the DSS design.

3.3. Diamond 3 — Development

The Decision Support System (DSS) is developed using the Final Design (DMF + SD) as a theoretical input. Microsoft Excel is chosen as the program to make the DSS because it is user-friendly and widely known among civil servants. A case study was used to develop the DSS, with Amsterdam selected as the case study. However, only one part of the city was included due to complexity and time constraints, and not all aspects of the DMF and SD were included for simplification purposes. The focus was on testing the method rather than the final result. Figure 2 shows the steps involved in the DSS, with grey blocks indicating all steps and light grey blocks showing the information from the case study included for each step. Figures 5 and 6 show the DMF and SD and indicate which parts were used in the DSS. The overview of the DSS reveals its relationship to the theoretical part (DMF + SD).

In Figure 2 the 'Overview DSS' is shown. Step 1 of Figure 2 involves deciding which bridges to include in the DSS. After step 1, the process splits off in two directions. In the first split-off, information is collected on a small scale per individual bridge, and an estimate is made per bridge as to which strategy might be a good option. In split 2, the relationship between the different bridges is looked at on a large scale (network level) instead of looking at each individual bridge. Next, these two splits come together while creating the scenarios, which are tested and compared in the final step.

Figure 5 shows the already designed DMF with the numbers indicating which parts are included in the 'Overview DSS' (Figure 2). Several blocks have not been given a number here. For example, the block 'policy of the municipality' of the DMF does not play a role at the moment, as a municipality does not currently run through it; however, the DSS does take into account that municipalities have different values for parameters. Furthermore, the 'choosing a scenario' block has not been implemented. As can be seen, scenarios are tested, but no choice is made in this. This is because the DSS is only used to support the decision and not to make it. However, these blocks should be considered in practice.

Which elements of the SD are included in the DSS is shown in Figure 6. The means of the SD are not explicitly included in the DSS but should be kept in mind when used. The means 'available money' and 'policy of the municipality' in some manner incorporated since the values (e.g., the available budget and the Value of Time) can be adjusted in the DSS. Furthermore, all external factors and most criteria are included. The criteria 'livability' and 'sustainability' are not included because this is difficult with the available data. However, they are indirectly included. As shown in light grey under the dark grey block 'testing the scenarios,' the top four elements are related to the SD, i.e., to the strategy chosen for an individual bridge. The bottom three (early replacement, late replacement, and flexibility) are unrelated to the choice of an individual bridge regarding a strategy. These values come from classifying which bridge is addressed in which phase. However, an early and late replacement can be related to the criteria 'sustainability,' and flexibility can be linked to 'livability,' since flexibility is mainly about not overrunning the project, since the longer the project takes, the more extended inconvenience is experienced, which affects livability.

The case study considered 23 bridges, including the 'Oranje Loper' and 'Leidse Corridor'. The' Oranje Loper' is currently under construction, and the' Leidse Corridor' is waiting for the work at the' Oranje Loper' to be completed before work can start. Besides the bridges currently under construction, only urgent bridges are included due to interviews indicating it is not convenient to replace non-urgent bridges. Information about the state, general information, and traffic for each of the 23 bridges is used to estimate which strategy might be a good option. On the other hand, the relation between the bridges is researched. It is investigated which bridges are each other's alternative bridge and which bridges are on the same route next to each other or on the same tramway. This is useful to know for creating good scenarios with flexible planning. Five scenarios are created (as shown in block' defining scenarios' of Figure 2) to test the DSS against criteria. These criteria include loss of business, vehicle loss hours, safety, construction costs, early and late replacement, and flexibility.

As shown in Figure 3, the results indicate that scenario 5 is the best option (lowest total and out-of-pocket costs) within the given boundaries, criteria, and assumptions. However, it should be noted that the accuracy of certain factors, such as active mode intensities, may be higher in reality, and temporary bridges could be a viable option for some bridges. Despite these limitations, the DSS offers valuable insight into the implications of selecting a scenario and comparing different scenarios. However, other not researched scenarios may lead to better results in practice.

The study included a sensitivity analysis where different values of parameters were investigated. Adjusting parameters makes the DSS useful for various municipalities. Results show that changing parameters does not significantly affect the outcome. Scenarios 3 and 5 are consistently the best options, which is desirable because they are stable solutions. Depending on the values of the parameters, the best scenario may vary. However, a different scenario might be the best if other criteria are considered or if different scenarios are created. Furthermore, it is examined how the DSS needs to be used in practice, as shown in Figure 4.

The DSS was evaluated by one expert. According to J. de Leeuw (personal communication, January 23, 2023), the DSS is a rational approach to decision-making. Nevertheless, some other factors in Amsterdam play a role in the decision-making that are not captured in this model, which is why this model is presumably not applied in Amsterdam.

4. Conclusion and Discussion

This study designed a DMF, SD, and DSS, solving the gaps as stated in the introduction. First, the DMF solves the theoretical gap about how decision-making should be done. The DMF highlights the crucial steps that need to be taken to make a good decision and what is required as input. The DMF also shows how the large scale of the entire city relates to the small scale of the individual bridge. In addition, the SD solves the second theoretical gap by providing a clear overview of what effects play a role in choosing a potential strategy for an individual bridge and the interactions between these effects. Finally, the design of the DSS partly solves the methodological gap by measuring these effects.

The designed DSS can support a municipality in making decisions. It also provides insights into decision-making as it presents a broad picture of the whole situation in the city and how the many elements involved in the decision-making are related. Current decision-making in Amsterdam only considers a few factors (e.g., tram accessibility and active modes), while the DSS considers more factors (e.g., costs, safety, and residual life of bridges). The designed DSS provides a broader view than the current decision-making; however, some aspects of the DMF + SD still need to be implemented to arrive at a complete view. Moreover, the DSS has some simplifications and limitations, as further explained in the discussion. However, the DSS clearly shows how this method works and offers insights. Finally, the DSS provides a systematic and user-friendly approach for municipalities to think about their decision-making. The DSS supports the decision for municipalities by showing the consequences of each scenario. Note that the DSS does not decide which scenario should be chosen. Instead, the DSS investigates various scenarios and their differences to provide insight into what factors play a role in the decision-making and the trade-off in criteria that should be made. In the most complex decisions, trade-offs must be made between criteria, such as accessibility and cost. By identifying these trade-offs, the municipality's policy can be evaluated according to the criteria between which there is a trade-off. This shows the municipality which criteria play a critical role and need to be considered. For instance, a municipality has to determine which criteria they consider most important and how much they are willing to spend on this. By showing the costs related to the criteria, the DSS reveals between which parts the trade-off should be made and how difficult this decision is. For example, in this case, the difference between scenarios 1 and 5 in active mode costs is only a few million. In contrast, the difference in total costs is several tens of millions. Therefore, making this choice would be relatively easy. However, it is more complicated when the difference in total costs would also be only a few million. Moreover, creating multiple scenarios ensures the user looks broadly and considers multiple options. However, due to the user-friendly nature of the DSS, municipalities are motivated to take a critical look at their decision-making. The products created (DMF + SD + DSS) make municipalities aware of this problem and show how their current decision-making relates to theory. Therefore, the DSS translates theory (DMF + SD) into practice (DSS). Finally, the DSS provides insights into what effects are involved when a particular scenario is chosen, allowing the municipality to take additional measures.

The designed DSS is plausible and leads to meaningful insights into decision-making, as can be concluded from the expert

Legend → Worst *(highest value)* | Medium | Best *(lowest value)* — *Note: all values are in millions of euros*

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Costs Loss Car	3.8	3.8	3.8	3.8	3.8
Cost Loss Active Modes	5.4	8.9	9.9	8.9	9.9
Detour times above Limit?	NO	NO	NO	NO	NO
Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
Safety Costs	1.2	1.2	0.7	1.2	0.7
Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
(Additional) Construction Costs	36.0	15.7	0.7	15.7	0.7
Flexibility Costs	0.1	0.4	0.4	0.1	0.1
Total costs:	47.9	30.2	16.2	30.0	16.0
Of which 'Out-of-Pocket'	36.0	15.7	0.7	15.7	0.7
Feasibility	NO	YES	YES	YES	YES

Figure 3: Results of the five scenarios

evaluation. However, other choices are made in Amsterdam, which means that unobserved factors, not included in the model, play a role in the decision-making process in Amsterdam. Therefore, the Municipality of Amsterdam will probably not use the DSS. Moreover, the DSS might be used by other municipalities where it does match their decision-making.

This research has limitations since the design of the DSS did not include all elements from the DMF and SD, and only a small part of the city was studied in the case. These decisions were made due to time constraints. When the DSS is implemented in practice, some aspects need to be handled differently than in the case study. As no models were utilized, and various assumptions were made for the calculations, further exploration is required in practice to validate the accuracy of these assumptions and calculations before using the DSS.

5. Recommendations

For the municipalities, it is recommended to gather data on the condition of the bridges since these conditions are often unknown. Furthermore, recommendations were provided for municipalities when the DSS is used in practice, i.e., including other aspects that may play a role, checking whether the parameters' values are correct and using available transport models. In addition, municipalities are advised to be critical of their current decision-making and assumptions.

It is advised to conduct further research on including components of the DMF + SD, which are not yet included. It is also recommended to do further research on quantifying the current impacts. Furthermore, it was found in the expert interviews that there were significant differences between Delft and Amsterdam regarding their current approach and vision; therefore, it is also interesting to research other municipalities. Finally, it is recommended to develop a Decision Support System for large groups of bridges using a linear programming model to arrive at good scenarios. Indeed, this will ensure that the DSS can be easily applied in practice, helping cities get through this enormous renovation challenge in the best possible way.

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		Case Study	In Practice
Scope		Part of the city	Entire city
#scenarios		5	10+
SD	*Means*	/	Taken into consideration
	External Factors	Simplified	Well researched
	Criteria	4 of 6	6 of 6
DMF		Not all steps	All steps
#sensitivity analysis		5	10+

Figure 4: Comparison of the DSS in the case study and in practice

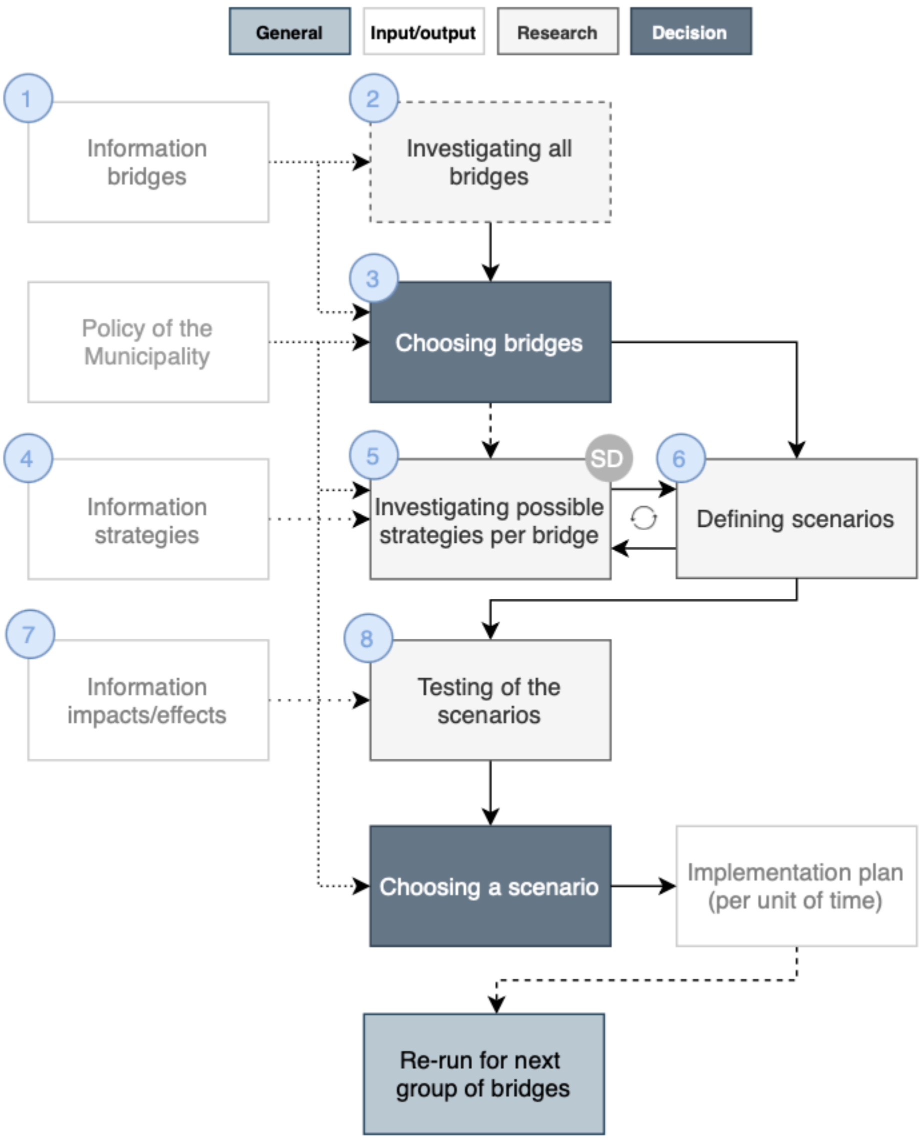

Figure 5: DMF (+ parts related to the 'Overview DSS')

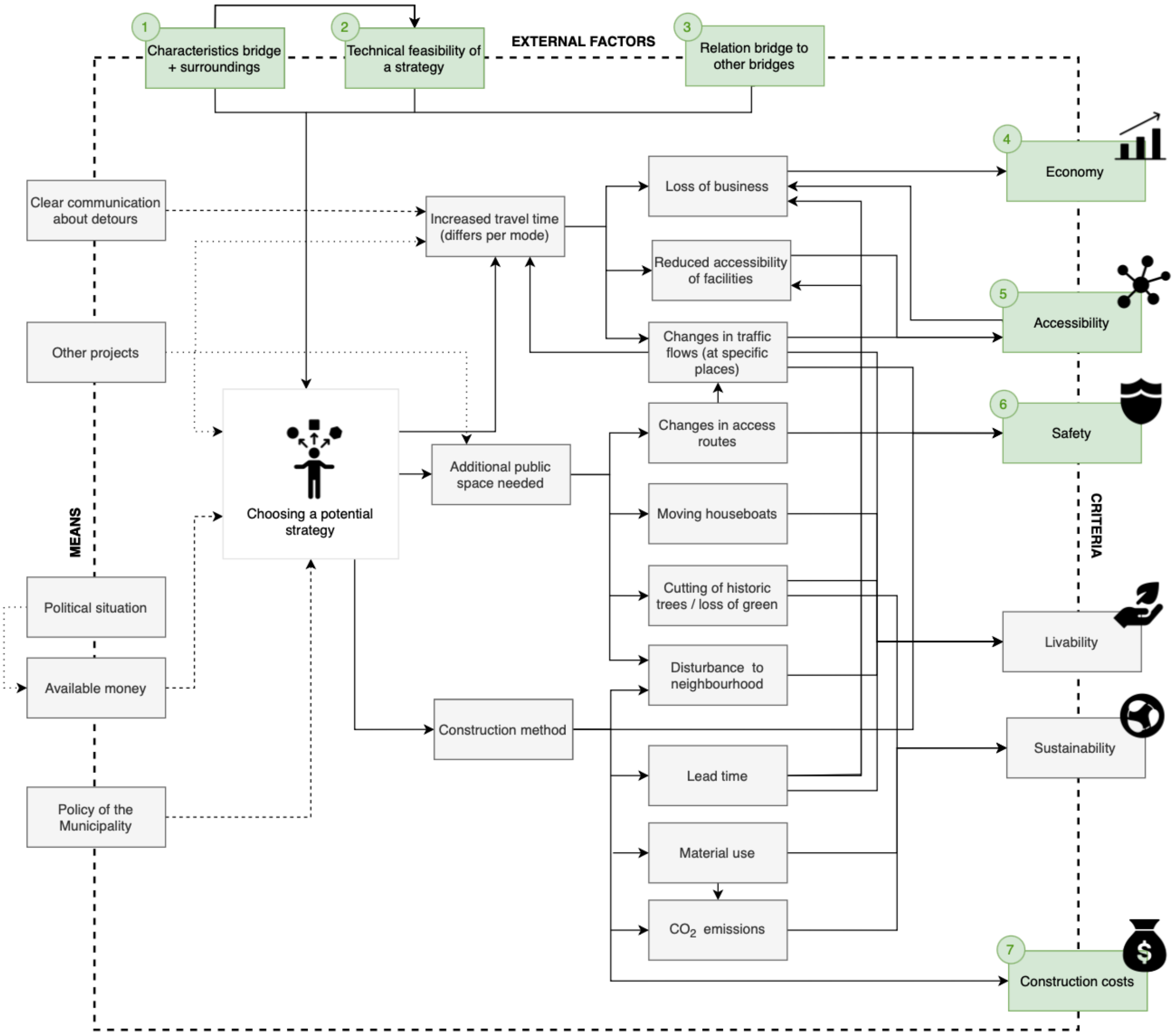

Figure 6: SD (+ parts related to the 'Overview DSS')

B

Expert Interview Guide

Hieronder is de Interview Guide te zien. Naast deze Interview Guide is er een PowerPoint presentatie gebruikt ter ondersteuning van de interviews. Onderstaande vragen zijn deels aan alle interviewees gesteld, maar sommige vragen enkel aan de interviewees met een bepaalde expertise.

Voorstellen

- Vragen of ik het gesprek mag opnemen.
- Interviewde vragen naar huidige functie, expertise en ervaring.
- Mijzelf voorstellen + project uitleggen
  - MSc Transport, Infrastructuur & Logistiek, TU Delft
  - Afstudeerder bij W+B
  - W+B werkt mee aan Programma Bruggen en Kademuren. Uitdaging waar de gemeente Amsterdam voor staat gaat ook voor andere steden in NL gelden. Daarom framework maken als ondersteuning voor deze opgave. Wanneer welke brug vervangen moet worden en welke strategie (gegeven een groot aantal bruggen dat vervangen moet worden waar maar een klein deel tegelijk kan worden aangepakt).
  - Kwalitatieve aanpak; dus veel expert-interviews voor het toetsen van het gemaakte framework en het ophalen van nieuwe informatie.
- Niet erg als u niet alles weet! Focussen op uw expertise!
- Vragen of diegene eventueel iets langer beschikbaar is dan een uur.

Vragen deel 1/3

- *[Introductievraag voor experts van Gemeente]* Hoe gaat het proces (welke brug wanneer vervangen en op welke manier) op dit moment? (Hoe vindt u dat het gaat? Aat gaat er goed? Wat kan er beter?)
- *[Introductievraag voor experts van Witteveen+Bos]* Hoe zou jij het zelf aanpakken?

Laten zien Conceptual Framework (CF)

- Eerst geheel globaal uitleggen en vervolgens per stap in meer detail
- Voorbeeld gebruiken qua aantallen

Vragen deel 2/3

- Is de outline van het conceptuele framework logisch? Ontbreken er dingen/klopt er iets niet?

- Komt het conceptuele framework overeen met wat er in de praktijk gebeurt? Zo niet; waar zitten de verschillen in? Wat zou gewenst zijn?
- Welke methoden kunnen per onderdeel van het CF worden gebruikt?
- Om welke redenen kan er maar een x aantal bruggen tegelijk worden aangepakt?
- Tot hoeverre is er informatie bekend over de bruggen?
- Zijn er naast de genoemde strategieën (hulpbrug, gefaseerd bouwen, geheel afsluiten) nog meer strategieën mogelijk?
- Wat is de haalbaarheid van de strategieën?
- Welke effecten/impacts heeft het afsluiten van de brug op de omgeving?
- Welke scenario's zijn logisch om te maken?
- Hoe verschillen de impacts/effecten per scenario?
- *[Vraag voor expert van Gemeente]* Zijn er karakteristieken van uw stad die veel invloed hebben op welke impacts/effecten een rol spelen? Die in andere steden niet/minder van toepassing zijn.
- *[Vraag voor experts van Witteveen+Bos]* Zijn er karakteristieken per stad die veel invloed hebben op welke impacts/effecten een rol spelen?
- Voor hoeveel jaar vooruit wordt er een planning gemaakt/zou een planning gemaakt moeten worden?

Laten zien System Diagram (SD)

- Doel duidelijk maken
- Begrippen (means, external factors, criteria) uitleggen

Vragen deel 3/3

- Wat verwacht je nog meer op de randen van de SD (means, external factors, criteria)?
- Wat verwacht je nog meer in het midden van de SD?
- Heb je verder nog vragen/opmerkingen/input over de SD?
- Is het logisch om met deze categorieën te werken qua criteria? Bereikbaarheid, leefbaarheid en veiligheid?
- Hoe definiëren jullie deze begrippen?
- *[Vraag voor experts van Gemeente]* hoe maken jullie als gemeente de afweging tussen de criteria (bereikbaar/leefbaar/veilig <> geld)? (indien andere criteria eruit komen daarop ingaan)
- *[Vraag voor experts Witteveen+Bos]* Hoe wordt in het algemeen de afweging gemaakt tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?
- Hoe werkt de verhouding tussen de beslissing van 1 brug in relatie tot de grote schaal/andere bruggen?
- *[Vraag voor Gemeente Delft]* Hoe ziet de decision-making van de Sint Sebastiaansbrug eruit?

Afsluiting

- Wat voor een framework is zinvol voor de gemeente?
- Is er data beschikbaar voor het testen van mijn casus?
- Sta je open voor een eventueel 2e interview?

- Ken je nog meer mensen die relevant zijn om te interviewen? Directe/indirecte collega's. Buiten het bedrijf?
- Bedanken voor interview!
- Heeft u nog tips voor mij?

C

Expert Interviews

This appendix contains the summaries of the expert interviews. All these summaries have been approved by the respective expert.

The term ”Conceptual Model” was used in the expert interviews, however, this term was changed to ”Decision-making Framework” during the process.

C.1. Interview A

1. Voorstellen

- **Huidige functie/ervaring**: Marieke Nonhebel vertelt dat zij van 2002-2007 omgevingsmanagement heeft gedaan vanuit DHV in bodemsanering. Sinds 2007 is zij werkzaam bij de Gemeente Amsterdam als omgevingsmanager waar zij meerdere projecten voor heeft gedaan. Zij werkt 2 dagen per week bij PBK en daarnaast ook als Omgevingsmanager bij de transformatie van het Weteringcircuit naar Weteringpark.

2. Opmerkingen tussendoor

- **Her-ijking programmering bruggen**: Doordat er op dit moment een stuk minder geld beschikbaar is dan van tevoren was verwacht is er een her-ijking bezig in de programmering van de bruggen. De Gemeente Amsterdam is nu bezig om te inventariseren wat er binnen de uitvoeringsteams allemaal bekend is over de bruggen die geprogrammeerd stonden voor 2025-2016 om met een nieuwe blik te kijken wat er met deze programmering moet worden gedaan. Kunnen we op een andere manier kijken naar bepaalde keuzes? En mocht er weer meer geld zijn moet er dan nog steeds worden gedaan wat er oorspronkelijk was bedacht?.

3. Antwoorden vragen deel 1/3

- **Hoe gaat het proces op dit moment?** We zitten in een keten (verschillende stapjes en verschillende besluitvormingsstapjes) en de eerste stap die gezet wordt is de programmering. In hoofdlijnen wordt gekeken wat logisch is vanuit bereikbaarheid om bepaalde bruggen in een bepaalde fasering te zetten. Eerst wordt er gekeken wat de technische staat is van de bruggen; moeten de bruggen überhaupt worden aangepakt? Bij de programmering is er iets breder gekeken; als we 1 brug hier gaan doen kunnen we beter de bruggen die - daar en daar en daar - liggen ook meteen meepakken ook als zijn ze technisch niet net zo slecht zijn? Dit was bijvoorbeeld heel erg logisch bij de Leidsestraat. Dus alles in één bereikbaarheidsroute in één keer aanpakken zodat je daar niet nog een keer terug hoeft te komen. De stad ligt overal overhoop. Naast PBK nog veel andere projecten (bijv. veel kruisingen zijn gevaarlijk en moeten snel veilig worden gemaakt, en daardoor dicht voor verkeer). Dit heeft allemaal veel impact op de gebiedscirculatie. Het is logisch dat er is gedacht vanuit bereikbaarheid in corridors om de programmering tot stand te brengen. Dit is altijd hoe er gedacht werd. Oranje loper zijn ze nu mee bezig. Als die klaar is kan pas de Leidsestraat. Er rijdt namelijk een tram door de Leidsestraat en niet zo wel de Oranje Loper als de Leidse straat kunnen zonder tram. Zodra de Leidsestraat klaar is kan pas weer de Utrechtsestraat. Dit moet zo worden gedaan zodat er altijd een stabiel tramnetwerk is. Dat is hoe er geredeneerd werd vanuit programmering en dat vond ik een hele logische, maar dat gaat dus nu veranderen doordat we minder geld hebben. Ook steeds meer bekend over de staat van de bruggen. Nu er minder geld is moeten we creatiever zijn; wat is er echt nodig? Waar kan je eventueel verkeer afhalen zonder dat het tot een enorme verkeerssluiting in je buurtcirculatie leidt. En kan je met veel goedkopere middelen toch een brug weer veilig krijgen? Waar nu ook naar gekeken wordt is het levensduur verlengend aanpassen van een brug. Kost mogelijk minder geld en is mogelijk sneller (dit weten we nog niet zeker, maar dit wordt onderzocht). Voor 30 jaar de levensduur verlengen en dan 'zien we dan wel weer' na die 30 jaar. Het frame is dus de logica van een bereikbare stad, en dat is een hele terechte.

4. Opmerkingen tussendoor (tijdens laten zien CF)

- **Opmerking over blokje keuze 'choosing bridges'**: Marieke vraagt of de keuze welke bruggen worden meegenomen alleen vanuit de techniek (technische staat) wordt gemaakt. Ik leg uit dat dit nog een discussiepunt is of je alleen de urgente bruggen meeneemt of juist ook de anderen zodat ze bijvoorbeeld op één route liggen. Hier is Marieke het mee eens.

- **Opmerking over blokje 're-run for next group of bridges'**: Idealiter zou je wel heel ver vooruitplannen in hoofdlijnen en het dan steeds bijstellen. Hiervoor wil je zo goed mogelijke informatie hebben over de staat van de brug. De omgeving zal niet snel veranderen. Maar de staat van de brug, het dek en het maaiveld, tram, K&L moet je ook allemaal meewegen. In het geval van de Leidsestraat loopt er een tram over de brug. Zodra je een brug aanpakt moet je iets met die tram en K&L die er liggen. Uit het oogpunt van 'je komt er maar 1x', 'werk met werk maken overlast beperken' is alles in 1x doen. Uit de gesprekken die we hebben gevoerd met de GVB blijkt dat zij ook een bepaalde scope hebben in die periode. Als je gaat schuiven in je project veranderd die situatie ook. Dus dan kan het zijn dat de tram eerst wel goed genoeg was dan en als het project dan een paar jaar verschuift de tram misschien bijna niet meer goed genoeg is en dan dus wel tegelijk meegenomen kan worden, omdat je niet nog een keer terug wil. Dit geldt ook voor K&L. Maaiveld vaak eens in de 15 jaar onderhoud, en je wil dus niet in een korte periode 2x terugkomen. Vooral niet bij de Leidsestraat waar heel veel ondernemers zitten. Je wil eigenlijk alles op hetzelfde moment vervangen, het gaat dus niet alleen om de brug. Als Gemeente Amsterdam willen we dus voorkomen dat we steeds weer terug moeten komen omdat elke keer de impact op een hele boel andere dingen (dus niet alleen de overlast), maar ook de tram, dingen die stuk gaan, calamiteiten, wil je allemaal zo veel mogelijk voorkomen dus worden allemaal tegelijk meegenomen. Dat is natuurlijk een hele exercitie maar zorgt er wel voor dat de straat een paar jaar later niet opnieuw helemaal open hoeft. Als je niks van tevoren coördineert gaat het niet goed. Vooral bij de GVB en nutsbedrijven moet dan ook geïnventariseerd worden hoe zij daarin staan, want dat moet in de hele herprogrammering wel goed meegenomen worden.

3. Antwoorden vragen deel 2/3

- **Is de outline van het conceptuele framework logisch? Ontbreken er dingen/klopt er iets niet?** Over het algemeen klopt het framework, maar wat wel heel belangrijk is om mee te nemen is de bereikbaarheidsscan. Een standaard bij PBK is 'vierkant afsluiten tenzij…' dit betekent dat we een scan hebben gemaakt van wat er gebeurt als je vierkant afsluit. Met vierkant afsluiten kan je namelijk wel het snelst en het veiligst werken. Toen bleek heel snel dat het niet kan. Een hele simpele reden kan bijvoorbeeld zijn de nood- en hulpdiensten. Deze moeten er gewoon overheen kunnen. Dit in het geval van de Leidsestraat. Je hebt een aantal dingen die gewoon echt eisen (niet aan tornen) zijn die geen bestuurlijke keuzes zijn. Eisen moet je ook al gelijk vastleggen want dan weet je welke keuzes je hebt. Het is denk ik wel terecht dat je zegt dat iedere Gemeente er anders mee omgaat. Omdat Gemeente Amsterdam zegt 'vierkant afsluiten tenzij…' accepteren ze ook dat de bereikbaarheid slechter is dan dat we zouden willen maar de consequenties moet je wel kunnen uitleggen. Er moet bijvoorbeeld dan ook geaccepteerd worden dat ondernemers een paar jaar lang geen omzet hebben omdat er niemand meer langs komt (als je die 4 bruggen afsluit in Leidsestraat), dit kan je wel weer deels oplossen met hulpbrug maar die kost weer 2 à 3 miljoen.

En als je daar geen geld voor hebt is het geen andere optie. Bij veel verlies van ondernemers kunnen deze aanspraak maken op de verordening nadeelcompensatie. Dit moet worden betaald uit de projecten. Dus er is ook een financiële reden om "de winkel open te houden". Aan de andere kant zou je met vierkant afsluiten ook heel veel geld besparen in verkeersbegeleiding omdat dat heel erg duur is. Principiële keuze van tevoren: hoeveel overlast accepteer je maximaal? Moeten we dan nog het gesprek aanzwengelen met nood- en hulpdiensten op hoog niveau om voor te leggen dat we zo veel geld/tijd besparen als we jullie er niet overheen laten gaan, is daar nog iets in mogelijk? Het antwoord is dan gewoon 'nee', als ze die aanrijdtijden niet halen zijn de gevolgen niet te overzien. En zo zijn er nog wel meer dingen. In een corridor kan je niet alle bruggen afsluiten voor nood- en hulpdiensten want dan gaan er mensen dood maar als je bijvoorbeeld maar 1 brug aanpakt kan het vaak weer wel omdat de hulpdiensten dan van 2 kanten kunnen komen. Dus welke eisen zijn er en welke maximale bereikbaarheidshinder accepteer je zijn hele belangrijke basisprincipes om vervolgens die in die varianten (= scenario's in mijn CF) te onderzoeken. Wij wilden een variantenstudie gaan doen, hebben we helaas de stekker uit moeten trekken van hoe gaan we nou die bruggen aanpakken. Eigenlijk wilden we een variantenstudie doen van 1 brug maar het is dan heel lastig te zien in het licht van een corridor, want de effecten zijn over die gehele corridor. En dat is dan natuurlijk weer anders als je een clustertje hebt van bruggen die weer wat minder met elkaar te maken hebben. Als je 1 brug aanpakt in een cluster en mensen moeten eventjes een stukje omfietsen dat is dan maar zo, dan gaat het niet echt mis. Maar bij een corridor gaat het helemaal mis.

- **Komt dit overeen met wat er in de praktijk gebeurt?** Er wordt steeds meer bekend over de staat van de bruggen omdat de onderzoeken nog lopen. Kan ook voorkomen dat soms bruggen minder slecht zijn dan oorspronkelijk gedacht. Met deze onderzoeken en vanuit de bereikbaarheid is vervolgens gekeken hoe kunnen we dat programmeren. Die 2 dingen zijn de basis geweest voor de programmering op hoofdlijnen. Programmering op detail vond de laatste tijd plaats. En die fasering is nog niet opgestart, dus het 'oefenen' is nog niet gedaan. Dat is ook wel wat jij omschrijft. Ik ben benieuwd of we in de her-ijking ook gaan kijken naar levensduurverlengende oplossingen, ben heel benieuwd of dat gaat kunnen. Bij Leidseplein toen ik daar werkte is er onderzoek gedaan naar restlevensduurverlengde oplossingen. Dat bleek daar uiteindelijk technisch gezien niet te kunnen. Maar los daarvan focust het zich vooral op de fasering. Het moet namelijk zo gefaseerd worden dat je veilig, snel en met zo min mogelijk hinder zo'n brug kan doen. Verder heeft iedere gemeente weer een andere situatie. Wat speelt er hier een rol waar we rekening mee moeten houden?

- **Welke andere mogelijke strategieën zijn er mogelijk?** Zojuist al levensduurverlengend genoemd. Verder is het eraf halen van modaliteiten ook een optie. De tram in de Leidsestraat blijft echt wel rijden, die gaat er echt niet uit. Maar voor een aantal bruggen keert het verkeer. Maar kan ook op de gracht een u-turn maken. Als je dan bijvoorbeeld voor die bruggen zegt dat er geen auto meer overheen mag rijden is de staat van de brug misschien wel weer oké. Dat is iets wat onderzocht gaat worden. Soms geldt ook voor dat het verkeer eraf wordt gehaald en dan kan zo'n kade weer veel langer blijven staan en zijn allemaal dure stalen damwanden niet nodig en is er niks nodig. Dit heeft natuurlijk wel impact op de bereikbaarheid.

- **Wat zijn impact/effecten dat het afsluiten van een brug heeft op de omgeving?** In het geval van de Leidsestraat is het een voordeel dat het geen fietsroute is. Dus geen doorgaande fietsers maar wel fietsers uit de zijstraten die moeten omfietsen, dat is dat is acceptabel. Voetgangers door zo'n gebied niet laten lopen is echt een no-go, hiervoor moet je dan ook een noodbrug maken als je dit niet op de brug kan faciliteren. Voor op de brug faciliteren moet je wel kijken of het qua ruimte en veiligheid kan. Daar kiezen we dan toch liever niet voor omdat het wel krap is, maar als het kan scheelt het wel weer geld. De werkzaamheden hebben veel invloed op de leefbaarheid. Dan is het nog niet eens zo zeer dat zo'n brug vierkant is afgesloten met hekken die daar steeds maar staan. Maar daarvoor en daarna moeten de kabels en leidingen worden vervangen en dat is eigenlijk veel heftiger. Omdat dat elke keer anders is, ook anders dan de projectorganisatie denkt, dus daar is de overlast vaak heel groot van, ook omdat het zeer vaak onderschat wordt. Dit heeft namelijk een enorme impact op de bereikbaarheid en het benodigde werkterrein is heel erg groot. Uiteindelijk gaat er tot zeer dicht op de gevel gewerkt worden. De kabels kunnen diep liggen en het is vaak een enorme wirwar. Er zijn overeenkomsten gesloten met twee grote nutsbedrijven met als doel om in de samenwerking een heldere afsprakenstandaard te hebben. Dit moet wel nog allemaal concreter worden uitgewerkt, maar het is wel al een begin om de samenwerking goed op poten te zetten. In de praktijk is het echter vaak moeilijk te coördineren. De mensen in de voorbereiding zijn net weer anderen dan in de uitvoering. Dan komt de uitvoering erachter dat wat de voorbereiding heeft bedacht niet kan en dan duurt het weer weken. Dan gebeurt er niks en is er geen vordering zichtbaar wat tot frustratie leidt. Verder leidt deze vertraging dan ook weer tot meer overlast omdat de weg dan wel openligt maar er niks gebeurt. In een winkelstraat zijn daardoor minder gasten/bezoekers wat leidt tot minder omzet. Daar is een regeling voor vanuit de gemeente om deze bedrijven te compenseren. Maar je hebt daar alleen recht op als je meer dan 1 maand minder omzet per maand hebt. En geluidoverlast natuurlijk ook maar dat kan je allemaal wel redelijk managen. Wel belangrijk om te weten welke werkzaamheden gepaard gaan met veel geluidsoverlast. Dat vraagt wel enige technische kennis van OMmers. Leefbaarheid, als dat lang duurt, bruggen duren ongeveer 2 jaar, maar de totale doorlooptijd is inclusief nutswerkzaamheden heb je het al wel snel 3 jaar bezig. Voor de gemeente is dat wel snel en kort, maar voor de ondernemers is dat heel lang. Wat wel zo is is dat er veel frustratie is bij de ondernemers en bewoners van Amsterdam omdat er op heel veel plekken wordt gewerkt, de routes steeds weer veranderen en overal ongelofelijk veel gele omleidingsborden staan.

- **Hoe verschillen de impacts/effecten per scenario?** Marieke geeft aan dat de impacts/effecten zeker gaan verschillen als je per corridor afsluit of juist bruggen verspreid door de stad afsluit. Hiervoor moet elke keer weer opnieuw een stakeholderanalyse worden gedaan. Wat nu ook speelt bij deze bruggen in de Leidsestraat is dat het monumentale bruggen zijn en die moeten weer met monumentale waarde worden teruggebracht. Maar een andere stakeholder kan weer zeggen dat die wil dat de brug wordt opgehoogd (wat de monumentale waarde tenietdoet). En zo heb je dus elke keer weer andere stakeholders. Wat ook zo is, is dat een brug in Amsterdam ook een grote impact heeft op de toeristensector door de rondvaartboten. Dat is een extra partij die je niet overal zal hebben waar je ook rekening mee moet houden.

- **Zijn er karakteristieken van uw stad die veel invloed hebben op welke impacts/effecten een rol spelen?** Naast de toeristensector moet er ook rekening worden gehouden met de grote hoeveelheid festivals (maar hebben sommige andere steden natuurlijk ook), zoals SAIL en 'Amsterdam 750 jaar'. Je moet elke keer als je een project start een goede stakeholdersanalyse doen en daar hoort ook bij dat je inventariseert welke belangrijke evenementen er zijn. SAIL is allemaal op water, voornamelijk in het IJ, maar die week is er heel veel en dan wil je niet dat zo'n stad overhoopligt. 'Amsterdam 750 jaar' moet het een feestje zijn en vervolgens zijn er heel veel straten afgesloten, dat draagt natuurlijk niet bij aan de feestvreugde. Daar moet je dan ook goede afspraken over maken om het dan toch mogelijk te maken. Bij de oranje loper zijn er veel hulpbruggen en daar is een ontwerptraject gestart met de omgeving om deze mooi te maken. Die bruggen liggen er jaren. Dat zijn dingen die je kan doen om de leefbaarheid te vergroten. Terrassen kan je misschien ook wel deels kwijt op een tijdelijke brug als je deze iets breder maakt.

6. Opmerkingen tussendoor (tijdens laten zien SD)

- **Toevoeging op SD**: Wat nog moet worden toegevoegd zijn parkeerplekken, gehandicaptenplekken en slechte kades. Als je een brug wil gaan bevestigen voor een langere tijd moet de kade waaraan dat gebeurt dat wel aankunnen. Een kade hoeft niet per se vervangen te worden maar kan wel te zwak zijn voor een hulpbrug.

- Binnen de Gemeente Amsterdam is er vanuit het Programma Varen gevraagd of een aantal bruggen opgehoogd kunnen worden zodat de vaarroutes beter gebruikt kunnen worden. Het gaat dan om een x aantal centimeters. De vraag is dan of het zinnig is om één brug een beetje op te hogen als vervolgens de andere bruggen op die vaarcorridor nog niet worden gedaan, en dit daar een brug in die net 3 jaar terug is gedaan die niet zo hoog is. Wat je dan gaat doen is iets dat integraal binnen de gemeente moet worden besloten (hoe ziet het hele netwerk eruit). Dit is echt iets waar het bestuur iets over moet zeggen wat de ambitie is op lange termijn wat er verbeterd moet noemen en wat daarvan het prijskaartje is.

7. Antwoorden vragen deel 3/3

- **Verwacht je nog meer dingen op de randen? Is het logisch?** Beleid van de gemeente is iets waar je ook controle over hebt. Vaak wordt er iets besloten wat vervolgens niet past met andere projecten/programma's (beleid ten aanzien van autoluw, bomen, ...). Er spelen zaken in de omgeving en die hebben invloed op je programmering. Op korte termijn heb je te maken met bepaalde grootschalige particuliere verbouwingsopgaven die invloed hebben op een lokaal iets. Dat is allemaal onderdeel van je stakeholderanalyse. Maar in de programmering zagen we net dat we daar wel een eerste beeld van willen hebben. Er zijn natuurlijk een aantal projecten/programma's binnen de gemeente bekend zijn, maar die kunnen heel veel invloed gaan hebben. Tijdens de vergunningaanvraag kan je er wel degelijk invloed op uitoefenen (niet de bouwaanvraag maar de WIOR-aanvraag). Bijvoorbeeld bij prinsengracht is er een verbouwing van het paleis van justitie en dit heeft enorm veel invloed. Ze kunnen niet tegelijk een brug en kade aanpakken en die verbouwing, en die verbouwing duurt gewoon 3 à 4 jaar. Wat ook lastig is qua techniek de staat van de panden in de omgeving. Als de staat heel slecht is kan je gebouwen wel aanschrijven dat de fundering herstelt moet worden, maar dat zijn projecten die jaren duren. En ik kan mij indenken dat in de nabijheid van een brug heel veel gebouwen in een slechte staat zijn. Soms kan je met andere bouwmethoden zetting van slechte panden in de omgeving voorkomen, maar dat is niet altijd zo (ook weer techniek).
- **Mis je dingen in het midden van de SD?** Wat er nog ontbreekt zijn de trafo-stations (transformatorhuisjes). Het is ook vaak een opgave om meer capaciteit te creëren. En dat op elkaar afstemmen is vaak een hele klus. Maar als een trafo-station er al staat heeft dit veel invloed, ook op je kosten. Soms kan je het verplaatsen maar vaak ook niet omdat er geen ruimte is in de openbare ruimte. Dit is dan ook echt een externe factor waar je veel last van kan hebben en ook echt je variantenstudie kan beïnvloeden. Je zei het al, de monumentale bomen, dit is een enorme issue in Amsterdam. Geldt ook voor niet-monumentale bomen. Verder ook denken aan vleermuizen etc. (meer standaard).
- **Is het een logische om met deze categorieën te werken qua criteria?** Ja, in Amsterdam moet elk project dat invloed heeft op de verkeersmodaliteiten moet een BLVC-plan (Bereikbaarheid, Leefbaarheid, Veiligheid, Communicatie) maken waarin je omschrijft wat de effecten zijn van je werk en hoe je deze beheerst. Vroeger alleen in Amsterdam maar misschien nu ook wel in andere gemeenten, is een hele handige methode. Is een plan dat moet worden goedgekeurd door de afdeling Stadsregie want die toetsen het weer op raakvlakken met andere projecten die al vergund zijn. Dat is iets wat je zelf natuurlijk ook moet checken maar zij geven het finale akkoord of je ook daadwerkelijk in dat tijdvak aan het werk mag gaan.
- **Hoe maken jullie als gemeente de afweging tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?** Goede vraag, dit weet ik helaas niet maar ik verwacht dat het maatwerk is. Alle disciplines zijn op zich geborgd in de besluitvorming maar wat helpt is om van tevoren te bepalen wat je minimale BLV is: wat moet er ten minste worden geregeld? Dit hangt natuurlijk er ook vanaf hoeveel geld er beschikbaar is binnen de gemeente. En dan kijken hoeveel geld er beschikbaar is voor extra naast de minimale BLV. Vroeger gingen we heel vaak voor zo min mogelijk hinder en iedereen blij houden, maar als er minder geld is accepteer je ook eerder dat niet meer kan doen. Het is ook niet zo dat kort en hevig altijd beter is dan lang en minder hevig, het is altijd weer maatwerk. Idealiter zou je dat ook binnen de omgeving die vraag neerleggen. Bij het Leidseplein kwamen we erachter toen we net klaar waren met het maken van een waterdichte wand dat we heel dicht op de terrassen van de ondernemers kwamen. Door die dichte wand zou er toch te veel waterstuwing zijn waardoor er een drain moest worden aangelegd. Het was april (dus het mooie weer begon net). Voor het aanleggen van de drain qua planning en geld maakte het voor de gemeente niet uit wanneer het zou plaatsvinden. Daarom kon er aan de omgeving worden gevraagd wat zij liever hadden: in de winter volgend jaar wordt de drain aangelegd, maar je moet nu dan nog wel even wachten op nieuwe mooie bankjes en bomen OF nu doen en dan kan je de komende 3 maanden je terras niet opzetten, maar dan is het wel gelijk helemaal af. Uiteindelijk gaf de horeca aan dat ze het liefst optie 1 hadden. Dit kan natuurlijk niet altijd, deze keuze is gegeven omdat alle opties waren financieel en qua planning vergelijkbaar, dan is OM onderscheidend. Het kan ook zijn dat het voor omgeving beter is, maar dat het wel veel duurder

is of langer duurt. Dan wordt het een veel lastigere integrale afweging, die soms bestuurlijk wordt. Het blijft een bestuurlijke afweging: wat vinden we acceptabel? Is vooral belangrijk dat die minimale eisen vaststaan.

8. Afsluiting

- **Welke andere mensen zijn interessant om te spreken?** Leuk als ik ga praten met Katinka Fledderus kan ik mee gaan praten, is BLVC-specialist werkt voor PBK. Zij heeft de scan voor gebied bij Leidsestraat gemaakt. Kan ook meer vertellen over hoe dingen bij de gemeente werken.
- **Tips?** Dit is heel blauw; goed voorbereid, goed meegenomen in denkproces. Voor uitleggen framework wel handig als ik per stapje even stilstaat hoe het werkt bij Amsterdam. Anders vergeet ze ondertussen wat ze had bedacht. Gelijk vragen laten stellen. Veel was logisch hoor, maar mensen meteen laten reageren haal je misschien meer op.

C.2. Interview B

1. Voorstellen

- **Huidige functie/ervaring**: Rombout Jongejans is nu anderhalf jaar werkzaam bij de Gemeente Amsterdam. Functie formeel: taakveld trekker programmeren. Programmeren gaat over welke brug en kademuur doen we in welke volgorde in de stad.

2. Opmerkingen tussendoor

- De neiging is, in een politieke organisatie zoals Amsterdam, dat iedereen voor z'n eigen belang gaat. Nu getouwtrek welk belang voorop staat. Als het goed is staan bereikbaarheid, veiligheid en leefbaarheid voorop, dat staat in alle documenten. Veiligheid gegarandeerd door veiligheidsketen dus het systematisch plannen gaat langs de lijnen van bereikbaarheid en leefbaarheid. Je kan ook zeggen dat het langs de lijn van de techniek moet, maar daar is niet genoeg kennis over. Als je 30 bruggen wil kiezen moet je wel uit een batch van 100 kunnen kiezen.
- Een ander groot uitgangspunt is gebiedsgericht werken. 1x kort maar hevig i.p.v. lang en minder hevig. Perceptieverschil tussen wat de gemeente kort en hevig noemt en de burger. Burger denkt aan 3 maanden en gemeente aan 2 jaar. Weten niet echt of de burger liever kort maar hevig heeft dan lang en minder hevig.
- Verder moet je werk met werk maken, dus kadeprogramma tegelijk laten lopen met bruggen programma. Programmering opgebouwd aan de hand van wat we het belangrijkst vinden, de bereikbaarheid van de stad met de trams, dus de ov-corridors. Daarvan mogen er niet twee tegelijk uitvallen.
- Budget van 150 miljoen naar 83 miljoen, dus programmering gaat weer worden aangepast.
- Nu bezig met oranje loper, 7/8 bruggen, al het verkeer gaat daardoor de stad uit en de brandweer de stad in. Door die bruggen lopen alle kabels, incl. internet. Kabels moeten naar de hulpbrug, het gaat om 1800 kabels, hele brug ligt vol. Het wordt wel teruggedaan in mantelbuizen. Verder kloppen de tekeningen vaak niet.
- Programma wordt bijgesteld en gaan nu veel minder bruggen doen. Eerst 8/9 per jaar en 2km kademuur. Gaan nu naar 2 bruggen en 1200m kademuur. Heeft er mee te maken dat er al contracten zijn voor kademuren. Na 2026 wil PBK terug naar de oorspronkelijke doelstelling 2 km en 8 bruggen per jaar.
- Een brug heeft veel meer impact op de bereikbaarheid dan een kademuur. Als die instort is het heel vervelend maar een brug waar 20 trams per uur overheen rijden. Ook al rijdt er geen brug overheen kan het heel onhandig zijn. Wel zijn er stukjes in de stad waar heel veel bruggen zijn en dan is het wat minder erg, mensen kunnen daarvoor wel omfietsen. Ook al zijn de buurtbewoners het daar niet mee eens.

- Andere steden in NL staan al voor dit probleem. Gouda, Den Haag, Utrecht, Delft etc. Ook algemeen probleem dat we geen geld over hebben in NL voor harde infrastructuur. Enige reden waarom het nu nog goed gaat is dat er vroeger veel overdimentioneerd is.

- Interessant in mijn casus is dat de beslissing om van 150 naar 83 miljoen niks te maken heeft met de noodzaak tot vervanging maar de politieke wens. Dat is in dit geval heel sturend geweest. Men heeft geen zin om geld te besteden aan infrastructuur maar aan andere dingen, staat op de partij-agenda. Het gaat dus niet altijd vanuit het technische oogpunt. Qua hoeveelheid geld krijgen gaat het er heel erg om over hoe je het organiseert en hoeveel bestuurlijk lef je hebt. Het probleem is dat je 5/6 jaar bezig bent voordat je aan een brug begint. Dus als je je programma niet financiert over de collegeperiode heen. Begroting alleen over de periode waarover de gemeente gaat, wat dus tot een conflict leidt met langdurige opgaven zoals deze. Je moeten een lange horizon hebben. Den Haag vindt het bijvoorbeeld heel belangrijk en geeft voor 10 jaar lang een bedrag, en dan kan je iets. Als je iedere 4 jaar het weer om moet gooien is dat heel bepalend voor je programmering. Gaat er dus om hoe de governance geregeld is. Gamechanger (qua budget) is ook zeker als er dingen instorten, zijn nu ook weer recentelijk 2 sinkholes geweest bij kades in Amsterdam. Nu hebben ze dan toch weer de neiging om toch maar weer meer geld aan het programma te geven.

3. **Antwoorden vragen deel 1/3**

- **Hoe gaat het proces op dit moment?** Persoonlijk vind ik dat we naar een model toe moeten waarbij we langdurig stabiele financiering hebben. Hierdoor wordt er rust gecreëerd in een programma. Dat er wordt geprogrammeerd vanuit de bereikbaarheid van de tram vind ik persoonlijk nog steeds de beste manier. Ik vind dat we te veel aandacht hebben voor kleine bruggen die weinig impact hebben op de stad. Ik zou 90% van het budget besteden aan de belangrijkste 40 van de 800 bruggen en die met absolute prioriteit. Op dit moment is het niet zo georganiseerd, nu zijn we gebiedsgericht bezig, maar absoluut niet met de belangrijkste bruggen. Als je aan iemand zou vragen wat de belangrijkste brug is krijg je geen antwoord. Naar mijn mening is de belangrijkste brug 'brug 198 – Oeterwalerbrug' omdat aan het einde van de lijn de trams onderhouden worden, 25 per week. Als die brug er niet meer is moeten er 50 tot 60 trams op een dieplader per week laden. Brug staat al in een veiligheidsconstructie. Het is ook geen makkelijke brug qua constructie en weinig ruimte in de omgeving.

4. **Opmerkingen tussendoor (tijdens laten zien CF)**

- **'Choosing bridges'**: het is belangrijk dat je je selectiecriteria voor hoe je die bruggen kiest beschrijft. Hoe urgent moet het zijn? In Amsterdam hebben we dus bruggen gekozen aan een corridor maar je kan ook kiezen om alleen de bruggen in slechte staat mee te nemen. Maar het effect daarvan kan zijn dat je de tram eraf gooit en een paar jaar later dat opnieuw moet doen omdat dan een andere brug in een slechte staat is. Hangt er dus vanaf of je qua criteria gaat sturen op urgentie, techniek, bereikbaarheid (per corridor? Per gebied?).

- Arbo veiligheid een issue bij gefaseerd bouwen. We hebben tot nu toe vaak zo veel mogelijk gebruik toegestaan tijdens de werkzaamheden. Wat leidt tot veel risico's voor de mensen die aan het werk (bijvoorbeeld omdat ze schikken van voorbijgangers die opeens op een rare plek zijn) en de voorbijgangers zelf. Bijvoorbeeld met hijskranen en beton verplaatsen. Daarom wordt er gestreefd naar totale afsluiting. Alleen de tram eroverheen laten rijden is nog wel goed te plannen. Dus vooral het probleem zit bij fietsers en voetgangers die overal doorheen lopen. Toegankelijk houden voor een tram is vaak niet mogelijk. TBGN-en worden ook steeds langer door deze veiligheidsissues.

- **Verschillen per gemeente**: Den Haag is er een langetermijn budget dus heeft een hele andere visie ten opzichte van infrastructuur in vergelijking tot Amsterdam. Verschilt ook per stad hoeveel inspraak de burgers krijgen.

- **'Re-run'**: politiek gezien dus heel moeilijk. Maar technisch inhoudelijk heb je zeker gelijk.

5. Antwoorden vragen deel 2/3

- **Is de outline van het conceptuele framework logisch?** Er zit een logica in, maar het politieke proces zit er niet in. En in het geval van Amsterdam is dat politieke proces heel bepalend.

- **Komt dit overeen met wat er in de praktijk gebeurt?** Op technisch vlak streven we hiernaar. Maar voor de uiteindelijke besluitvorming is het politieke deel dominanter.

- **Waarom worden er maar een x aantal bruggen per jaar aangepakt?** We hadden veel moeite om aan de 8 bruggen per jaar te komen. Dit nu omlaag door de keuzes uit de politiek. Dit kwam door de voorbereiding, kennis, weerstand en doorpakkend vermogen en waar allemaal rekening mee gehouden moest worden. Ook speelt de aansturingcultuur binnen de Gemeente werkt. Dus naast het aantal mensen ook de heersende cultuur. Deadlines worden makkelijk verplaatst. Ik ben zelf vrij scherp op de deadlines maar veel mensen zijn dit niet. Om bijvoorbeeld 20 bruggen tegelijk aan te pakken zou kunnen qua bereikbaarheid, maar dan moet je wel echt over de hele stad werken. Die 8 zijn bijvoorbeeld in een geconcentreerd gedeelte. Aannemers zijn er genoeg. Nu dus gekort door het budget.

- **Waarom is er weinig informatie bekend over de bruggen?** Omdat kennis van infrastructuur niet 'sexy' is. Je hebt het alleen nodig op het moment dat je het gaat vervangen/onderhouden. Het is ook veranderd en er zijn normveranderingen. Eerst centraal in Amsterdam opgeslagen, toen naar stadsdelen gegaan, net als de archieven. In deze verhuizing veel informatie verdwenen. Daarna is omdat de stadsdelen het niet oppakte (deden alleen dingen voor de korte termijn), waardoor de informatie dus letterlijk weggegooid. Later alsnog gecentraliseerd omdat het toch wel pijn ging doen, maar de gegevens zijn er al niet meer. En nu kost het weer heel veel tijd en geld om het te doen, sommetjes moeten worden gemaakt qua staat en restlevensduur. Maar zodra je alles weer weet kan je ook weer miljoenen besparen. En je kan waarschijnlijk ook vaak concluderen dat de status niet meer helemaal goed is maar het nog wel 20 jaar blijft staan. Is ook niet heel erg om voor ene miljoen onderzoek te doen naar een brug om te concluderen dat die nog 20 jaar kan blijven staan. Gemeente hier dus nu hard mee bezig. Gemeente heeft enigszins de verplichting om aan te kunnen tonen wat de staat van een brug is, hier zit echter wel wat speling in. Als de Omgevingsdienst (OD) aangeeft dat een brug niet meer voldoet, mag de gemeente met een berekening aantonen dat het nog wel kan.

- **Welke strategieën zijn nog meer mogelijk?** De ProRail methode is ook nog mogelijk. Maak een nieuw landhoofd en een nieuwe brug, deze nieuwe brug zet je er nog heel even naast. Vervolgens haal je voor een korte tijd alles van de brug af en de brug weghalen en zet je de nieuwe brug erin. Dus kleine buitengebruikname van de tram en de andere modaliteiten. ProRail gebruikt deze manier veel, want het spoor kan er niet lang uit liggen. Is dus een manier van gefaseerd vervangen. Wel heel erg duur. Veel duurder dan een hulpbrug, 2 à 3 keer die kosten. Als je het zuiver bekijkt moet je naar de life cycle kosten kijken maar ook de buitenbedrijf verliezen. Wordt niet goed meegenomen vaak. Bij de hoogovens was dat echt het allerbelangrijkst. Niet te veel rammen worden de risico's groter bij de in gebruik name, dus aan het einde weer even rustig aan doen om te zorgen dat het helemaal correct is afgerond.

- **Haalbaarheid strategieën?** Heel afhankelijk van de situatie welke strategie mogelijk is, maar allemaal worden weleens gedaan in Amsterdam.

- **Wat voor een impact/effect heeft het afsluiten van een brug op de stad?** Belangrijkste impact zijn de nood- en hulpdiensten. Die wordt vaak heel erg onderschat. En dan heb je het niet alleen over de brandweer. Brandweer gaat meestal nog wel maar de ambulance en het reddingsvoertuig zijn vaak het probleem. Reddingsvoertuig is het voertuig waarmee iemand vanaf een paar hoog naar beneden moet worden gehaald. Brandweer kan er vaak wel doorheen omdat die iets smaller is het vaak geen probleem. Eerst mocht er bij het vervangen van een kade maar 35m tegelijk worden gedaan omdat de slang van de brandweer 17m lang is. Aannemers willen eigenlijk liever 120m in één keer aanpakken. Nu is er bedacht dat er onderaan het bouwhek een brandleiding ligt die om de 17m een aftappunt heeft en aan het uiteinde is er parkeerplek om de pompauto neer te zetten. Dit is dus vaak eentje die snel wegvalt als er naar impacts/effecten wordt gekeken.

- **Verschillende impacts/effecten per scenario?** Verschillen heel veel of je corridor doet of verspreiden. Door het kiezen voor een corridor en gebiedsaanpak is het scenario van het verspreiden door de stad eigenlijk nooit echt als een scenario ernaast gelegd. Die corridor aanpak heeft een veel grotere vlekwerking. Het scenario van verspreiden door de stad is een beetje wegberedeneerd omdat we het principe 'kort en hevig' hebben, ook al kan deze misschien wel eens herzien worden. Aan de ene kant maakt 'werk met werk maken' is heel voordelig, maar alles zit op alles te wachten waardoor het heel gecompliceerd wordt. Hier nu discussie over gaande omdat bijvoorbeeld een rails vervangen maar 3 ton is moet je dan wel heel erg veel moeite doen om al die projecten tegelijk uit te voeren? Nu aantal situaties in de stad waarbij de trambaan heel urgent vervangen moet worden. Ook al zijn de gevolgen beter te overzien wanneer het misgaat aangezien een tram maar 25km/h gaat in vergelijking tot andere modaliteiten die rails gebruiken met een hogere snelheid.

- **Karakteristieken stad die een grote rol spelen?** De Amsterdammer; heeft een grote mate van eigendunk en kan goed voor zijn belangen opkomen. Politiek zeer geëngageerd, zeker in de binnenstad. Hier is het al heel complex maar hierdoor wordt het nog complexer. Collega vertelde dat het probleem van het programma helemaal niet de techniek is maar het probleem van het programma is omgekeerd evenredig met het aantal juristen per km. Bijvoorbeeld een wisselplaatslocatie waar steeds tijdelijk woonboten heen worden geplaatst wordt heel veel over geklaagd. Hiernaast is karakteristiek aan Amsterdam is dat enorm veel en hele oude grachten zijn. Is echt om de 50m een brug, dit kost ook geld. De Amsterdamse cultuur bepaald dus heel veel. Rondvaartboten lobby is ook behoorlijk sterk maar uiteindelijk laten toeristen zich niet echt afschikken hierdoor, is meer een detail. Overlast van de toeristen is juist ook heel erg een spanningsveld. Door corona nu minder, maar moeten we wel terug willen naar de oude situatie. Is natuurlijk wel een grote inkomstenbron. Side verhaal: OV in stad minder in gebruik nu na corona, GVB verliezen, bezuiniging en daardoor minder OV inzetten waardoor het gebruik uiteindelijk nog meer afneemt. Eigenlijk visionair denken en zorgen dat OV blijft bestaan voor de bereikbaarheid van Amsterdam. Termijnagenda van 4 jaar die wordt gedaan past dus niet bij de grote opgaven waar de stad voor staat. Dit probleem is van alle tijden, was ook het geval bij de afsluitdijk.

- **Hoeveel jaar vooruitplannen?** Voor ons 20 jaar. In blokken van 2 jaar in detail. Was tot 2040 helemaal vastgesteld maar staat nu dus weer op losse schroeven. Planning van 20 jaar verder nog niet in beton. Maar wel een hoofdprogrammering.

6. Opmerkingen tussendoor (tijdens laten zien SD)

- **Aanbestedingsrecht toevoegen**: Europees aanbesteden moet worden toegevoegd als external factor. Alle regels die daarbij komen kijken ten aanzien van transparantie moet je aan denken en alle openbaarheid die daarbij hoort. Een vraag van een inschrijver moet je ook naar de andere inschrijvers sturen. Je kan bijvoorbeeld niet zomaar een bloementje halen voor een zieke medewerker, aangezien als die kosten jaarlijks over de aanbestedingsgrens heengaat moet het worden aanbesteed. Ditzelfde geldt voor lunches etc. Die regels die knellen dus ook. Kademuren zijn al aanbesteed, en nu is er opeens minder budget. Dan kan je dus niet zomaar terug. Aannemers hebben dan rechten. Aanbesteding is zo kritisch omdat de accountantscontrole, met name de rechtmatigheidscontrole voor de raad afhankelijk is. Als jij je materiaal inkoopt waarvan een paar procent niet rechtmatig (dus niet volgens de regels) is gekocht krijg je geen rechtmatigheidsverklaring. Dan krijg je een niet-rechtmatigheidsverklaring, de beleving van je journalistiek is dan dat je bedrijf een boevenbende is, wat leidt tot reputatieschade.

7. Antwoorden vragen deel 3/3

- **Verwacht je nog meer dingen op de randen? Is het logisch? Mis je dingen in het midden van de SD?** Scopebepaling: op dit moment moeten we de Dacosta kade aanpakken. Deze kade is in een best wel slechte staat. Ook veel monumentale bomen en woonboten. Omdat de woonboten te hoog zijn moeten ze een beetje worden afgezonken zodat ze onder de brug door kunnen komen. De bruggen zijn geen onderdeel van de scope van het Dacosta project. Bruggen zijn ook niet zo goed en worden als risico gezien. Nu dus het probleem dat als de woonboten eruit worden gehaald en de brug vervolgens misschien in een veiligheidsconstructie moet worden gezet en daardoor de woonboten niet terug kunnen. Dit heeft te maken met hoe je de scope van je project hebt gedefinieerd. Bijvoorbeeld bij de afsluitdijk liep het allemaal vast. Vervolgens is de scope kleiner gemaakt om zo wel binnen budget te blijven om vervolgens alsnog meer geld kwijt te zijn aan het resterende stukje scope die dan opnieuw wordt aanbesteed. Verder ziet het er allemaal goed uit, alleen dus aanbestedingsrecht en scopebepaling nog meenemen.

- **Is het een logische om met deze categorieën te werken qua criteria?** In Amsterdam wel, omdat dat hier zo gedefinieerd is
- **Definities?** Veiligheid is hoeveel risico je loopt dat er iets gebeurt. Bereikbaarheid zoals verkeersmodel Amsterdam en ook eenvoudigere versies. Er zijn ook modellen waar je kan zien als je een brug eruit gooit wat het effect is van de reistijd van verschillende postcodes. Wel altijd in je achterhoofd houden dat het model niet de waarheid is maar een versimpeling van de werkelijkheid. Waar je ook goed op moet letten is dat er veel statistiek in zit en er causaliteit bestaat.
- **Hoe maken jullie als gemeente de afweging tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?** Beoogd strak te sturen op het budget. En als we daar overheen gaan moeten we zo dicht mogelijk bij het budget blijven. Een zo goed mogelijke optie vinden die binnen het budget valt. Als je een heel mooi verhaal hebt kan je soms meer budget krijgen. Eigenlijk zou de discussie moeten zijn dat je optie 1 hebt met een kans op een dodelijk ongeluk van 10% voor bedrag x, eigenlijk te veel en optie 2 is 2x zo duur maar een veel kleinere kans. Maar zo scherp is de afweging eigenlijk nooit. Een probleem is dat het een politieke organisatie is waardoor bepaalde pijnpunten niet geformaliseerd moeten/kunnen worden. Bijvoorbeeld zo'n veiligheidsrisico wordt dan weggeschreven als 'wij doen ons uiterste best om te zorgen dat de veiligheid niet in het geding komt' en op dat vlak worden dan allemaal procedures aanscherpen en verbeteren en verwachten daarmee het risico te beheersen'. Dus een additioneel risico wordt op die manier politiek weggeschreven. Value of life wordt vaak niet meer echt gebruikt. De veiligheidsinspectie is wel heel erg laks naar overheden, er wordt niet echt gecontroleerd. Wordt ook niet goed aangehouden. Werkvergunning, werkvergunning hoog, veiligheidsslot, nog niemand over gehoord. Vanuit de hoogovens werd alles met een veiligheidsslot gedaan, dus door dat slot omdat iemand er mee bezig is kan de installatie niet worden aangezet. We kennen die procedures niet die in het bedrijfsleven wel worden gedaan. Verschilt per bedrijf hoe ze omgaan met een incident, of de hoogste baas terugkomt van vakantie of niet. Bedrijf ook verantwoordelijk voor woon-werkverkeer, dus sommige bedrijven geven werknemers een slipcursus en zetten overal trapjes neer zodat mensen niet op stoelen gaan staan. Kosten als 1 iemand valt kan je echt 100 trappen van kopen.
- **Hoe kan de beslissing van 1 brug vertaald worden naar de grotere schaal?** Ik zou hem omdraaien, dus van grof naar fijn. Je kijkt bijvoorbeeld naar 5 bruggen en die koppel je aan elkaar, daar zit een bepaalde logica in. En als ze gekoppeld zijn gaan we ze zo uitvoeren. Je kijkt of je aan elkaar gekoppeld zijn, bijvoorbeeld door de tram, hoofdstraat of een belangrijke fietsroute. Bijvoorbeeld de staande mastroute; door Amsterdam kan je met alle hoogtes varen op 2 routes; hier kunnen alle bruggen open kunnen. Als je hiervan 1 brug aanpakt waardoor deze niet meer beweegbaar is ligt die hele route eruit, hiermee moet je ook rekening houden.
- **Hoe gaat Amsterdam om met auto's?** Auto heeft zijn positie verloren, wordt vooral voor langzaam verkeer en OV geprogrammeerd. Ook qua parkeerplekken zie je dat die ruimte minder aan de auto wordt gegund. Burgers naar nieuwe parkeergarages en parkeerplekken in de stad opgeheven. Modellen zeggen dat 60% van de auto's van bewoners zijn en gemiddeld 1x per week bewegen. Waar mensen ook veel hun auto gebruiken is opslag, bijvoorbeeld de kinderwagen als je op 3 hoog woont. Zou je niet naar deelauto's moeten of buiten de stad parkeren? Deze autocongestie die zie je ook bij fietsen gebeuren. Fiets parkeren op de stoep is te groot en nu heb je ook nog eens die bakfietsen die nog meer ruimte innemen. Fat bikes zijn nu ook helemaal populair omdat die geen helmplicht hebben wat de scooter wel heeft.

8. Afsluiting

- **Wat voor een soort framework is zinvol?** Ik denk dat het vooral heel goed is omdat het je leert nadenken over hoe je naar je eigen systeem kijkt. Dus het inzichtelijk maken en op een betere manier kijken van wat wij nou anders doen dan een andere stad. Ik hamer dan heel erg op het politieke systeem, misschien vinden sommige mensen dat weer overdreven, als je als andere stad een lumpsum krijgt van 10 jaar. Dan zou je hier niet zo op hameren. En dan wordt het veel meer een technocratische oplossing terwijl het hier vooral politiek is.
- **Iemand anders?** Brug is eigenlijk een openbare ruimte dus het gaat over werken in de openbare ruimte. Maar dan trek je m breder. Je zou nog eens met Ronald Damstra kunnen spreken, hoofd TCVK, technische man van de bruggen. Komt uit de aannemerij, heel beschouwend over het proces en het krachtenveld dat er zit. Hij bekijkt het totale plaatje.
- **Tips?** Geen, leuk gesprek

C.3. Interview C

1. Voorstellen

- **Huidige functie/ervaring**: Cyntha Nijmeijer vertelt dat zij bijna 4 jaar werkt bij Witteveen+Bos binnen de afdeling planstudies en procesmanagement, nadat zij de Master Engineering & Policy Analysis aan de TU Delft heeft afgerond. Deze afdeling is het meest gericht op het maken van keuzes in projecten. Welke informatie heeft onze opdrachtgever nodig om een beslissing te kunnen nemen? Vaak voor verkenningen in dijkversterkingen of snelwegprojecten, maar ook vaak beleidsvraagstukken over o.a. havens. Het gaat vooral om het samenbrengen van alle informatie van alle disciplines binnen Witteveen+Bos. Waar ik zelf veel mee bezig ben zijn MCBA's en milieueffectrapportages voor allerlei projecten.

2. Antwoorden vragen deel 1/3

- **Hoe gaat het proces op dit moment?** *Cyntha geeft aan dat ze dit niet weet.*

3. Opmerkingen tussendoor (tijdens laten zien CF)

- **Opmerking over blokje 'choosing bridges'**: Cyntha vraagt of je alle bruggen meeneemt die in een slechte staat zijn. Ik geef aan dat dat vaak niet lukt omdat je dan enorm veel verschillende scenario's krijgt. Cyntha merkt op dat het dus een capaciteitsprobleem is dat je niet alles mee kan nemen. Ik vertel dat je idealiter natuurlijk wel alle bruggen mee zou willen nemen. Cyntha geeft aan dat je in ieder geval alle bruggen in een slechte staat wil meenemen.
- Verder moet het wel nog duidelijk worden hoe vaak je dit framework moet doorlopen en door wie? Is dit 1 groep die het gehele proces hetzelfde blijft? Welke mensen zijn hierbij? Zit is voor mij iets om over na te denken. Je hebt dan waarschijnlijk iemand nodig die iets weet over de constructie van de brug, iemand over verkeer en bereikbaarheid en iemand voor leefbaarheid.

4. Antwoorden vragen deel 2/3

- **Is de outline van het conceptuele framework logisch?** Het framework is logisch maar het kost wel tijd om hem te snappen, ook omdat er veel feedbackloops in zitten. Dus waar ik nog wel benieuwd naar ben is dat het uiteindelijk natuurlijk een lineair proces wordt omdat de tijd lineair is. En dit proces is nog heel iteratief namelijk door de feedbackloops. Hoe gaat dat eruitzien? Ben je hier een jaar mee bezig qua doorlopen? Je kant dit zowel in 1 dag doorlopen als je met 10 experts zit en de hele dag samen zit. Maar je kan ook hele modellen laten lopen, bijvoorbeeld voor de bereikbaarheid als je een tram eruit haalt. Wat is volgens mij nodig om dit goed te doen. Is het prima om 10 experts samen te zetten of wil je het echt met modellen doen? De meeste gemeenten hebben wel modellen maar het veel tijd kost en geld. Dus weet niet of ze het echt zouden toepassen. Dus toevoegen aan het framework welk detailniveau van de informatie ik wil hebben. Moet bijvoorbeeld de 'information bridges' en 'information impacts/effects' super gedetailleerd zijn of is dat niet nodig? Dus wat gebeurt er in de praktijk en wat zouden mensen doen in de ideale situatie?

- **Komt dit overeen met wat er in de praktijk gebeurt?** Ik weet niet hoe programmering van bruggen in de praktijk gaat maar het sluit wel aan bij andere projecten. Dus dat je van verschillende scenario's bekijkt wat de effecten zijn en op die manier je keuzes maakt.

- **Welke methode per onderdeel framework logisch om te gebruiken?** Voor 'choosing bridges' zou ik voor de MCA gaan. Omdat je daar ook denk ik een hele duidelijke ranking hebt van belangrijk is. Volgens mij is de staat van de brug het allerbelangrijkst dus dan kan je daar een hoge weging aan geven. En alle andere criteria van je lijstje kan je dan ook een weging geven. Bij 'testen scenario's' zou ik eerder zonder weging doen maar aangeven wat de effecten zijn. En dan is het eigenlijk iets heel bestuurlijks hoe daarmee om moet worden gegaan en wat er belangrijk is. Ik weet niet of dat iets is wat je zelf moet willen doen. Dus je kan prima een MCA gebruiken maar met de weging overal hetzelfde, zodat je objectief zegt wat het effect is en de gemeente de keuze laat maken. Terwijl je bij 'choosing bridges' nog wel zelf de keuze kan maken. 'Choosing bridges' is minder een mening maar meer een gegeven. 'Strategie per brug' denk dat dat ook vrij technisch is. Voor het bepalen van de effecten zit ik wel meer aan verkeersmodellen en geluidsmodellen. Dus dat is niet zo zeer de keuzemethode maar de methode voor het verkrijgen van informatie.

- **Wat zijn impact/effecten dat het afsluiten van een brug heeft op de omgeving?** Op de doorstroming van het verkeer, verkeersstromen gaan heel anders lopen, dus andere stukken worden drukker of juist minder druk, dus de impacts op de bereikbaarheid. Tijdens het vervangen van de brug heb je natuurlijk effecten van de bouw zelf zoals overlast van stof, geluid, luchtkwaliteit etc. Maar ook doordat je de verkeersstromen veranderd heeft dat weer invloed op de leefbaarheid in andere delen van je stad. Als bijvoorbeeld 1 weg helemaal vastloopt hebben mensen die daar omheen wonen daar ook last van, dus op veel grote schaal dan de mensen die aan de afgesloten brug wonen. Bereikbaarheid is al genoemd. Kunnen de boten er nog onderdoor varen? Heeft ook invloed op de recreatievaart. Het is eigenlijk heel breed. Waterkwaliteit lijkt me niet echt van toepassing, is waarschijnlijk al niet al te best. Monumentale bomen, cultuurhistorische landschapselementen moet je ook wel naar kijken. Een boom kan je niet tijdelijk verplaatsen. Bereikbaarheid voor bedrijven is er ook eentje. Voor bewoners is het natuurlijk vervelend maar de bedrijven krijgen natuurlijk minder klanten wat leidt tot economische effecten.

- **Welke scenario's zijn logisch om te maken?** Als eerste zou ik denken verspreiden aangezien je dan de effecten meer verspreid. Dan heb je overal het hele jaar door een beetje last. Aan de andere kant is dat ook misschien wel duurder, dat weet ik niet. Aan de andere kant hebben mensen misschien liever 1 jaar 1 weg eruit dan 10 jaar telkens iets, dat vind ik moeilijk in te schatten. Ik denk dat dat ook juist iets is om mee te nemen in het testen wat daarin naar voren komt. Ik zou de scenario's daarom heel breed kiezen wanneer je de eerste keer het framework doorloopt (1 in lijn, 1 verspreid) en dat je aan de hand van de effecten daarvan kan kijken wat het fijnst voor mensen is en wat het goedkoopst. Dit is dus echt iets wat je in het testen van de scenario's mee moet nemen. Effecten verschillen dus zeker per scenario.

- **Karakteristieken stad die veel invloed hebben op welke effecten en impacts een rol spelen?** Ik zou wel van al die steden in ieder geval in beeld brengen hoe het nu is met de verkeerssituatie. Loopt het nu al overal vast? Als voor de ene stad er niks aan de hand is als je iets afsluit en voor de andere wel is dat iets wat je mee moet nemen in je framework. Verder is het denk ik redelijk vergelijkbaar. Schaal is wel anders, maar ik neem aan dat je in Amsterdam meer bruggen per jaar aan kan pakken dan een Utrecht. Waar je ook nog wel naar kan kijken is welke middelen een gemeente heeft. Net als de verhouding tussen hoeveel bruggen zijn er totaal, hoeveel kunnen er per jaar vervangen worden en hoe veel middelen heeft de gemeente. Als dat heel erg verschilt tussen steden is dat ook iets waarmee je rekening mee moet houden in je framework.

- **Hoeveel jaar vooruitplannen?** Ik zou het gedetailleerd niet al te ver vooruitplannen, misschien 5 jaar. Omdat er natuurlijk nog veel meer andere projecten zijn in de stad waar rekening mee gehouden moet worden, bijvoorbeeld kruispunten. Of je moet zorgen dat je wel ver vooruit plant en de kruispunten maar hiermee rekening moeten houden. Dus ik zou zeggen niet al te ver vooruit. En dus ook in samenhang met alle andere afdelingen. Ik zou wel een globale indeling maken van welke bruggen binnen 5 jaar moeten gebeuren, welke binnen 10 jaar, binnen 50 jaar etc. zodat je wel zicht houdt op de urgente bruggen.

5. **Antwoorden vragen deel 3/3**

- **Verwacht je nog meer dingen op de randen? Is het logisch?** Ik vind livability vrij breed, veel breder dan bijvoorbeeld accessibility dus daar valt heel erg veel onder. Bereikbaarheid wel apart gecategoriseerd en niet onder leefbaarheid. Wat je nog als externe factor of als middel (=mean) kan zien zijn die andere gemeentelijke projecten. Aan de ene kant is het voor dit project een externe factor maar heeft dezelfde eigenaar dus dan zou het weer een middel (=mean) zijn. Want dat heeft ook weer invloed op o.a. de availability tram en de travel time. Dus die nog een plekje geven. Verder mis ik niks. Duurzaamheid zou je ook nog kunnen toevoegen als criterium, bijvoorbeeld materiaalgebruik en CO2 uitstoot. Vroegtijdig vervangen er niet onder zetten, het is een effect dat dan optreedt dat valt te schalen onder materiaalgebruik (materiaal niet optimaal benut), maar misschien kan je wel materiaal hergebruiken. Een tijdelijke brug klinkt alsof je iets bouwt en daarna weer afbreekt, dus zonde. Ook al kan het natuurlijk nodig zijn.
- **Mis je dingen in het midden van de SD?** Wat ik nog mis is de link tussen 'increased traffic volume' en 'livability'. 'Increased traffic volume' leidt dan ook weer tot meer noise en minder veiligheid. Bij accessibility heb je nu 'loss of business' als binnenstukje in het systeem, misschien is dat ook wel een criterium omdat het ook een soort eindeffect is dat je niet wil, dit is iets economisch. Hetzelfde geldt voor bereikbaarheid van voorzieningen (ziekenhuis, school etc.) is ook een goede om mee te nemen, valt dat dan denk ik onder accessibility.
- **Is het een logische om met deze categorieën te werken qua criteria?** Ja, dit is logisch. Zou dus wel nog misschien iets qua economie toevoegen, en daar dan 'loss of business' onder schalen. In het algemeen wordt deze categorisering veel gebruikt. Duurzaamheid kan je ook nog toevoegen.
- **Definities bereikbaarheid, leefbaarheid en veiligheid?** Verschilt per project. Verschilt ook weer net per gemeente. Je kan kijken bij een referentieproject kijken binnen Witteveen+Bos hoe het daar is geformuleerd. Leefbaarheid wordt ook weleens impact op omgeving genoemd. Duurzaamheid vaak ook niet echt een duidelijke definitie, dus die moet je zelf definiëren.
- **Hoe zou je de afweging maken tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?** Je kan het in een MCA doen en dan tijdens een werksessie met de gemeente de waarden bepalen. Ik zou niet zo snel zelf de weging geven. Ik kan wel leuk zeggen dat kosten minder belangrijk zijn dan leefbaarheid maar daar heb ik natuurlijk geen zicht op. Misschien ook echt op bestuurlijk niveau doen. Je wil objectief de effecten presenteren. Dus qua bereikbaarheid gebeurt er dit, kosten zijn dit, zoveel CO2. Dan de discussie voeren wat belangrijk is en dan de wegingen toepassen. De gemeente beslist erover.
- **Dit is de decision-making van 1 brug, hoe staat deze in relatie met de grote schaal, klopt het zoals hier weergegeven?** Gaat dus eigenlijk terug naar het CF. Per brug bepaal je de effecten en kan je een ranking maken qua strategie. Bijvoorbeeld voor een brug is optie 1 een hulpbrug en optie 2 gefaseerd. Daarna bij het maken van de scenario's kan je altijd nog de 2e optie kiezen qua strategie als het beter past en dan ook van die combinatie (scenario) de effecten bepalen. Werken die juist samen of juist tegen qua effecten? Effecten verschillen dus per scenario.

6. **Afsluiting**

- **Data/modellen voor impacts/effecten?** Verkeersmodellen, geluidsmodellen en luchtkwaliteitsmodellen worden veel gebruikt. Dus binnen Witteveen+Bos zijn er veel mensen die zich mee bezig houden. Ook materiaalgebruik en CO2 uitstoot, die mensen zijn misschien ook wel interessant om te spreken.
- **Iemand anders die ik nog kan spreken?** Iemand van duurzaamheid proberen, zoals Ronald Hendriks. Geluid- en lucht kan ik ook nog iemand van doen, zoals Pascal Verrache van luchtkwaliteit. Hij weet ook wel iemand van geluid als dit nodig is.
- **Tips?** Misschien framework van tevoren sturen, is namelijk veel informatie. Je kan mensen de optie geven als ze tijd hebben er alvast naar te kijken en anders niet.

C.4. Interview D

1. Voorstellen

- **Huidige functie/ervaring**: Ik (Aries van Beinum) ben PMC-leider verkeer en wegen. Ik geef leiding aan een groep van een man of 40. Wij houden ons bezig met de engineering van wegen, vooral provenciale en rijkswegen. Van variantenstudies en haalbaarheidsstudies tot het bepalen van de dikte van het asfalt. Ben begonnen op de MTS, daarna HTS, daarna Delft Civiele Techniek Transport en Planning en in 2018 gepromoveerd.

2. Opmerkingen tussendoor

- Redelijk bekend met PBKA.

3. Antwoorden vragen deel 1/3

- **Hoe zou je dit proces zelf aanpakken?** Je hebt 2 dingen: de brug zelf met een restlevensduur die misschien op een gegeven moment kritiek wordt en je hebt de functie van de brug zelf(tram, weg) en die heeft dan weer een functie in het netwerk. En die zou ik naast elkaar zetten. Aan de hand van hoe kritiek een brug is constructief gezien zou ik een prioritering maken en daartegenover zou ik zetten wat is de functie van de brug in het netwerk. En op basis daarvan zou ik een programmering maken van dat je niet te veel bruggen met een belangrijke functie tegelijk doet want dan krijg je netwerkproblemen. Dus ik zou een mix maken van een belangrijke brug en dan een x aantal minder belangrijke bruggen. Wat daar dan nog meer bij speelt is de technische complexiteit. Hoe lastig is een bepaalde brug om te vervangen. Een belangrijke brug die simpel en snel te vervangen is is een heel ander verhaal dan een belangrijke brug die lastig te vervangen is.

4. Antwoorden vragen deel 2/3

- **Is de outline van het conceptuele framework logisch?** Ik zou het anders aanpakken. Nu heb je een stroomlijn van boven naar beneden en wat mij opvalt is dat je de bruggen echt als solitaire dingen ziet. Wat volgens mij niet gaat werken straks is dat je die verschillende scenario's batches zijn. Bijvoorbeeld dus 5 bruggen in een batch. En die batch wil je een score gaan geven. En je zei zelf al bereikbaarheid, kosten, veiligheid en tijd. En in je stroomschema moet je een plek krijgen waar je die score uit krijgt. En je hebt verschillende 2 scores: scores die samenhangen met die specifieke locatie (kosten, tijdsduur, veiligheid), maar de bereikbaarheid is een netwerkelement en staat los van die locatie, dat is een andere schaal. En die twee schalen moet je uit elkaar zien te trekken. Die batches hebben een samenraapsel van die drie eerste dingen maar hebben vooral een effect op het netwerk. Dus netwerk ene kant en locatie specifieke dingen aan de andere kant. Die strategie bepalen is een op zichzelf staand optimalisatie probleempje. Als je oplossing A bij de ene kiest hoef je die niet per se voor de ander ook te kiezen, dat is onafhankelijk van elkaar. Je hebt dus eigenlijk 3 componenten: zelfstandig component, netwerkcomponent en interactie component, deze komt er nu bij. En die leiden dan uiteindelijk tot een score waarop je die scenario's kan waarderen. Hoe ik het dan voor me zie hoe ik dit zou aanpakken is dat ik een database heb met alle bruggen en een aantal eigenschappen die je een score geeft. Vervolgens heb je een script nodig om die bruggen te combineren. Kwantitatievere aanpak. Het zou handig zijn als dat in je schema terugkomt.

- **Komt dit overeen met wat er in de praktijk gebeurt?** Nooit zelf gedaan, maar gaat inderdaad wel spelen.

- **Welke methoden kan je voor het doorlopen gebruiken?** Je kan er een soort lineair programmeer probleem van maken. En dan heb je wel wat minder zachte criteria eraan hangen en dingen die moeilijk te kwantificeren zijn. Dus misschien inderdaad met een MCA om er wat gevoel in te gooien, ik denk dat dat wel mooi is. Van belang om te kijken welke criteria je dan meeneemt en hoe je deze waardeert. Informatie impacts en effecten zou je kunnen doen met verkeersmodellen.

- **Welke strategieën zijn nog meer mogelijk?** Je kan een brug ook prefab nieuw bouwen. De oude eruit halen en de nieuwe erin. Snelle methode, hoeft niet heel duur te zijn, wordt vaak gedaan. Hangt wel van de brug af. Historisch gemetselde brug is minder handig dan als er een brug ligt met een los dek.

- **Wat zijn impacts/effecten dat het afsluiten van een brug heeft op de omgeving?** Volgens mij heb je dit al wel scherp. Gaat er natuurlijk om of er een alternatieve route is in de buurt is, hoeveel verkeer gebruik maakt van een brug, functie in het netwerk, hoe lang die eruit ligt. Normaal rekenen we in voertuig verlies uren, dat is een factor, = extra omrijdtijd x aantal voertuigen. En dan kan je de VoT gebruiken.

- **Welke scenario's zijn logisch om te maken?** Combinatie maken tussen 1 route en verspreid door de stad. Als je op 1 route meerdere bruggen tegelijk kan vervangen lijkt me handiger dan om de beurt, want dan heb je in tijd gezien veel minder hinder op een route. Ik zou ook niet 2 belangrijke routes, bijvoorbeeld van noord naar zuid, tegelijk afsluiten (dus ook niet twee parallelle routes).

- **Impacts/effecten verschillen per scenario?** Je zou voor beiden moeten omrekenen naar VVU en die dan vergelijken.

- **Karakteristieken van een stad die een rol spelen?** Er zijn zeker verschillen per stad. Amsterdam heeft echt een ringstructuur met die grachten met een aantal radialen erin. Dat is een heel ander systeem dan in Amerika met die grids. Utrecht zit er een beetje tussenin. Binnenstad wel een ring maar daar omheen meer haaks gemaakt. De structuur van de stad verschilt heel erg.

- **Tot hoe verre zou je vooruit plannen?** Ligt eraan hoe veel bruggen er op instorten staan. Als je 50 bruggen hebt die de komende 10 jaar moeten worden gedaan zou ik wel echt voor die 10 jaar een planning maken. Ook al verandert er in de omgeving van alles, de restlevensduur van een brug veranderd niet. Kan wel zijn dat de realisatie op een gegeven moment complexer of juist makkelijker wordt en dat de functie van een brug in het netwerk veranderd.

5. Antwoorden vragen deel 3/3

- **Verwacht je nog meer dingen op de randen? Is het logisch?** Het tijdsaspect, die heeft bijvoorbeeld impact op die voertuigverlies uren. Die heb je volgens mij nu als accessibility neergezet. Je moet kijken wat er gaat gebeuren. Volgens mij heb je 3 opties: hulpbrug, gefaseerd bouwen en volledig afsluiten. Die laatste twee is een principekeuze; kort en hevig of lang en niet zo hevig. En het is maar even de vraag hoe dat uitpakt en wat gunstiger is. Als je hem voor de helft afsluit en je zet er een verkeerslicht neer zodat soms de ene kant eroverheen mag en soms de andere kant en dat werkt goed dan is je probleem een stuk minder erg dan dat je een enorme file krijgt. Bij hoofdweg lukt misschien niet maar bij een kleinere weg wel. Dit krijg je inzichtelijk door de voertuig verlies uren te berekenen, want dan komt dat tijdscomponent erbij. Bij livability zit ook een tijdscomponent, wat is voor de omgeving fijn. Maand in de zooi of een half jaar wat minder in de zooi?

- **Mis je dingen in het midden van de SD?** Safety breder trekken, traffic nu tussen haakjes. Hulpbrug veiliger dan gefaseerd bouwen omdat er dan natuurlijk verkeer door je werk komt. Helemaal afsluiten is het veiligst, helemaal niemand komt er en geen gammele hulpbrug.

- **Is het een logische om met deze categorieën te werken qua criteria?** ? Logisch, wordt veel gebruikt.

- **Wat zijn de definities van deze criteria?** Vaak beetje politiek ingegeven, wat er op dat moment belangrijk wordt gevonden. Duurzaamheid en circulariteit zou je ook erbij kunnen nemen. Cutting of historic trees gaat nu over het behoud van historie, maar zegt nog niks over het behoud van groen. Als het geen historic tree was geweest was het alsnog zonde geweest. CO_2 uitstoot en materiaalgebruik ook aan denken.

- **Hoe maken jullie de afweging tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?** Over het algemeen met een MCA. Gewichten zijn altijd een beetje dubieus, probeer mijzelf hier altijd buiten te houden. Pure feitelijke verschillen weergeven tussen de varianten. Kosten, VVU etc. allemaal weergeven. Objectief feitelijke informatie van de verschillende scenario's weergeven.
- **Vertaling 1 brug naar de grotere schaal?** Uiteindelijk heb je een netwerk in je stad met daarin een object. En als je gaat kijken naar je verkeersafwikkeling en je voertuigverlies uren en dan heb je uiteindelijk zones. Hieruit een OD-matrix waaruit komt wat waarheen gaat. De vraag is uiteindelijk in je verkeersmodel hoe je verkeer zich gaat verdelen. Capaciteit van brug veranderd gegeven je scenario. Verkeer neemt andere routes. Als je van 1 brug naar een batch toegaat in je model dan krijg je het samenspel te pakken. Dus uiteindelijk een knip maken tussen wanneer iets een lokaal probleem is en wanneer een netwerkprobleem. Dus 3 bruggen op dezelfde link kan ook niet heel veel uitmaken als eentje daarvan sowieso al op 0 procent moest. Dus echt onderscheid maken tussen lokaal en netwerk.

6. Afsluiting

- **Modellen beschikbaar?** Deze statische modellen voor dit soort netwerkberekeningen hebben we niet. Sander Veenstra heeft zelf een model gemaakt, vrij eenvoudig maar werkt prima voor dit soort vraagstukken. Wel ook een meer gedetailleerd model, microscopisch. Maar als je dit daarin wilt stoppen ben je wel even bezig om heel Amsterdam te modelleren, heel gecompliceerd. Wij hebben een dataset van Amsterdam, misschien dat de gemeente dat wel heeft.
- **Wat is handig voor de gemeente qua framework?** Uiteindelijk zouden zij ook naar zo'n programmering willen van hun kunstwerken. Uiteindelijk willen ze een agenda. Het is wel goed om te weten waar je nou tegenaan loopt. Dus zo'n overzicht is wel fijn.
- **Andere mensen?** Kan je in contract brengen met een oud-collega van ons, werkt nu bij de Gemeente Amsterdam en houdt zich bezig met verkeersmodellen. Robert Verwij. Geef maar een seintje als je hem wil benaderen.
- **Tips?** Nee, was duidelijk. Probeer het hele proces van voor naar achter door te lopen en het gelijk geheel te testen. Niet dat je bij de MCA komt en je eigenlijk de verkeerde data hebt gegenereerd. Hoeft niet per se met case study maar kan ook met indicatieve waardes. Je wil op een gegeven moment waardes creëren, dus moet nog wel iets kwantitatiefs gaan maken.

C.5. Interview E

1. Voorstellen

- **Huidige functie/ervaring**: Mijn (Elisabeth Ruijgrok) functie is publieke goederen econoom. Ik doe aan effectbepaling (MCA, MKBA, kosteneffectiviteitsanalyses). Kiezen doe je in principe op grond van de effecten, maar er wordt weleens vergeten dat je ook alle alternatieven moet meenemen. Alles wat je niet bedenkt qua mogelijkheid kan je nooit kiezen.

2. Antwoorden vragen deel 1/3

- **Hoe zou jij dit aanpakken?** Kijken naar welke als eerste op instorten staat en wat daar het gevolg van is. Ook kijken of er bijvoorbeeld een lastbeperking nodig is. Vervolgens kijken hoe veel mensen hebben daar dan last van hebben en aan de hand daarvan de brug met de grootste maatschappelijke schade als je niks doet als eerste nemen. Aangezien alle bruggen uiteindelijk moeten worden aangepakt is relateren aan de kosten niet nodig.
- **Impacts verschillende scenario's?** Als je twee bruggen op één route aanpakt is er mogelijk een goede alternatieve route voor het verkeer, waardoor het een goede optie is om gelijk een derde brug op deze route ook erbij te pakken als deze niet tot extra maatschappelijke kosten leidt, ook al ga je hierdoor een beetje over het budget heen, uiteindelijk moeten namelijk toch alle bruggen aangepakt worden. Wanneer deze derde brug nog een restlevensduur heeft van 10 jaar moet er een afweging worden gemaakt of het handig is om deze al mee te nemen, als een brug nog 25 jaar mee kan wordt deze nog overgeslagen. De beste manier van bundelen door te kijken naar cumulatief maatschappelijk effect, dit moet zo klein mogelijk zijn en is het enige criterium.

- Ook rekening houden met andere werkzaamheden in de stad (riool, drinkwater, gasleiding), die allemaal hun eigen vervangingsritme hebben, welk ritme leidend is verschilt. Combineren van werkzaamheden vaak handig (uitvoeringstechnisch vaak goedkoper en qua verkeershinder en bewoners) en zo hoeft de straat niet in een paar jaar meerdere keren open.

3. Opmerkingen tussendoor

- Scenario geen scenario noemen (scenario zijn omstandigheden van buitenaf, bijv. klimaatverandering of economische groei), maar het woord 'cumulatiealternatieven' gebruiken. Als een alternatief meerdere variaties heeft noem je die varianten.
- Andere mogelijkheden zijn: (1) Pondje (toeristenattractie, geen bomen kappen zoals bij hulpbrug nodig kan zijn), (2) mensen uit de tram laten stappen, op een pondje, en dan met een andere tram weer verder, dus een overstap, (3) fietsen neerzetten, (4) drijvende pontons gebruiken (wiebelt, wel goedkoop). Alternatieven die niet meegenomen worden kunnen ook niet gekozen worden.
- De keuze of er prefab of ter plekke wordt gebouwd heeft invloed op de doorlooptijd, het gaat er namelijk om hoe lang je zonder brug zit. Verder ook naar hergebruik (leuning, hulpbrug) kijken en of hier nog keuzes in zijn.
- Gefaseerd vervangen waarschijnlijk vaak wel mogelijk. Bruggen waar een tram overheen kan zijn constructief vaak sterk.
- **Afweging tussen kosten, bereikbaarheid, leefbaarheid en veiligheid**: Leefbaarheid goed specificeren, daar zit namelijk veiligheid en bereikbaarheid in. Bereikbaarheid zijn ook kosten, namelijk je omrijkosten in tijd en benzine. Veiligheid zijn vermeden gewonden en ongelukken, ook in euro's. Als de bouwperiode langer is dan heb je er langer last van maar dat is waarschijnlijk het enige. Bouwoverlast zijn de trillinghinder (uitdrukken in gezondheidsschade) en geluidshinder en kan heel heftig zijn voor de omwonenden, dit versta ik onder leefbaarheid. Geluid en stof verschillen waarschijnlijk niet per strategie. Dus trilling, geluid en minder loop comfort (lopen op planken), smalle toegangsroutes naar winkels. De ene gemeente zal voetgangersleed belangrijker omdat winkeliers daar over klagen en de andere gemeente zal de kosten ten gevolge van de bereikbaarheid belangrijker vinden. Als gemeente moet je enkel kijken hoe groot het probleem is, dus tellen hoeveel mensen het treft i.p.v. zomaar iets belangrijker vinden dan het andere. Denk ook nog aan gevolgen voor scheepvaart.
- In de praktijk wordt vaak het gehele budget besteed, ook al had dit beter anders kunnen worden besteed. Als een alternatief bijvoorbeeld 2 miljoen extra kost maar je hebt voor die extra kosten maar 5 winkeliers een microgunst bewezen kan je je afvragen of je het geld wel daar aan uit had moeten geven en of het wel het geld waard is. Effect is altijd een hoeveelheid x prijs. Kan ook zonder in euro's uit te drukken, prijs bijvoorbeeld in minuten qua omlooptijd. Als gemeente dus altijd tellen hoeveel mensen het treft om een goede keuze te maken, je kan je geld maar één keer uitgeven.
- **Blokje 'repeat proces'**: je moet gelijk een totaalindeling maken, de optimale rangorde voor je complete portefeuille. Het gaat om de laagste maatschappelijke kosten voor de complete opgave. Het meeste kan in euro's uitgedrukt worden, behalve de comfortissues (leed klanten en winkels). Omzetschade bij winkeliers speelt geen rol, want een winkelier een eindje verderop krijgt dan juist weer meer omzet want we gaan niet minder geld geven hierdoor. Dus is een verdelingsissue. Wel tellen om hoeveel mensen het gaat.

4. Antwoorden vragen deel 2/3

- **Is de outline van het conceptuele framework logisch?** Wat je verteld is kloppend, maar dus wel een ander woord voor scenario's gebruiken.

5. Antwoorden vragen deel 3/3

- **Verwacht je nog meer dingen op de randen? Is de SD logisch?** Externe factoren veranderen naar interne factoren, gaat over de brug zelf, tenzij dit gebruikelijk is in een SD. Staat onderhoud nog toevoegen.

- **Mis je dingen in het midden van de SD?** Het mechanisme erachter, zoals o.a. modal shift, niet weergeven. Enkel de finale effecten weergeven (reistijdverliezen en omrijkosten). 'Increased traffic volume' duidelijker formuleren (niet meer verkeer in het algemeen, maar wel op bepaalde plekken). Naast 'availability tram' ook availiability van andere modes toevoegen (opdelen in beschikbaarheid over brug en onder brug door, scheepvaart ook meenemen). Verkeersveiligheid loopt denk ik niet via 'use of space', 'use of space' anders noemen: namelijk verlies van openbare ruimte. Verder zie ik niet hoe dit van toepassing is op 'change of infrastructure', dit gaat toch eigenlijk om de beschikbaarheid/veranderingen van aanrijdroutes. Onder openbare ruimte vallen woonboten, bomen en terrassen. Visuele kwaliteit onder omgevingshinder zetten (de ene persoon vindt het leuk, de ander niet), verder qua omgevingshinder heb je trilling, stof en geluid. Trilling is het kritiekst (en geluid daarna), trilling is nu gerelateerd aan constructiemethode (hulpbrug bouwen zorgt voor stof, prefab neerleggen niet). Het gaat om de sloop en de bouwactiviteiten (wel of geen hulpbrug). De constructiemethode hangt af van wat er met de brug moet gebeuren (gehele brug of maar een deel? Landhoofd en machinekamer? Fundering? Afdammen? Alleen het dek?) dit is het meest kritiek qua trilling, geluid en veiligheid. Onder externe veiligheid valt de kans op instorten en hijsgevaar. Verder speelt 'traffic safety' ook een rol.

6. Afsluiting

- **Iemand anders die interessant is om te spreken?** Bruggenafdeling van W+B kan. Verder ooit een project geweest van RWS waar ze druk bezig waren met het modelleren van de keuze of een hulpbrug gebruikt moet worden versus geheel afsluiten, kijkende naar de tijdelijke verkeerseffecten.

- **Tips?** Nee, wel testen inderdaad. Rotterdam, Amsterdam, Delft. Kleine bruggen in Delft hebben geen machinekamer dus scheelt veel qua trillinghinder. Dus onderscheid bewegend en niet bewegende brug ook belangrijk om mee te nemen.

C.6. Interview F

1. Voorstellen

- **Huidige functie/ervaring**: Maurice Simons heeft de Bachelor Bouwkunde aan de TU Delft afgerond, MSC Architectuur en stedenbouw (niet afgerond). Zelf stedenbouwkundig architectenbureau begonnen, vooral actief in buitenland; Tel Aviv, Haïti. Daarvoor bij Antea gewerkt. Bij de gemeente Delft werkzaam als Civieltechnisch Adviseur. Beoogd beheerder van de infrastructuur. 3 taken de ik op dit moment vervul: adviseur kabels en leidingen, adviseur wegen (beheer en vervangen), hoofdtaak beheer en onderhoud civieltechnische objecten (bruggen, sluizen, kademuren, geluidsschermen); ik maak de planning voor het onderhouden of zorg dat het in de planning komt voor het vervangen.

2. Opmerkingen tussendoor

- In Amsterdam doen ze nu aan kapitaalvernietiging. Verder is er geen capaciteit door de onderzoeken in Amsterdam, aan duikteams is bijvoorbeeld niet te komen.

- **Verhaal vooraf**: binnen een aantal parameters functioneer ik, en dat zijn 9/10 keer de zaken die de gemeenteraad heeft vastgesteld. Dus om een areaal te beheren, ongeacht wat het is, bomen of bruggen, heb je te maken met de kwaliteit en de kwantiteit. Om een areaal goed te beheren moet je eerst weten wat je hebt (kwantiteit) en vervolgens een plan maken. In Nederland heb je het CROW, deze stelt de normen vast. Je hebt A (nieuw) t/m E. Je stelt vast op welke categorieën je welke kosten maakt, dan stelt de raad bijvoorbeeld vast dat we gaan beheersen op een bepaald niveau. In Delft is de binnenstad beschermd stadsgezicht dus wordt beheerst op niveau B (moet er goed uit zien en functioneel, niet nieuw) net als Agnetapark. De rest niveau C, daar mag er iets meer groen tussen de tegels zitten. Aan de ene kant heb je je areaal qua hoeveelheden, aan de andere kant je kwaliteitsniveau waar een bedrag aan vasthangt. Dat wordt voorgelegd aan de wethouder en de raad en zij gaan vervolgens kijken hoe veel geld zij eraan willen besteden en wat reëel is. Als je lager dan niveau C gaat beheren doe je aan kapitaalvernietiging, omdat je pas gaat ingrijpen moet je er zo veel meer geld in steken om het weer werkend te krijgen dat je eigenlijk kapitaal aan het vernietigen bent t.o.v. af en toe onderhouden. Om daar tot een conclusie te komen heb je dus je areaal en je kosten, en wordt er vastgesteld op welk niveau je iets beheerd. Vervolgens ga je een planning maken, je hebt maar een beperkt budget. In het ene jaar heb je meer dan genoeg aan dat budget maar een ander jaar een tekort. Indien tekort moet je een afweging maken waarom je een bepaald object wel doet en de ander niet. En dan kom je in een diagram terecht met aan de ene kant 'hoe groot is de kans dat het misgaat?' en aan de andere kant 'als het fout gaat; hoe groot is de impact?'. Risico = kans x impact. Vaak is het zo dat hoe groter het object is hoe groter het risico, en daar stuur je dan op. Dit is kort door de bocht hoe wij 'm inschieten

- **Tot hoeverre hebben jullie nu dit probleem?** In de binnenstad zijn er ongeveer 71 bruggen waarvan er 42 verkeersbruggen zijn, de rest fiets- en voetgangersbruggen. De fiets- en voetgangersbruggen zijn over het algemeen van metaal, enkeling gemetseld, en daardoor makkelijker te onderhouden. De verkeersbruggen zijn op 1 na in de jaren 60/70 aangepakt, daar is beton in gestort. Daardoor zijn deze redelijk goed. We hebben nu maar 1 hele slechte brug en dat is de ene waar geen beton in zit. Dat is de Hoogbrug, deze is nu afgesloten. Valt dus mee hoe veel bruggen er in een slechte staat zijn. Hebben wel een aantal bruggen die in slechte staat lijken te zijn, die hebben heel veel scheurvorming, craquelé en dat er af en toe een steen vanaf valt. Maar dat is alleen de aankleding en niet de brug zelf. Dus daar moet wel wat aan gedaan worden, want het is beschermd stadsgezicht. Maar in de kern, op de Hoogbrug na, zijn alle bruggen tot zo ver ik het nu kan inschatten goed.
- **Waarom jullie het goed onder controle en Amsterdam niet?** Ik weet natuurlijk niet hoe het in het verleden in Amsterdam is gegaan. Er is natuurlijk wel een schaalvergroting. Op het moment dat je in Amsterdam een beslissing neemt van we gaan het op een bepaald niveau beheren heeft dat natuurlijk een enorme financiële impact. Dat is natuurlijk relatief, want de stad is veel groter, dus op zich zou dat niet uit hoeven maken. Ik kan niet voor Amsterdam spreken maar in Delft is het allemaal redelijk goed bijgehouden, inclusief de kades. Het probleem speelt hier veel minder. Afgelopen 2 jaar bezig geweest om veel weer op te knappen, daar gaat veel geld in om. We zijn nu bezig met de Oude Delft, Noordeinde tot arsenaal. Dit wordt nu schoongemaakt, uitgespoten, opnieuw gevoegd (inclusief de bruggen), voor dat stuk kost het al een miljoen. Dat stuk is 1/7 à 1/10 van de binnenstad. Dus de komende paar jaar nog een paar miljoen nodig voor de rest van de binnenstad. Grote bedragen maar valt ergens ook wel weer mee.
- Ruwgenomen 2 budgetten. De ene is exploitatie, dat is het onderhoudsbudget. Je krijgt grof gezegd een miljoen om de stad te onderhouden, of het nou wel of niet opgaat, aan het einde van het jaar is dat weg. Daarnaast heb ik nog een investeringsbudget voor objecten die meer geld kosten dan dat ik uit dat potje kan betalen. Dat potje is een soort stuwmeer, dat vervalt niet, tot de projecten zijn afgerond. Ieder jaar wordt weer gekeken welke projecten hiervoor in aanmerking komen. In dat potje is voldoende geld voor alsnog. Probleem speelt hier dus eigenlijk niet.
- Dit probleem van achterstallig onderhoud speelt dus in Delft eigenlijk niet. In Delft was het eerst niet allemaal goed geregeld. Ik werk hier nu 5 jaar ongeveer, in het begin vooral bezig om het areaal te leren kennen en alle probleemgevallen. Ik heb nu 2 aannemers, die geef ik een wijk (buiten de binnenstad) waarin ze gaan werken dat jaar. Ze pakken daarin alle objecten aan. De echte probleemgevallen zijn al opgelost. Dus daarnaast wordt het wijkgericht aangepakt. Hetzelfde geldt nu voor de binnenstad. Ik begin nu bij het Noordeinde en zak af tot het arsenaal. En als ik daar ben keer ik om en pak ik de andere gracht en ga ik weer door tot boven. Dan komt het weer in niveau A terecht na het restaureren. Is economisch gezien altijd voordelig om iets te restaureren en terug te brengen naar niveau A.
- Urgentie kan je op een aantal manieren framen. Urgentie kan zijn de staat van de brug maar kan ook zijn het gebruik van de brug. Beiden spelen daarin mee. Als een brug in een slechte staat is maar bijna niet gebruikt wordt hoef je er niet echt iets mee. Als bijna niet gebruikt wordt en is in goede staat hoef je er ook niks mee, dan sluit je m gewoon af.
- **Blokje 'choosing a strategy'**: wat ik doe is het niet individueel bekijken maar gelijk per categorie. Op moment dat ik een brug laat vervangen, bijvoorbeeld een composieten, moet die in de fabriek

worden gemaakt aan de hand van een mal. Bijvoorbeeld 3x10m. Die mal wordt dan besteld en wordt de brug gegoten. En dan ga je door naar de volgende brug. Als de volgende brug net een andere afmeting heeft dan moet die hele mal opnieuw worden gemaakt. Daarom de bruggen gecategoriseerd op lengte, in de breedte valt nog een beetje te spelen (van de bruggen met een restlevensduur tot ongeveer 5 jaar). Zo ongeveer 1 mal per jaar, waaruit dan 5 of 6 bruggen kunnen worden gehaald. Anders zou je voor dat geld maar 3 of 4 bruggen kunnen doen. Natuurlijk is dit bij gemetselde bruggen net een ander verhaal.

- In Amsterdam natuurlijk een aantal beweegbare bruggen, dat is een aparte categorie waarmee je rekening moet houden. Verder kijken of het hout, composiet, staal of eventueel zelfs beton is. Daar kan je ook in spelen, categoriseren qua materialisatie. Je kan ook categoriseren op dezelfde steensoort, zodat je dat in één keer kan bestellen.
- Hulpbruggen zijn pas 1x toegepast in Delft. Veel bedrijven komen hiermee, maar we zijn hier niet in geïnteresseerd. Een hulpbrug is bijna altijd een brug van de aannemer. Kan zijn dat je hem zelf koopt maar dan moet je m achteraf ook weer ergens op kunnen slaan. Een hulpbrug huren is vrij kostbaar en in de stad (zo wel binnen als buiten het centrum, bebouwde kom) is er altijd een alternatieve route in de buurt. De enige keer is geweest in het Delftse Hout toen er een brug werd aangepakt zonder goede alternatieve route, mensen moesten hier 1,5 tot 2km omlopen. Mijn inschatting is dat je een hulpbrug alleen inzet buiten de bebouwde kom waar weinig andere infrastructuur is. In de bebouwde kom is dat bijna nooit het geval. Tenzij er een tram overheen kan, dan kan ik het wel begrijpen. Hulpbrug is anders kapitaalvernietiging.
- Mijn rol is niet alleen om de stad optimaal te houden qua infrastructuur maar ook om fatsoenlijk om te gaan met het geld van de gemeenschap. Dus als ik overal hulpbruggen neer ga leggen ben ik kapitaal aan het vernietigen en doe ik dat dus niet.

3. **Antwoorden vragen deel 1/3**
   - **Hoe gaat het proces op dit moment?** *Hierboven alles al besproken.*

4. **Antwoorden vragen deel 2/3**
   - **Is de outline van het conceptuele framework logisch?** Ja, hangt er wel vanaf wat de situatie in de stad is; hier de meeste rotte appels aan aangepakt toen ik hier aan kwam. Je pakt altijd eerst de meest risicovolle bruggen aan. Als die gedaan zijn ga je kijken wat het meeste zin heeft voor de stad, die ‘zin’ is een stukje omgevingsmanagement en kosten een rol spelen. Elke week komen er weer bruggen voorbij waar dingen slecht aan zijn. Moet gekeken worden of een brug bijvoorbeeld voor 40.000 gerenoveerd wordt of voor 60.000 een nieuwe, deze afwegingen moeten constant weer worden gemaakt. Aannemer keet in laten richten kost maar 5.000 euro maar om dat steeds te laten verplaatsen is zonde. Dus liefst 1x keet in laten richten en dan in dat gebiedje blijven werken en daar ongeveer 8 bruggen doen. Ik pak het gebiedsgericht aan, dat is natuurlijk niet de heilige oplossing. Maar in ons geval is de afweging zo gemaakt en werkt dit goed.
   - **Komt dit overeen met wat er in de praktijk gebeurt?** *Al eerder in dit interview besproken.*
   - **Informatie over de bruggen?** Ten eerste hebben alle historische objecten geen bouwtekeningen. Je kan onderzoek gaan doen maar achter elke steen zit weer iets anders. Je mist heel vaak de basisgegevens. Je kan wel allemaal boringen gaan doen, maar alsnog als je de brug openmaakt kan je van alles tegenkomen. Verder hebben we de digitalistering meegemaakt. Hele archieven zijn gescand en daarna weggegooid. Of alles is weggegooid en niet eens ingescand. Dus alle informatie die er was van 1850 tot ongeveer 2000 is een deel verloren gegaan, dit heeft waarschijnlijk iedere gemeente, dat kan nauwelijks anders. Mappen werden in archiefkasten soms net verkeerd teruggezet en konden daarna niet meer worden teruggevonden. Geen enkele gemeente heeft het 100% op orde. Deels kan je aan de scheuren de staat van de brug bepalen, maar hangt ervan af hoe de scheuren lopen. Het is heel erg afhankelijk van het schadebeeld en van de situatie van de brug, hoe die gebruikt wordt, wat de oorzaak is. Dus bij schade kan een brug in zo wel een prima als in een slechte staat zijn. Kans ook aanwezig dat brug niet in een

goede staat is en geen scheuren heeft, vooral bij bruggen met betonnen kernen als deze een slecht mengsel heeft gehad (slecht gemengd of verkeerde verhouding), maar is hier in Delft nog niet gebeurd. Veel gemetselde bruggen scheuren boven de doorgang (zijaanzicht), dit is niet erg, alleen verveld als iemand eronderdoor vaart. Komt doordat je eigenlijk de hele tijd tegen de kuip aan rijd en het daardoor gaat scheuren en er misschien een steen vanaf valt. Maar is dus niet erg qua constructie, puur uiterlijk, maar moet wel actie ondernomen worden.

- **Welke andere strategieën zijn mogelijk?** Aslastbeperking erop zetten. Ik gebruik altijd de term 'Prins Clausplein', dat betekent dat alles eroverheen moet kunnen, grote viaduct bij Den Haag, Flyover. Wat je soms hebt is dat je een brug hebt waar in principe 60 ton overheen moet kunnen, maar dat die al wel schadebeelden begint te vertonen, je rijdt er namelijk tegenaan waardoor de brug vervormd. Bij minder zwaar verkeer minder aanrijdschade. Daarom hebben veel bruggen en tunnels een betonnen aanrijdplaat om te zorgen dat je eerst daar tegenaan rijdt en niet direct tegen het object waardoor er minder kracht tegen het object aan komt, maar de oude bruggen hebben dat niet.

- **Wat zijn impact/effecten dat het afsluiten van een brug heeft op de omgeving?** Hangt af van de ligging van de brug. Als er 2 bruggen naast liggen dan maakt het niet uit. Het heeft altijd te maken met toegankelijk. Dat kunnen 2 dingen zijn: voor de bewoner, vaak met auto, en voor bedrijven. Op dit moment een brug bij het arsenaal (=legermuseum) afgesloten. Daardoor kan de vrachtwagen die hoek niet meer maken, en moet die bij een verhuizing even tegen het verkeer inrijden. Impact is dus heel erg locatieafhankelijk. Voor bewoners vooral vervelend bij verhuizing, is wel incidenteel en komt niet vaak voor. Maar als het een commercieel gebied is qua bedrijven en winkels die productie draaien en aan- en afvoer hebben van producten dat wordt het wel een dingetje. Bij een fabriek in Delft was dit een probleem, moesten afspraken worden gemaakt qua planning zodat er wel productie kon worden gedraaid en producten tussentijds worden opgeslagen. Als je dit niet oplost heb je een schadeclaim aan je broek hangen.

- **Welke scenario's zijn nog meer logisch om te maken?** Voorbeeld in Delft, nergens anders van toepassing (beetje Den Haag): reden om van Noordeinde naar het zuiden is omdat dat de route is die wordt gebruikt met de koets als er iemand van het koningshuis overlijdt en daar begraven wordt. Dus nu is dat alvast gedaan mocht Prinses Beatrix overlijden, hoe langer we wachter hoe groter de kans dat zij overlijdt. De kans dat het gebeurt wordt iedere dag groter. Toen Prins Claus onverwacht overleed lag de hele markt open, toen moesten van overal stratenmakers door heel NL gezocht worden om op tijd de markt weer te verharden. Normaal duurt dat 2 weken en nu was het in 2 dagen klaar.

- **Combineren jullie het ook met andere werkzaamheden?** Werken met assetmanagement, veel gemeentes hebben dat nog niet is relatief nieuw. Meeste gemeentes sturen incidenteel, kijken waar het mis gaat en dan pakken ze het daaraan. Met assetmanagement proberen wij het hele areaal in beeld te krijgen en daarvoor een planning te maken. De volgende stap is de burger ontlasten door het integraal aan te pakken. Heeft geen zin om weg open te gooien als die 2 jaar later weer open moet. Loopt weinig door een brug, af en toe een kabel of leiding, dit is anders voor een weg. Met wegen is dat belangrijker. In binnenstad bij wegen te maken met grijs gietijzer. Gasleiding vroeger van gietijzer, die moeten vervangen worden want gaan kapot. Zijn ook veel andere kabels zoals internet etc. Dus dat proberen we zo veel mogelijk integraal aan te pakken. In voorhof nu bijvoorbeeld alles aangepakt en vernieuwd en dan voor de komende 50 jaar klaar.

- **Verschillende impacts en effecten per scenario?** Ja, zeker als je alles in 1x aanpakt, dus voor meerdere onderdelen (dus ook riolering etc.) moet je voor al deze onderdelen geld hebben. Nu doen we dus qua scenario per gebiedje aanpakken, daarbij moet je niet 2 bruggen naast elkaar aanpakken want dan haal je de alternatieve route weg. Dus gecentreerd maar de bruggen elkaar kunnen opvangen waardoor de overlast minimaal is. Altijd een afweging tussen impacts en kostenbesparing en daarin een optimale oplossing zoeken. Verkeerszaken (afdeling binnen gemeente) heeft model wat er gebeurt als je een bepaalde brug afsluit. Bij verkeerszaken aanmelden als je ergens aan gaat werken en zij zorgen bijvoorbeeld dat aannemers elkaar niet in de weg zitten qua dat er 2 bruggen tegelijk afgesloten worden waarbij dat niet kan.

- Belangrijkste is de veiligheid, daarmee worden de nood- en hulpdiensten bedoeld. Moeten altijd binnen een bepaalde periode aanwezig zijn. Dat ze moeten omrijden is geen probleem. Maar als ze moeten omrijden doordat er iets is afgesloten wat niet is aangemeld is dat natuurlijk een heel groot probleem.
- Gefaseerd vervangen wordt ook weleens gedaan, heel locatieafhankelijk wat handig is, geen specifieke voorkeur.
- **Karakteristieken stad?** In de binnenstad mag ik tussen de intocht van Sinterklaas en Oud & Nieuw geen wegen afsluiten. En ik mag geen wegen afsluiten in het touristenseizoen (ongeveer half april tot half augustus). Dus ben al een half jaar in de binnenstad kwijt waarin ik niks mag afsluiten, tenzij het echt urgent is. Dit omdat het beschermd stadsgezicht is. Veel werkzaamheden aan bruggen en kades kan gelukkig vanaf het water, dus dat kan wel doorgaan. Januari, februari, maart dan weer vaak te oud om te werken.
- **Hoe ver vooruit wordt er gepland (blokje: 're-run')?** Ruwgenomen 3 planningen. Jaarplanning (begin ik eind juli mee, eind oktober klaar, voor het jaar erna), die planning bespreek ik in het najaar met de aannemers zodat zij capaciteit kunnen reserveren. Daarnaast heb ik een beheerplan voor de komende 4 à 5 jaar waarin de grote projecten buiten het onderhoud zijn vastgesteld. Daarnaast is er een planning voor 50 jaar. Deze planning zorgt ervoor dat projecten indien nodig projecten naar voren of naar achteren worden geschoven zodat er genoeg geld per jaar beschikbaar is. Als je dat niet doet krijg je politieke problemen omdat het gewoon niet georganiseerd is, beetje als wat er in Amsterdam aan de hand is. Beheer is vooral op lange termijn denken en op korte termijn de risico's eruit halen. Je bent afhankelijk van de politiek omdat zij het geld beschikbaar stellen. De politiek is persoonlijk gebaad bij herverkiezingen, en dit is niet heel sexy. In delft is dit niet het geval geweest maar in Amsterdam wel. Maar het moet alsnog worden aangepakt. Bij een goed ambtelijk apparaat als stad staan eigenlijk 90 procent van je uitgaven vast en die laatste 10 procent is voor de accenten als politiek.

5. Antwoorden vragen deel 3/3

- **Verwacht je nog meer dingen op de randen? Is het logisch?** Ik denk dat die wel redelijk klopt. Maar in de praktijk werk je eigenlijk nooit met zo'n schema. Schema zit eigenlijk al in je hoofd. Ik heb een brug, welke andere assets zitten er, welke andere bedrijven, afstemmen met verkeerszaken. Dan volg je wel het schema maar niet in letterlijke zin. In de praktijk gaat het redelijk op intuïtie.
- **Mis je dingen in het midden van de SD?** Nee
- **Is het een logische om met deze categorieën te werken qua criteria?** Ja, is vaak ook op uitvraag. Als je een aannemer zoekt doe je een uitvraag. Aannemers geven door hoe duur alles is. Beoordelen op ENVI en ook op andere aspecten bijvoorbeeld SROI (social return of interest), omgevingsmanagement, vervoer (bijvoorbeeld dieplader of bootje), omgaan met milieu, uitstoot. Hierop allemaal punten scoren en die wordt omgezet in een fictieve korting op hun ingeschreven aannemerssom. Dit bepaalt bij de inschrijving de rangorde. Hier krijgt de aannemer de kans zich te onderscheiden en wint dus niet de goedkoopste aannemer die geen rekening houdt met de omgeving.
- **Hoe maken jullie als gemeente de afweging tussen de criteria (bereikbaar/leefbaar/veilig <> geld)?** Met uitvraag heel simpel, leidraad waar je op kan scoren. Tijd, geld, milieu-impact spelen ook een rol. Iedere afweging is een individuele afweging. Als ik een object groots aanpakt wil ik hem de rest van mijn carrière niet meer iets mee hoeven doen, behalve klein onderhoud. Dus kies liever de duurdere oplossing en dat het dan voor een langere periode gedaan is dan de snelle en goedkopere oplossing. Zo optimaal mogelijk met geld omgaan, maximaal effect voor de minimale prijs.
- **Hoe zag de decision-making van de Sint Sebastiaansbrug eruit?** Qua hulpbrug geen optie om te maken, en brug ernaast. Reden voor dichtgaan is scheurvorming, brug was op, moest echt vervangen worden. Landhoofden hadden veel scheuren. Scheur hoeft niet heel fataal te

zijn, maar je wil het aanpakken voordat het echt te laat is. Geheel vervangen, renoveren niet te doen. Hambrug was goede omrijroute, wel alternatieve route naar deze brug aangelegd zodat je niet door de bouwplaats heen hoefde, deze route tijdelijk verlegd voor de veiligheid.

- Werken bij BOR met 45/50 man, doen alles van bruggen, groen, afval en verkeerszaken. Eigenlijk alle technische dingen. Verder wel realisatie/ingenieursbureau voor het ontwerpen van bijvoorbeeld grote bruggen. Met realisatie samen totaal ongeveer 90/100 man.

6. Afsluiting

- **Wat voor een framework is handig?** Kostentechnisch efficiënt op lange termijn de goedkope oplossing. Alle randvoorwaarden goed op orde hebben. Alles wat aannemer doet goed moet zijn voor de stad (geluidsarm, milieuvriendelijk). Niet te lang afgesloten zijn. Dit zijn de belangrijke aspecten en denk dat je die wel allemaal te pakken hebt.
- **Testen data Delft**: Zeker mogelijkheden om hier je case study te gaan doen.
- **Iemand anders die interessant is om te interviewen?** Niet echt, alleen mijn baas maar dat is niet echt nieuwe info.

D

DSS

In this Appendix the Excel about the DSS will be shown. The excel consists of four Spreadsheets: the introduction, the DSS, the Values of Parameters and the Sensitivity Analysis.

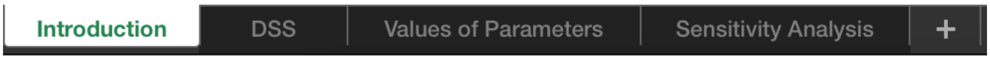

Figure D.1: Spreadsheets Excel

D.1. Excel Spreadsheet 1: Introduction

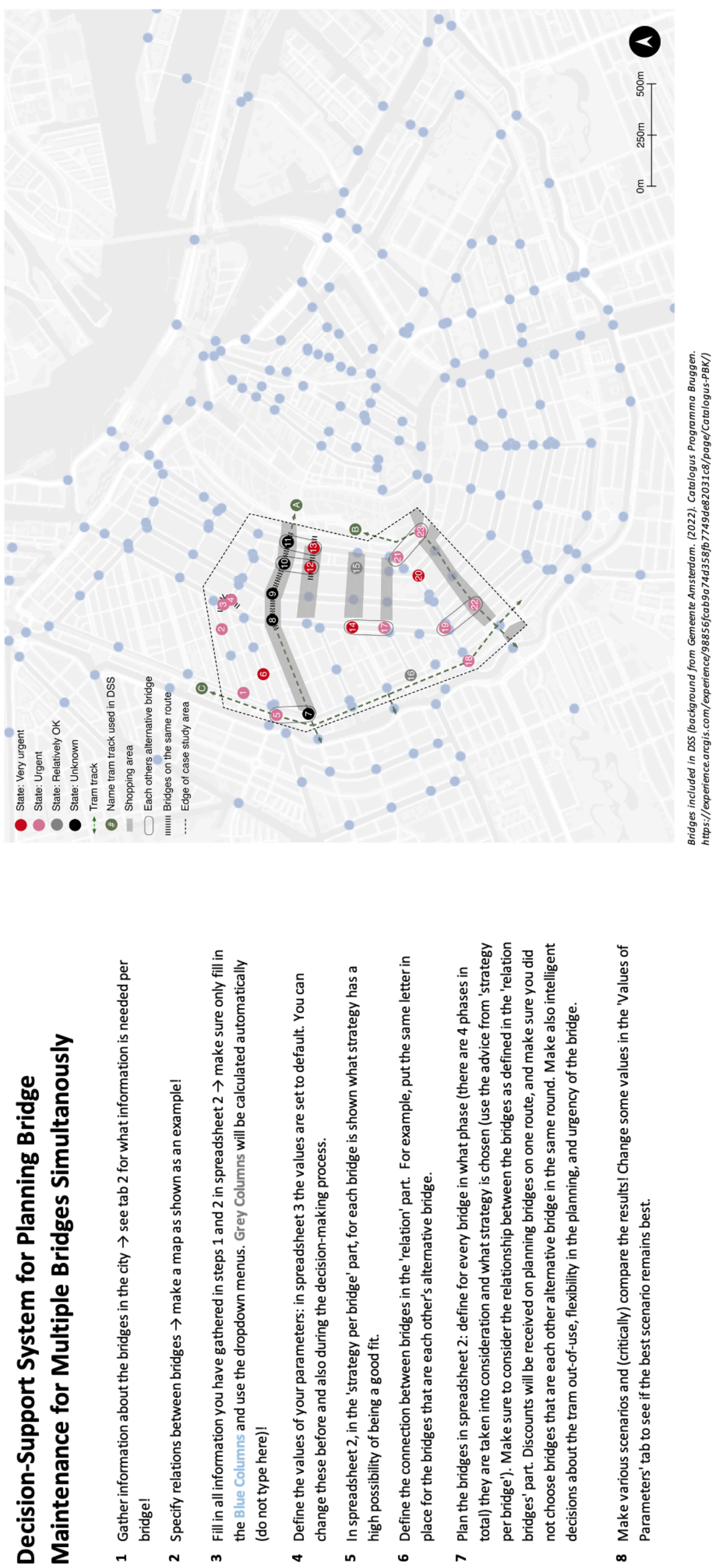

Figure D.2: Excel Spreadsheet 1: Introduction [this figure is rotated]

D.2. Excel Spreadsheet 2: DSS

D.2.1. DSS: Overview

The overview of the DSS is shown below. From left to right, top to bottom, all these parts will be looked at in the Subsection 'DSS: zoomed in per component'.

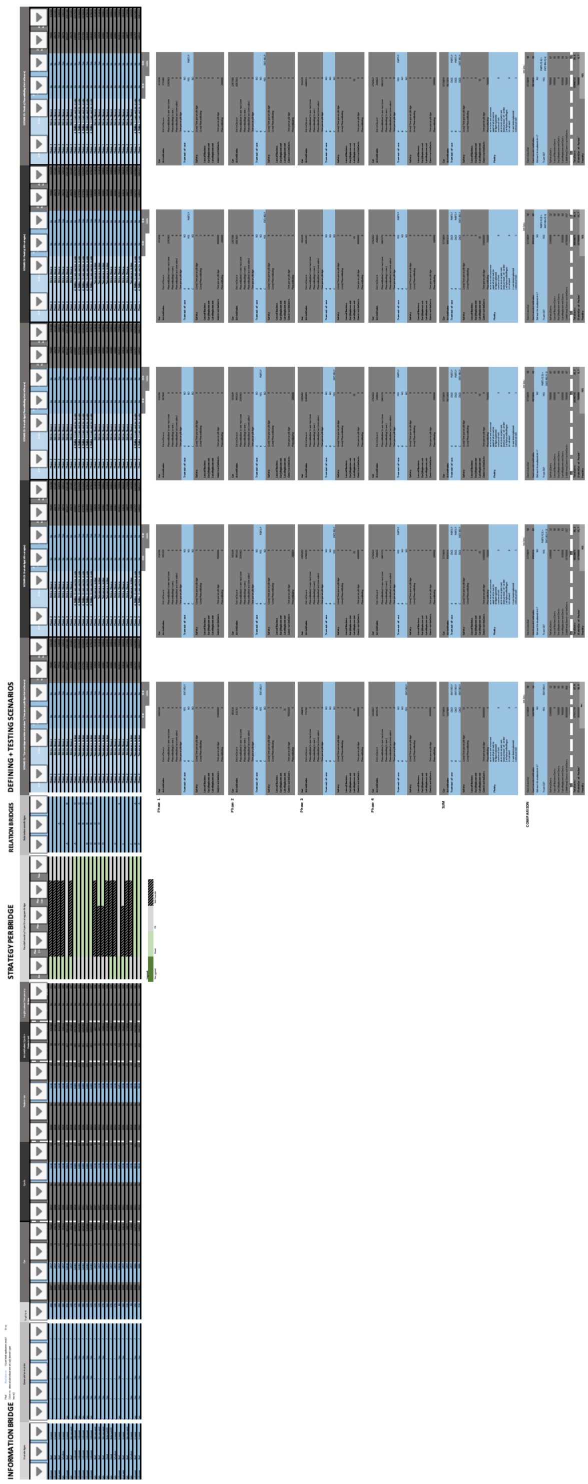

Figure D.3: Excel Spreadsheet 2: DSS (Overview)

D.2.2. DSS: zoomed in per component

INFORMATION BRIDGES Fill in all Blue Columns! Use the dropdown menu's! Grey Columns will be calculated automatically (do not type here)!

	State bridges			General information					Traffic →	Car			
Bridge Nur[…]	Risk	Dive inspection	Conclusion State Bridg[…]	Tram?	(Access) route in/to shopping area[…]	Wide enough for phased building (tram+a[…] modes[…]	Wide enough for active modes OR tram[…]	Substantially more acci[…]	Distance to alternative bridge [m]	Detour Time Car [hr]	Intensity Car per Day	Vehicle Loss Hours Car per day [hr]	Costs Vehicle Loss Hours Car per year […]
1	Unknown	Bad	Urgent	/	/	/	/	/	200	0.007	1937	13	70685
2	Unknown	Bad	Urgent	/	/	/	/	/	140	0.005	1937	9	49479
3	Average	Bad	Urgent	/	/	/	/	/	260	0.009	1937	17	91890
4	High	Medium	Urgent	/	/	/	/	/	100	0.003	1937	6	35342
5	Unknown	Bad	Urgent	Yes	/	Yes	Yes	/	350	0.012	14018	164	895427
6	High	Bad	Very urgent	/	/	/	/	/	140	0.005	1937	9	49479
7	Unknown	Unknown	Unknown	Yes	Yes	Yes	Yes	/	170	0.006	14182	80	439997
8	Unknown	Unknown	Unknown	Yes	Yes	Yes	Yes	/	180	0.006	14182	85	465879
9	Unknown	Unknown	Unknown	Yes	Yes	Yes	Yes	/	180	0.006	14182	85	465879
10	Unknown	Unknown	Unknown	Yes	Yes	Yes	Yes	/	120	0.004	14182	57	310586
11	Unknown	Unknown	Unknown	Yes	Yes	Yes	Yes	/	120	0.004	14182	57	310586
12	High	Bad	Very urgent	/	Yes	/	/	/	120	0.004	1937	8	42411
13	High	Bad	Very urgent	/	Yes	/	Yes	/	120	0.004	1937	8	42411
14	High	Bad	Very urgent	/	Yes	/	Yes	/	170	0.006	1937	11	60082
15	High	Good	Relatively OK	/	Yes	/	/	/	160	0.005	1937	10	56548
16	High	Good	Relatively OK	/	/	/	/	/	170	0.006	1937	11	60082
17	High	Medium	Urgent	/	/	/	/	/	170	0.006	1937	11	60082
18	Unknown	Bad	Urgent	Yes	/	Yes	Yes	/	80	0.003	13836	37	202011
19	Average	Bad	Urgent	/	/	/	Yes	/	180	0.006	1937	12	63616
20	High	Bad	Very urgent	/	/	/	/	/	110	0.004	1937	7	38877
21	High	Medium	Urgent	/	Yes	/	/	/	90	0.003	1937	6	31808
22	Unknown	Bad	Urgent	Yes	Yes	Yes	Yes	/	190	0.006	3886	25	134757
23	Unknown	Bad	Urgent	Yes	Yes	Yes	Yes	/	210	0.007	3886	27	148942

	Cyclist				Pedestrian				Active Modes (Cyclist + Pedestrian)		Insights about Temporary Bridge	
Bridge Nur[…]	Detour Time Cyclist […]	Detour Time Cyclist above Limit[…]	Intensity Cyclists per Da[…]	Loss Hours Cyclist per Day […]	Detour Time Pedestrian […]	Detour Time Pedestrian above Limit[…]	Intensity Pedestrians per Day	Loss Hours Pedestrian per Day [h[…]	Sum Active Modes Loss Hours per Day	Costs Active Modes Loss Hours per Year	Costs Active Modes Loss Hours per Year >Costs Tem[…] Bridge	Ratio Costs Active Modes Loss Hours per Year : Cost[…] Temporary […]
1	0.012	No	1116	13	0.040	No	1116	45	58	316288	No	0.11
2	0.008	No	1116	9	0.028	No	1116	31	40	221401	No	0.07
3	0.015	No	1116	17	0.052	No	1116	58	75	411174	No	0.14
4	0.006	No	1116	7	0.020	No	1116	22	29	158144	No	0.05
5	0.021	No	5043	104	0.070	No	5043	353	457	2501180	No	0.83
6	0.008	No	1116	9	0.028	No	1116	31	40	221401	No	0.07
7	0.010	No	6466	65	0.034	No	6466	220	285	1557659	No	0.52
8	0.011	No	6466	68	0.036	No	6466	233	301	1649286	No	0.55
9	0.011	No	6466	68	0.036	No	6466	233	301	1649286	No	0.55
10	0.007	No	6466	46	0.024	No	6466	155	201	1099524	No	0.37
11	0.007	No	6466	46	0.024	No	6466	155	201	1099524	No	0.37
12	0.007	No	1116	8	0.024	No	1116	27	35	189773	No	0.06
13	0.007	No	1116	8	0.024	No	1116	27	35	189773	No	0.06
14	0.010	No	1116	11	0.034	No	1116	38	49	268844	No	0.09
15	0.009	No	1116	11	0.032	No	1116	36	46	253030	No	0.08
16	0.010	No	1116	11	0.034	No	1116	38	49	268844	No	0.09
17	0.010	No	1116	11	0.034	No	1116	38	49	268844	No	0.09
18	0.005	No	6491	31	0.016	No	6491	104	134	735850	No	0.25
19	0.011	No	1116	12	0.036	No	1116	40	52	284659	No	0.09
20	0.006	No	1116	7	0.022	No	1116	25	32	173958	No	0.06
21	0.005	No	1116	6	0.018	No	1116	20	26	142329	No	0.05
22	0.011	No	9010	101	0.038	No	9010	342	443	2425863	No	0.81
23	0.012	No	9010	111	0.042	No	9010	378	490	2681217	No	0.89

Figure D.4: Excel Spreadsheet 2: DSS (Information Bridges) [this figure is rotated]

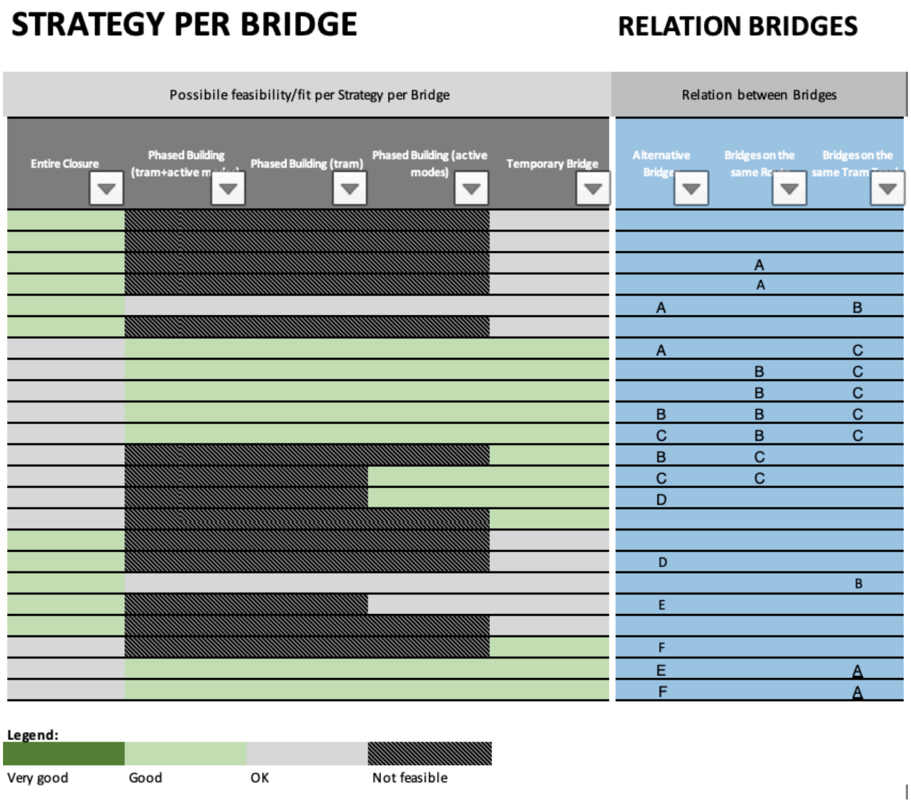

Figure D.5: Excel Spreadsheet 2: DSS (Strategy per Bridge + Relation Bridges)

DEFINING + TESTING SCENARIOS

SCENARIO 1 - "Current Approach Amsterdam" (Temporary Bridge + Entire Closure)						SCENARIO 2 - State Bridge (All Strategies)					
1 | Planning	1| Strategy	1| Alternative Bridge Chosen in Same Pha	1| Discount	1 | Costs Car inc. Discour	1 | Costs Active Modes inc. Discour	2 | Planning	2| Strategy	2| Alternative Bridge Chosen in Same Pha	2| Discount	2 | Costs Car inc. Discour	2 | Costs Active Modes inc. Discour
Phase 3	Entire Closure	No	No	70685	316288	Phase 2	Entire Closure	No	No	70685	316288
Phase 2	Entire Closure	No	No	49479	221401	Phase 2	Entire Closure	No	No	49479	221401
Phase 3	Entire Closure	No	Yes	73512	328939	Phase 2	Entire Closure	No	Yes	73512	328939
Phase 3	Entire Closure	No	Yes	28274	126515	Phase 2	Entire Closure	No	Yes	28274	126515
Phase 4	Entire Closure	No	No	895427	2501180	Phase 3	Entire Closure	No	No	895427	2501180
Phase 2	Entire Closure	No	No	49479	221401	Phase 1	Entire Closure	No	No	49479	221401
Phase 1	Temporary bridge	No	No	439997	1557659	Phase 4	hased Building (tram+active modes	No	No	439997	1557659
Phase 1	Temporary bridge	No	Yes	372703	1319429	Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 1	Temporary bridge	No	Yes	372703	1319429	Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 1	Temporary bridge	No	Yes	248469	879619	Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 1	Temporary bridge	No	Yes	248469	879619	Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 3	Temporary bridge	No	Yes	33929	151818	Phase 1	Temporary bridge	No	Yes	33929	151818
Phase 3	Temporary bridge	No	Yes	33929	151818	Phase 1	Temporary bridge	No	Yes	33929	151818
Phase 2	Temporary bridge	No	No	60082	268844	Phase 1	Temporary bridge	No	No	60082	268844
Phase 3	Temporary bridge	No	No	56548	253030	Phase 3	Temporary bridge	No	No	56548	253030
Phase 4	Entire Closure	No	No	60082	268844	Phase 4	Entire Closure	No	No	60082	268844
Phase 4	Entire Closure	No	No	60082	268844	Phase 3	Entire Closure	No	No	60082	268844
Phase 4	Entire Closure	No	No	202011	735850	Phase 3	Entire Closure	No	No	202011	735850
Phase 4	Entire Closure	No	No	63616	284659	Phase 3	Entire Closure	No	No	63616	284659
Phase 2	Entire Closure	No	No	38877	173958	Phase 1	Entire Closure	No	No	38877	173958
Phase 4	Temporary bridge	No	No	31808	142329	Phase 3	Temporary bridge	No	No	31808	142329
Phase 2	Temporary bridge	No	No	134757	2425863	Phase 2	hased Building (tram+active modes	No	No	134757	2425863
Phase 2	Temporary bridge	No	No	148942	2681217	Phase 2	hased Building (tram+active modes	No	No	148942	2681217
		OK	OK					OK	OK		
			100%						100%		

Figure D.6: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - planning scenarios 1+2)

SCENARIO 3 - State Bridge (Phased Building + Entire Closure)					
2 | Planning	2| Strategy	2| Alternative Bridge Chosen in Same Pha	2| Discount	2 | Costs Car inc. Discour	2 | Costs Active Modes inc. Discour
Phase 2	Entire Closure	No	No	70685	316288
Phase 2	Entire Closure	No	No	49479	221401
Phase 2	Entire Closure	No	Yes	73512	328939
Phase 2	Entire Closure	No	Yes	28274	126515
Phase 3	Entire Closure	No	No	895427	2501180
Phase 1	Entire Closure	No	No	49479	221401
Phase 4	hased Building (tram+active modes	No	No	439997	1557659
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 1	Entire Closure	No	Yes	33929	151818
Phase 1	Entire Closure	No	Yes	33929	151818
Phase 1	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	56548	253030
Phase 4	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	202011	735850
Phase 3	Entire Closure	No	No	63616	284659
Phase 1	Entire Closure	No	No	38877	173958
Phase 3	Entire Closure	No	No	31808	142329
Phase 2	hased Building (tram+active modes	No	No	134757	2425863
Phase 2	hased Building (tram+active modes	No	No	148942	2681217
		OK	OK		
			100%		

SCENARIO 4 - Flexibility (All Strategies)					
2 | Planning	2| Strategy	2| Alternative Bridge Chosen in Same Pha	2| Discount	2 | Costs Car inc. Discour	2 | Costs Active Modes inc. Discour
Phase 3	Entire Closure	No	No	70685	316288
Phase 3	Entire Closure	No	No	49479	221401
Phase 2	Entire Closure	No	Yes	73512	328939
Phase 2	Entire Closure	No	Yes	28274	126515
Phase 2	Entire Closure	No	No	895427	2501180
Phase 2	Entire Closure	No	No	49479	221401
Phase 4	hased Building (tram+active modes	No	No	439997	1557659
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 1	Temporary bridge	No	Yes	33929	151818
Phase 1	Temporary bridge	No	Yes	33929	151818
Phase 1	Temporary bridge	No	No	60082	268844
Phase 3	Temporary bridge	No	No	56548	253030
Phase 4	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	60082	268844
Phase 2	Entire Closure	No	No	202011	735850
Phase 3	Entire Closure	No	No	63616	284659
Phase 2	Entire Closure	No	No	38877	173958
Phase 3	Temporary bridge	No	No	31808	142329
Phase 1	hased Building (tram+active modes	No	No	134757	2425863
Phase 1	hased Building (tram+active modes	No	No	148942	2681217
		OK	OK		
			100%		

SCENARIO 5 - Flexibility (Phased Building + Entire Closure)					
2 | Planning	2| Strategy	2| Alternative Bridge Chosen in Same Pha	2| Discount	2 | Costs Car inc. Discour	2 | Costs Active Modes inc. Discour
Phase 3	Entire Closure	No	No	70685	316288
Phase 3	Entire Closure	No	No	49479	221401
Phase 2	Entire Closure	No	Yes	73512	328939
Phase 2	Entire Closure	No	Yes	28274	126515
Phase 2	Entire Closure	No	No	895427	2501180
Phase 2	Entire Closure	No	No	49479	221401
Phase 4	hased Building (tram+active modes	No	No	439997	1557659
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	372703	1319429
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 4	hased Building (tram+active modes	No	Yes	248469	879619
Phase 1	Entire Closure	No	Yes	33929	151818
Phase 1	Entire Closure	No	Yes	33929	151818
Phase 1	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	56548	253030
Phase 4	Entire Closure	No	No	60082	268844
Phase 3	Entire Closure	No	No	60082	268844
Phase 2	Entire Closure	No	No	202011	735850
Phase 3	Entire Closure	No	No	63616	284659
Phase 2	Entire Closure	No	No	38877	173958
Phase 3	Entire Closure	No	No	31808	142329
Phase 1	hased Building (tram+active modes	No	No	134757	2425863
Phase 1	hased Building (tram+active modes	No	No	148942	2681217
		OK	OK		
			100%		

Figure D.7: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - planning scenarios 3+4+5)

Phase 1

		Scenario 1		Scenario 2	
Car		1682340		216296	
Active Modes	*Entire Closure*	0		395359	
	Phased Building (tram+active m	0		0	
	Phased building (tram)	0		0	
	Phased building (active modes)	0		0	
	Temporary Bridge	0		0	
Tram out-of-use	*A*	YES	ENTIRELY	NO	
	B	NO		NO	
	C	NO		NO	
Safety	*Use of Temporary Bridge*	5		3	
	Use of Phased Building	0		0	
Loss of Business		0		0	
Early Replacement		5		0	
Late Replacement		0		0	
Construction Costs	*Temporary Bridge*	15000000		9000000	
	Phased Building	0		0	

Phase 2

		Scenario 1		Scenario 2	
Car		481616		505649	
Active Modes	*Entire Closure*	616761		993143	
	Phased Building (tram+active m	0		1595963	
	Phased building (tram)	0		0	
	Phased building (active modes)	0		0	
	Temporary Bridge	0		0	
Tram out-of-use	*A*	NO		NO	
	B	YES	ENTIRELY	YES	PARTLY
	C	NO		NO	
Safety	*Use of Temporary Bridge*	3		0	
	Use of Phased Building	0		2	
Loss of Business		0		0	
Early Replacement		0		0	
Late Replacement		1.5		0	
Construction Costs	*Temporary Bridge*	9000000		0	
	Phased Building	0		200000	

Phase 3

		Scenario 1		Scenario 2	
Car		296876		1309492	
Active Modes	*Entire Closure*	771742		3790533	
	Phased Building (tram+active m	0		0	
	Phased building (tram)	0		0	
	Phased building (active modes)	0		0	
	Temporary Bridge	0		0	
Tram out-of-use	*A*	NO		NO	
	B	NO		NO	
	C	NO		YES	ENTIRELY
Safety	*Use of Temporary Bridge*	3		2	
	Use of Phased Building	0		0	
Loss of Business		0		0	
Early Replacement		0		0	
Late Replacement		2.5		2.5	
Construction Costs	*Temporary Bridge*	9000000		6000000	
	Phased Building	0		0	

Figure D.8: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - results scenario 1+2 phase 1-3)

			Scenario 1		Scenario 2	
Phase 4	**Car**		1313027		1742422	
	Active Modes	*Entire Closure*	4059378		268844	
		Phased Building (tram+active m	0		1861174	
		Phased building (tram)	0		0	
		Phased building (active modes)	0		0	
		Temporary Bridge	0		0	
	Tram out-of-use	*A*	NO		YES	PARTLY
		B	NO		NO	
		C	YES	ENTIRELY	NO	
	Safety	*Use of Temporary Bridge*	1		0	
		Use of Phased Building	0		5	
	Loss of Business		0		0	
	Early Replacement		0		0	
	Late Replacement		5		0	
	Construction Costs	*Temporary Bridge*	3000000		0	
		Phased Building	0		500000	
SUM	**Car**		3773859		3773859	
	Active Modes		5447880		8905016	
	Tram out-of-use	*A*	ONCE	ENTIRELY	ONCE	PARTLY
		B	ONCE	ENTIRELY	ONCE	PARTLY
		C	ONCE	ENTIRELY	ONCE	ENTIRELY
	Safety	*Use of Temporary Bridge*	12		5	
		Use of Phased Building	0		7	
	Loss of Business		0		0	
	Early Replacement		5		0	
	Late Replacement		9		2.5	
	Construction Costs	*Temporary Bridge*	36000000		15000000	
		Phased Building	0		700000	
	Flexibility	#times maintanance of a pair of alternative bridges is planned consecutively	0		3	
		#times multiple tram lanes are out-of-order (with phased building as strategy)	0		0	
		#times maintenance of tram lanes is planned consecutively	1		1	

COMPARISON	Scenario 1	in millions:	Scenario 2	in millions:
Costs Loss Car	3773859	3.8	3773859	3.8
Cost Loss Active Modes	5447880	5.4	8905016	8.9
Detour times above Limit?	NO		NO	
Tram OK?	YES	ENTIRELY	YES	PARTLY (2) + ENTIRELY (1)
Safety Costs	1200000	1.2	1200000	1.2
Loss of Business Costs	0	0.0	0	0.0
Early Replacement Costs	500000	0.5	0	0.0
Late Replacement Costs	900000	0.9	250000	0.3
(Additional) Construction Costs	36000000	36.0	15700000	15.7
Flexibility Costs	100000	0.1	400000	0.4
Total Costs:	47921739	**47.9**	**30228875**	**30.2**
Of which 'Out-of-Pocket'	36000000	**36.0**	**15700000**	**15.7**
Feasibility	**NO**		**YES**	

Figure D.9: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - results scenario 1+2 phase 4 + sum + comparison)

Phase	Category	Item	Scenario 3		Scenario 4		Scenario 5	
Phase 1	Car		216296		411638		411638	
	Active Modes	Entire Closure	967840		0		572480	
		Phased Building (tram+active m	0		1595963		1595963	
		Phased building (tram)	0		0		0	
		Phased building (active modes)	0		0		0	
		Temporary Bridge	0		0		0	
	Tram out-of-use	A	NO		NO		NO	
		B	NO		YES	PARTLY	YES	PARTLY
		C	NO		NO		NO	
	Safety	Use of Temporary Bridge	0		3		0	
		Use of Phased Building	0		2		2	
	Loss of Business		3		0		3	
	Early Replacement		0		0		0	
	Late Replacement		0		0		0	
	Construction Costs	Temporary Bridge	0		9000000		0	
		Phased Building	0		200000		200000	
Phase 2	Car		505649		1287580		1287580	
	Active Modes	Entire Closure	993143		4087843		4087843	
		Phased Building (tram+active m	1595963		0		0	
		Phased building (tram)	0		0		0	
		Phased building (active modes)	0		0		0	
		Temporary Bridge	0		0		0	
	Tram out-of-use	A	NO		NO		NO	
		B	YES	PARTLY	NO		NO	
		C	NO		YES	ENTIRELY	YES	ENTIRELY
	Safety	Use of Temporary Bridge	0		0		0	
		Use of Phased Building	2		0		0	
	Loss of Business		0		0		0	
	Early Replacement		0		0		0	
	Late Replacement		0		1		1	
	Construction Costs	Temporary Bridge	0		0		0	
		Phased Building	200000		0		0	
Phase 3	Car		1309492		332219		332219	
	Active Modes	Entire Closure	4185893		1091192		1486551	
		Phased Building (tram+active m	0		0		0	
		Phased building (tram)	0		0		0	
		Phased building (active modes)	0		0		0	
		Temporary Bridge	0		0		0	
	Tram out-of-use	A	NO		NO		NO	
		B	NO		NO		NO	
		C	YES	ENTIRELY	NO		NO	
	Safety	Use of Temporary Bridge	0		2		0	
		Use of Phased Building	0		0		0	
	Loss of Business		2		0		2	
	Early Replacement		0		0		0	
	Late Replacement		2.5		2.5		2.5	
	Construction Costs	Temporary Bridge	0		6000000		0	
		Phased Building	0		0		0	

Figure D.10: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - results scenario 3+4+5 phase 1-3) [this figure is rotated]

Phase 4

		Scenario 3		Scenario 4		Scenario 5	
Car		1742422		1742422		1742422	
Active Modes	*Entire Closure*	268844		268844		268844	
	Phased Building (tram+active m	1861174		1861174		1861174	
	Phased building (tram)	0		0		0	
	Phased building (active modes)	0		0		0	
	Temporary Bridge	0		0		0	
Tram out-of-use	*A*	YES	PARTLY	YES	PARTLY	YES	PARTLY
	B	NO		NO		NO	
	C	NO		NO		NO	
Safety	*Use of Temporary Bridge*	0		0		0	
	Use of Phased Building	5		5		5	
Loss of Business		0		0		0	
Early Replacement		0		0		0	
Late Replacement		0		0		0	
Construction Costs	*Temporary Bridge*	0		0		0	
	Phased Building	500000		500000		500000	

SUM

		Scenario 3		Scenario 4		Scenario 5	
Car		3773859		3773859		3773859	
Active Modes		9872856		8905016		9872856	
Tram out-of-use	*A*	ONCE	PARTLY	ONCE	PARTLY	ONCE	PARTLY
	B	ONCE	PARTLY	ONCE	PARTLY	ONCE	PARTLY
	C	ONCE	ENTIRELY	ONCE	ENTIRELY	ONCE	ENTIRELY
Safety	*Use of Temporary Bridge*	0		5		0	
	Use of Phased Building	7		7		7	
Loss of Business		5		0		5	
Early Replacement		0		0		0	
Late Replacement		2.5		3.5		3.5	
Construction Costs	*Temporary Bridge*	0		15000000		0	
	Phased Building	700000		700000		700000	
Flexibility	#times maintanance of a pair of alternative bridges is planned consecutively	3		0		0	
	#times multiple tram lanes are out-of-order (with phased building as strategy)	0		0		0	
	#times maintenance of tram lanes is planned consecutively	1		1		1	

COMPARISON

	Scenario 3	in millions:	Scenario 4	in millions:	Scenario 5	in millions:
Costs Loss Car	3773859	3.8	3773859	3.8	3773859	3.8
Cost Loss Active Modes	9872856	9.9	8905016	8.9	9872856	9.9
Detour times above Limit?	NO		NO		NO	
Tram OK?	YES	PARTLY (2) + ENTIRELY (1)	YES	PARTLY (2) + ENTIRELY (1)	YES	PARTLY (2) + ENTIRELY (1)
Safety Costs	700000	0.7	1200000	1.2	700000	0.7
Loss of Business Costs	500000	0.5	0	0.0	500000	0.5
Early Replacement Costs	0	0.0	0	0.0	0	0.0
Late Replacement Costs	250000	0.3	350000	0.4	350000	0.4
(Additional) Construction Costs	700000	0.7	15700000	15.7	700000	0.7
Flexibility Costs	400000	0.4	100000	0.1	100000	0.1
Total Costs:	**16196715**	**16.2**	**30028875**	**30.0**	**15996715**	**16.0**
Of which 'Out-of-Pocket'	**700000**	**0.7**	**15700000**	**15.7**	**700000**	**0.7**
Feasibility	**YES**		**YES**		**YES**	

Figure D.11: Excel Spreadsheet 2: DSS (Defining + Testing Scenarios - results scenario 3+4+5 phase 4 + sum + comparison) [this figure is rotated]

D.3. Excel Spreadsheet 3: Values of Parameters

Parameters used in part 'Information Bridges'

Blue Bocks can be changed! Do <u>not</u> change the values in the Grey Blocks!

Detour Times			
Limit for cyclists	0.08	hr	(0,08 is 5 minutes)
Limit for pedestrians	0.08	hr	(0,08 is 5 minutes)
Speed			
Car speed	30	km/h	
Cycling speed [km/h]	17	km/h	
Walking speed [km/h]	5	km/h	
General Costs			
Value of Time	15	€/hr/person	
Temporary Bridge	3000000	€	
Phased building (i.e. Gauntlet Track)	100000	€	

Figure D.12: Excel Spreadsheet 3: Values of Parameters (Parameters used in part 'Information Bridges')

Parameters used in part 'Strategy per Bridge'

	Criteria	Weight	Entire Closure	Phased Building (tram+active modes)	Phased Building (tram)	Phased Building (active modes)	Temporary Bridge	
Criteria 1	*(Access) route to/from shopping area*	1	/	Yes	Yes	Yes	Yes	
Criteria 2	*Substantially more accidents*	1	Yes	/	/	/	/	
Criteria 3	*Detour Time Cyclist above Limit?*	1	No	Yes	Yes	Yes	Yes	AND (No) OR (Yes)
	Detour Time Pedestrian above Limit?		No	Yes	Yes	Yes	Yes	
	Costs Active Modes Loss Hours per Year > Costs Temporary Bridge?		–	–	–	–	Yes	
	Tram?		–	Yes	Yes	–	–	GO / NOGO
	*Wide enough tram **+** active modes*		–	Yes	–	–	–	
	*Wide enough tram **or** active modes*		–	–	Yes	Yes	–	

Explanation:

Points are awarded per bridge when it meets the criteria linked to a strategy. This way, an estimation can be made for each bridge about which strategy might be a good option. For example: When a bridge has no tram (/), is not an (access) route to/from a shopping area (/), has a low VVU and detour time, and has substantially more accidents; choosing for entire closure might be a good option!

The importance of the criteria can be changed under the heading 'weight.' Furthermore, 'Yes' can be changed to '/' and the other way around, as indicated by the blue background. When changes want to be made regarding '-,' the excel file should be edited. Changes to the GO/NO GO criteria should also be edited in the excel script.

'Criteria 3' consists of 3 sub-criteria. A point is awarded to entire closure if both satisfy 'No' (AND-function Excel). The other strategies are awarded a point if there is at least 1 'Yes' between them (OR-function excel).

The results of the criteria of Phased Building (tram + active modes) and Phased Building (tram) are the same, but there is a preference for Phased Building (tram + active modes). Furthermore, the criteria of Phased Building (active modes) and Temporary Bridge are also similar, but there is a difference in the GO/NO GO criteria, and the acceptable detour time also plays a role in this decision.

Figure D.13: Excel Spreadsheet 3: Values of Parameters (Parameters used in part 'Strategy per Bridge')

Parameters used in part 'Defining + Testing Scenarios'

Discount factor bridges next to each other		
Car	0.8	
Active Modes	0.8	
Factor costs loss hours active modes		
Entire Closure	1	
Phased Building (tram+active modes)	0.25	
Phased Building (tram)	1	
Phased Building (active modes)	0.25	
Temporary Bridge	0	

Set to 1 if active modes can't access 100% of the time. Set to 0,25 if active modes can access 75% of the time. Set to 0 if active modes can

Factor for Additional Time		
Entire closure	1	
Phased Building (tram+active modes)	1.25	
Phased building (tram)	1.25	
Phased building (active modes)	1.25	
Temporary bridge	1.25	

1 = reference, 1,25 is 25% percent longer than the reference. When the reference is 1 year this one is 15 months.

Punishment points for Early Replacement	*Unknown*	*Relatively OK*
Phase 1	1	1
Phase 2	0.5	0.5
Phase 3	0.5	0
Phase 4	0	0

Punishment points for Late Replacement	*Urgent*	*Very Urgent*
Phase 1	0	0
Phase 2	0	0.5
Phase 3	0.5	0.5
Phase 4	1	1

Costs of 1 'point'		
Safety	100000	€
Loss of business	100000	€
Early replacement	100000	€
Late replacement	100000	€
Flexibility	100000	€
Budget Municipality		
4 year Budget to spend by the Municipality:	25000000	€

Figure D.14: Excel Spreadsheet 3: Values of Parameters (Parameters used in part 'Defining + Testing Scenarios')

D.4. Excel Spreadsheet 4: Sensitivity Analysis

Legend →	Worst (highest value)	Medium	Best (lowest value)	Note: all values are in millions of euros

Analysis 1	Settings		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	DEFAULT Settings	Costs Loss Car	3.8	3.8	3.8	3.8	3.8
		Cost Loss Active Modes	5.4	8.9	9.9	8.9	9.9
		Detour times above Limit?	NO	NO	NO	NO	NO
		Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
		Safety Costs	1.2	1.2	0.7	1.2	0.7
		Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
		Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
		Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
		(Additional) Construction Costs	36.0	15.7	0.7	15.7	0.7
		Flexibility Costs	0.1	0.4	0.4	0.1	0.1
		Total costs:	47.9	30.2	16.2	30.0	16.0
		Of which 'Out-of-Pocket'	36.0	15.7	0.7	15.7	0.7
		Feasibility	NO	YES	YES	YES	YES

Analysis 2	Settings		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	Changes in 'General Costs'	Costs Loss Car	7.5	7.5	7.5	7.5	7.5
	VoT: 15 >> 30 euro/hr	Cost Loss Active Modes	10.9	17.8	19.7	17.8	19.7
	Costs Temporary Bridge: 3 >> 2 million euro	Detour times above Limit?	NO	NO	NO	NO	NO
	Costs Phased Building: 100.000 >> 200.000 euro	Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
		Safety Costs	1.2	1.2	0.7	1.2	0.7
		Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
		Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
		Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
		(Additional) Construction Costs	24.0	11.4	1.4	11.4	1.4
		Flexibility Costs	0.1	0.4	0.4	0.1	0.1
		Total costs:	45.1	38.6	30.5	38.4	30.3
		Of which 'Out-of-Pocket'	24.0	11.4	1.4	11.4	1.4
		Feasibility	YES	YES	YES	YES	YES

Figure D.15: Excel Spreadsheet 4: Sensitivity Analysis (analysis 1+2)

Analysis 3	Settings		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	Previous changes + Flexibility Costs	Costs Loss Car	7.5	7.5	7.5	7.5	7.5
	Flexibility Costs: 100.000 >> 5.000.000 euro	Cost Loss Active Modes	10.9	17.8	19.7	17.8	19.7
		Detour times above Limit?	NO	NO	NO	NO	NO
		Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
		Safety Costs	1.2	1.2	0.7	1.2	0.7
		Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
		Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
		Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
		(Additional) Construction Costs	24.0	11.4	1.4	11.4	1.4
		Flexibility Costs	5.0	20.0	20.0	5.0	5.0
		Total costs:	50.0	58.2	50.1	43.3	35.2
		Of which 'Out-of-Pocket'	24.0	11.4	1.4	11.4	1.4
		Feasibility	YES	YES	YES	YES	YES

Analysis 4	Settings		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	DEFAULT + Safety + Loss of Business	Costs Loss Car	3.8	3.8	3.8	3.8	3.8
	Costs Safety: 100.000 >> 2.000.000 euro	Cost Loss Active Modes	5.4	8.9	9.9	8.9	9.9
	Costs Loss of Business: 100.000 >> 2.000.000 euro	Detour times above Limit?	NO	NO	NO	NO	NO
		Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
		Safety Costs	24.0	24.0	14.0	24.0	14.0
		Loss of Business Costs	0.0	0.0	10.0	0.0	10.0
		Early Replacement Costs	0.5	0.0	0.0	0.0	0.0
		Late Replacement Costs	0.9	0.3	0.3	0.4	0.4
		(Additional) Construction Costs	36.0	15.7	0.7	15.7	0.7
		Flexibility Costs	0.1	0.4	0.4	0.1	0.1
		Total costs:	70.7	53.0	39.0	52.8	38.8
		Of which 'Out-of-Pocket'	36.0	15.7	0.7	15.7	0.7
		Feasibility	NO	YES	YES	YES	YES

Analysis 5	Settings		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	DEFAULT + Early/Late Replacement + Costs	Costs Loss Car	3.8	3.8	3.8	3.8	3.8
	Costs Early and Late Replacement: 100.000 >> 5.000.000 euro	Cost Loss Active Modes	5.4	8.9	9.9	8.9	9.9
	Costs Temporary Bridge: 3.000.000 >> 1.000.000 euro	Detour times above Limit?	NO	NO	NO	NO	NO
		Tram OK?	ENTIRELY	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)	PARTLY (2) + ENTIRELY (1)
		Safety Costs	1.2	1.2	0.7	1.2	0.7
		Loss of Business Costs	0.0	0.0	0.5	0.0	0.5
		Early Replacement Costs	25.0	0.0	0.0	0.0	0.0
		Late Replacement Costs	45.0	12.5	12.5	17.5	17.5
		(Additional) Construction Costs	12.0	5.7	0.7	5.7	0.7
		Flexibility Costs	0.1	0.4	0.4	0.1	0.1
		Total costs:	92.5	32.5	28.4	37.2	33.1
		Of which 'Out-of-Pocket'	12.0	5.7	0.7	5.7	0.7
		Feasibility	YES	YES	YES	YES	YES

Figure D.16: Excel Spreadsheet 4: Sensitivity Analysis (analysis 3+4+5)