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The role of a calculative method in sustainable transitions

How to mitigate the sources of inaccuracy in cost-benefit analyses

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ABSTRACT

Sustainability is a growing concern globally and investments are needed to prevent irreversible and catastrophic impacts. For these investments to be a realized, they must be communicated in an attractive way. This can be achieved with the calculative method of cost-benefit analysis (CBA). CBA is commonly used to appraise infrastructure projects in the public sector, which is why the engineering department of the town of Canmore's intends to implement CBA as a method for their sustainable transition. This thesis aims to support the engineering department's implementation of CBA, and to contribute and expand upon previous research regarding CBA. To reach this aim, the study used the method of systematic combining. This method enables simultaneous development of academia and practice. Furthermore, the research was conducted by an extensive literature review, semi-structured interviews, and a conceptual CBA, including a sensitivity analysis. Previous research concludes that there are challenges with inaccuracy in CBA, with three possible explanations; technical-, political-economic-, and psychological explanations. The study shows that all explanations are, or could be, prevalent in Canmore, and describes three ways to mitigate the inaccuracies; putting an early effort to improve data, aligning incentives, and adopting the method of reference class forecasting. In contrast to previous research regarding inaccuracies in CBA, this study suggests a correlation between the cognitive structure of involvement and bias. This correlation might connect how individuals' make decisions with inaccuracies in a calculative method. Thus, Canmore has a good chance, of mitigating possible inaccuracies and implement CBA in an efficient way, to perform a sustainable transition.

Key words: sustainable transition, infrastructure investments, CBA, inaccuracy in CBA, bias, decision-making

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This chapter introduces the research topic by first explaining the background to sustainable transitions, cost-benefit analyses and inaccuracy in cost-benefit analyses. The chapter also introduces the aim and problematization of the thesis, followed by the delimitations. Lastly, the structure of the thesis is presented.

1.1 Background

The background describes the basic concepts necessary to understand the aim and problematization of the thesis.

1.1.1 Global warming and Canmore

Today, climate change is accelerating faster than predicted (United Nations, 2019). The UN summit's Science Advisory Group have compiled key findings from recent research on global climate change and concluded that the year of 2019 was one of the warmest years on record with a high degree of extreme weather around the globe. The increase in global temperature is the cause to numerous concerns such as extreme weather events, unique and threatened systems, large scale singular events etc (Intergovernmental Panel on Climate Change, 2018). However, science can tell us what needs to be done to prevent further global warming. To prevent irreversible and catastrophic impacts, global warming must be limited to 1.5°C from before the industrial age until the end of this century. With the current direction global temperatures will increase with 3°C (pre-industrial age) by 2100. Therefore, changes are necessary and carbon dioxide emission must decrease with 45% by 2030 and reach net zero by 2050.

A way to mitigate the climate change and decrease carbon dioxide emissions is sustainable transitions (Jensen, Cashmore and Elle, 2017). What is commonly agreed upon is that in order to decrease the emissions and reach a sustainable future, a transformation of large-scale socio-technological systems are needed. To decrease the emissions caused by transportation there must be a transition to transportation modes with little to zero emissions. The current heavily predominant automobile share in transportation thus needs to change in favour of more sustainable modes of transportation, i.e. non-vehicular transportation. However, this is not just a question of introducing new zero emission technologies. In a socio-technological systems perspective, such a transition relies on numerous concerted technological, political, economic and socio-cultural changes to succeed (Geels, 2012).

Canmore Municipality (see Figure 1) is currently in the midst of staging a transition to non-vehicular transportation to contribute to the sustainability transition. Presently, Canmore has a predominant automobile transportation share (80% automobile mode-share in summer 2018) (Stantec consulting; Mobycon corp, 2018). However, they have a goal of decreasing their automobile mode-share and reach a 40% non-vehicular mode-share by the summer of 2030. Non-vehicular mode-share means transportation either by walking, cycling, or public transit. This is a way for the town to become both more sustainable and to manage congestion. To realize the goal, there is a need to change transportation culture, for example making cyclists and pedestrians feel safe and prioritized (Gössling and Choi, 2015). Thus, for the transition to be possible there must be investments in infrastructure. These investments need to be prioritized according to a determining factor, which can be achieved by using the method of cost-benefit analysis (CBA).

FIGURE 1, LOCATION OF CANMORE (GOOGLE MAPS, 2020)

1.1.2 Cost-benefit Analysis

CBA is a calculative method used for decision-making (European Commission, 2014). CBA is defined in the following way:

"Cost-benefit analysis (CBA) is an analytical tool for judging the economic advantages or disadvantages of an investment decision by assessing its costs and benefits in order to assess the welfare change attributable to it." (European Commission, 2014, p.25)

Advantages and disadvantages used in infrastructure investments are for example project costs and vehicle operation costs, but also less obvious ones such as travel time, air pollution and gas prices (Damart and Roy, 2009). These parameters must be given a monetary value according to an accurate reference situation and estimated how they change over time and are influenced in the future.

1.1.3 Inaccuracies in cost-benefit analysis

However, there are challenges with the use of the calculative method of cost-benefit analysis. One of the bigger challenges seems to be inaccuracies in forecasting and valuation (Flyvbjerg, 2008). Flyvbjerg (2008) claims the average accuracy has not improved for the last 70 years and he states three possible explanations to the inaccuracy; technical-, psychological- and political-economic explanations.

Of the three explanations, technical has received the most attention (Flyvbjerg, 2008). It alludes to inaccuracy in terms of inappropriate forecasting models, measurement problems, insufficient data etc. It is the only explanation that does not consider human involvement as an explanation of inaccuracy but instead see data and statistics as the major issue.

According to Mackie and Preston (1998) the systematic "mega error" when evaluating infrastructure projects is, however, that of the appraisal optimism. Flyvbjerg (2008) agrees with this statement and in his article *Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice* he defines Optimism Bias as the main psychological explanation to why forecasting is so inaccurate. This type of bias is explained as a cognitive predisposition to being overly optimistic when anticipating future event. Therefore, it is really a question of a fundamental human error in rational thinking and optimism bias can be seen as an unintentional deception of oneself i.e. a self-deception.

Another cause of inaccuracy in forecasting is the political-economic bias of strategic misrepresentation (Flyvbjerg, 2008). Strategic misrepresentation is explained as an intentional overestimation of benefits and underestimation of costs to increase the chances of approval for a project. Unlike optimism bias, strategic misrepresentation can be seen as an intentional deception and stems from when the political or organizational pressure is high.

The reason these sources of inaccuracy in forecasting has such a big impact of the overall exactness of CBA is because they affect all included parameters throughout the CBA and can therefore be an irreversible contamination of the accuracy of the CBA. This could lead to the wrong projects being realized and ultimately not maximizing benefits for the society.

1.2 Aim and Problematization

Canmore Municipality has the goal of reaching a 40% non-vehicular mode share by the summer of 2030 and this study aims to support the town of Canmore in reaching the goal. The support is in the form of a collaboration with the engineering department of Canmore who intend to use CBA as a calculative method to achieve the sustainable transition.

The engineering department has not previously used CBA as a method for appraising infrastructure projects. By researching the sources of inaccuracy in CBA, Canmore will gain knowledge regarding what CBA entails and have an efficient implementation and usage of the method. Thus, the following research questions have been formulated:

- What does a cost-benefit analysis entail?
- What are the potential sources of inaccuracy in Canmore's future use of cost-benefit analysis?
- How can Canmore mitigate inaccuracies in their future use of cost-benefit analysis?
- How can cost-benefit analysis support decision-making in sustainable transitions?

1.3 Delimitations

This thesis is delimited to investments within the construction industry and the method of CBA and how it can support a sustainable transition. The context in which the method of CBA will be used is a small Canadian mountain community, Canmore, but since previous research is mainly focused on the European context, efforts will be needed in translating this research to suit the concerned context. Another delimitation is based on the town of Canmore's largest budget post, infrastructure investments. This thesis will therefore only focus on these types of investments. Also, since Canmore lack experience in using CBA, this thesis will only investigate the major explanations of inaccuracy in CBAs.

1.4 Structure of thesis

The report is structured into seven chapters in the following way:

- *Chapter 1 – Introduction*, gives a background to the investigated subject. The chapter also includes a problem formulation, research questions and delimitations.
- *Chapter 2 – Theoretical framework*, examines literature regarding cost-benefit analysis as well as topics related to answering the research questions. The chapter provides a theoretical framework for the topics used in the analysis and discussion.
- *Chapter 3 – Methodology*, describes how the study was conducted. The chapter presents the methods for data collection and literature review, accounts for ethical considerations, and the quality of the study.

- *Chapter 4 – Analysis*, combines empirical findings, including a sensitivity analysis, Canmore's integrated transportation plan and results from the interviews.
- *Chapter 5 – Discussion*, discusses the analysis in regard to the theoretical framework and lays the foundation for answering the research questions.
- *Chapter 6 – Conclusion*, gives answers to the research questions formulated in the introduction, and summarizes the findings from the thesis.

2. THEORETICAL FRAMEWORK

This chapter provides theory and knowledge of the method of CBA in decision-making and is used for the analysis to further support the empirical data. The chapter begins with an introduction to why there is a need for sustainable transitions and continues with decision-making and the decision-making process. This subtopic explores the cognitive systems behind decisions, and how the cognitive structure of involvement affects decision-making and the decision-making process. Furthermore, inaccuracies caused by technical-, psychological- and political-economic explanations are explored.

2.1 SUSTAINABLE TRANSITIONING

The global climate change has long been recognized as an issue that needs solutions (United Nations, 2019). Sustainable transitioning is the process of steering society towards becoming more sustainable (Sheldrick, Evans and Schliwa, 2017). To realize such a transition there must be change in the interrelation between technological improvements and societal behavior, i.e. a change to our socio-technological system (Geels, Berkhout and Vuuren, 2016). Sustainable transitioning has been studied by using several analytical approaches on how to best promote such a transition.

Integrated assessment models have the capacity to combine information regarding subjects such as engineering, economic and scientific information, and thus make a basis for decisions to be made based on a wider frame of information. These models are studied to see what drives the transition as well as what the consequences will be. In order to make the transition more politically attractive there is a need to communicate what a sustainable transition will entail (Jensen, Cashmore and Elle, 2017). To communicate the implications of a sustainable transition Jensen Cashmore and Elle (2017) argues that a calculative method is efficient to generate visibilities that can be used to create an attractive political narrative. The calculative method gives the possibility of having a measurement, and thus the visualization.

A cost-benefit analysis (CBA) is a calculative method, generally used to evaluate the socio-economic impact of public investment choices (Damart and Roy, 2009). A CBA has the ability to include the wider frame of information such as an integrated assessment model, and to monetize the information. The following section will discover the foundation and method of CBA.

2.2 COST-BENEFIT ANALYSIS

The purpose of a CBA is to maximize the net value for society by, in a systematic way, appraise costs and benefits (Transportministeriet, 2015). By assigning monetary value to parameters included in the analysis, a common unit can be set, and thus costs and benefits can be measured against each other. This makes it possible to prioritize the projects with the highest net value for society.

The European Commission's *Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020* (2015) defines the standard process of a CBA in seven steps. On the other hand, The Danish Ministry of Transportation (2015) defines the process in five steps. The overall content of the two processes are the same with the difference that the European Commission's (2015) steps are more detailed. For the purpose of highlighting the general steps of CBA, the steps of The Danish Ministry of Transportation's (2015) process are used. These steps are deemed sufficient for this purpose and it is worth to note that The Danish Ministry of Transportation's steps are influenced by the steps of the

European Commission due to the fact that Denmark is a part of the European Union and hence must abide by its regulations regarding CBAs. The steps are explained and developed based on relevant literature (European Commission, 2015; Transport Canada, 1994; Transportministeriet, 2015).

The steps showcased in Figure 2 are regarded as the general steps of CBA.

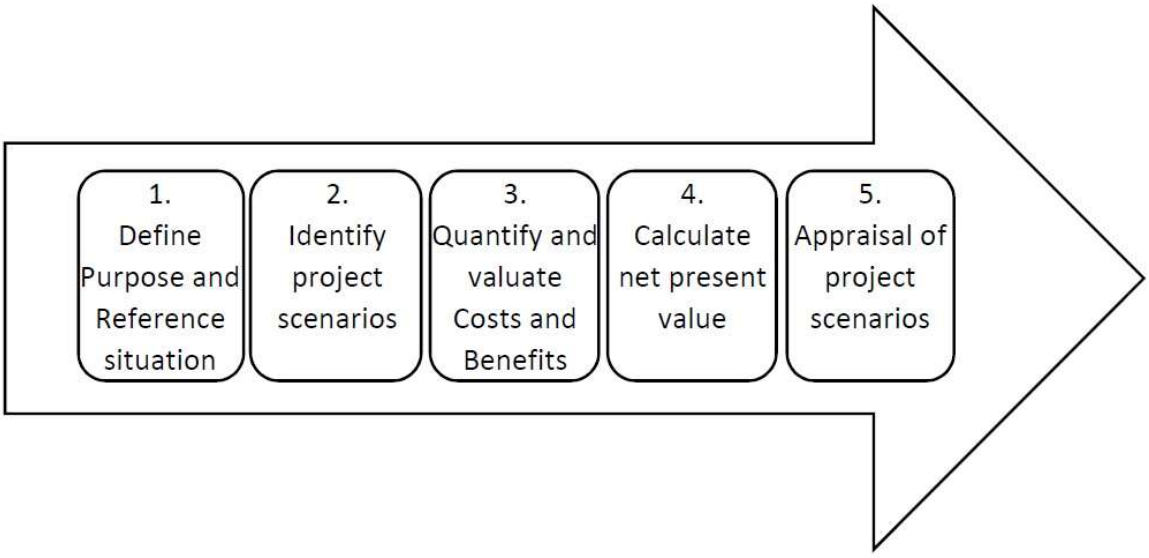

FIGURE 2, THE FIVE STEPS OF A CBA

The *first step* in doing a CBA is to define the purpose of the project and the reference situation in which the alternatives will operate in (Transport Canada, 1994; European Commission, 2014; Transportministeriet, 2015). This is important since an unclear purpose and incorrect reference situation will lead to error when quantifying and valuating costs and benefits (Step 3). To have a clear purpose and correct reference situation also helps to ensure that the project corresponds to the societal vision i.e. is relevant. It also makes it easier to locate alternatives (Step 2) and weigh them against each other in a meaningful way. After the purpose of the project and reference situation are set, the analyst should start to identify project scenarios.

The *second step* is to identify different project scenarios that ensures the aim of the project is fulfilled (Transportministeriet, 2015; Transport Canada, 1994; European Commission, 2015). One of the alternatives should be the base scenario. This scenario should resemble a status quo alternative, i.e. the do-nothing scenario. However, a do-nothing scenario is sometimes not possible. If so, present operations and facilities needs to be adjusted to maintain efficient operations. Thus, the base scenario can be seen as the best the managers can to without any major investments. When the scenario is set, it is used as a point of reference to which the costs and benefits of other alternatives are measured against. However, before doing that, the alternatives need to go through a screening process. The screening process should allude to the purpose of the project and be at a level that makes it possible to reject non-suitable alternatives. The screening process will later be used as an evaluation framework, which will work as a motivation for rejecting and accepting alternatives. After project scenarios have been identified the next step begins.

The third step is to quantify and valuate costs and benefits included in the different project scenarios (Transportministeriet, 2015; Transport Canada, 1994; European Commission, 2015). Quantifying and valuating parameters lead to costs and benefits for the different alternatives. The costs and benefits for each respective alternative are considered changes in the base scenario which is why all parameters changing the base scenario need to be considered. On the other hand, parameters with equal value, present in all project scenarios, (including the base scenario) do not need to be quantified. The relevant Costs and Benefits should however be quantified as much as possible with the available knowledge. When little or no data exists, an estimate needs to be made, thus increasing the risk of uncertainty. If the risk of uncertainty is too great, the parameter should remain unquantified and the analyst should provide a 'likely value' of the parameter and rank it according to how uncertain the estimate is. The analyst should be careful to exclude unquantified parameters in the analysis since the result can be an uninformed decision. Another important point when it comes to quantifying and valuating parameters is the distribution of costs and benefits. If the analyst distributes the costs and benefits to stakeholders, it will help to showcase who the key stakeholders are and what their main cost and benefits will be if the alternative is realised.

When identifying different costs and benefits it is beneficial to categorize them into direct and indirect parameters (Glavic, Mladenovic and Stevanovic, 2016). Direct costs and benefits are the direct impacts of the alternative whereas indirect costs and benefits can be seen as the effects. It is the indirect costs and benefits that have a higher risk of uncertainty because of the lack of available data, forcing the analyst to do an estimate. Figure 3 provides an example of direct and indirect parameters in a winter road improvement project.

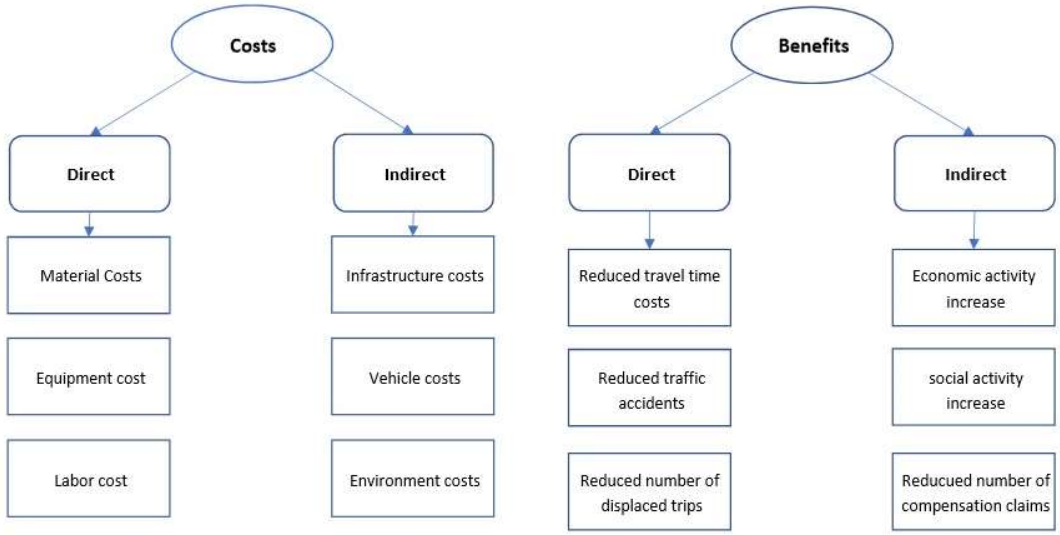

FIGURE 3, DIRECT AND INDIRECT COSTS AND BENEFITS

Table 1 provides examples and descriptions of different parameters that can be used in a CBA of transport investments (European Commission, 2014; Gössling and Choi, 2015).

Parameter	**Description**
Vehicle operating costs	The costs for operating a car, including fuel, engine oil, tires, repairs and maintenance, taxes, and depreciation.

Time cost	Accounts for the transportation mode's speed and the cost is calculated by people's willingness to pay for time, i.e. how much individuals value time.
Accident costs	How often accidents happen and what the entailing costs related to the accident are. For example, police and rescue costs, injuries, loss of productivity, and cost for possible material damage.
Air pollution	The pollution that comes with usage of the transportation mode. Increased pollution has a negative effect on human health and thus decreases overall health and increases mortality.
Climate change	The transportation mode's impact of greenhouse gas emissions. Both the impact that comes with manufacturing and transportation.
Noise	Increased noise is a cause for nuisance which leads to declining house prices as well as a cause for health-related costs.
Congestion	Calculated as discomfort caused by inefficient travelling.
Road deterioration	Costs for deterioration is based on the lifetime of the road, including costs such as repairs.
Life expectancy and health	The transportation modes effect on health. E.g. cycling is considered to improve health and therefore reduce costs for sick leave, premature deaths etc.
Perceived safety and discomfort	There is a perception from cyclists of feeling unsafe, which is believed to be a cause for costs (not yet quantified as of 2015)
Branding and tourism	The effects a transportation-mode can have in terms of city branding. E.g. being perceived as an eco-friendly or health promoting city can increase income from tourism.

TABLE 1, PARAMETERS IN CBA (GÖSSLING AND CHOI, 2015)

After the quantifying and valuating process is complete, the analyst continues to the next step.

To calculate the net present value (NPV) of the costs and benefits is the *fourth step* of doing a CBA (Transportministeriet, 2015; Transport Canada, 1994; European Commission, 2015). NPV is calculated to be able to compare costs and benefits on a common basis and is calculated by subtracting discounted costs from discounted benefits. To be able to discount the costs and benefits of parameters, a life expectancy of every parameter is required. This can, however, be an uncertainty since the analyst often needs to estimate life expectancy. The analyst can also

use benefit-cost ratio which is calculated by dividing the discounted value of benefits by discounted values of costs. If the ratio is greater than one, it means the projects is beneficial. The project scenario with the highest ratio is the most attractive one. Another method is the pay-back method, which showcases how long it will take for the initial investment to be paid back. However, the most common method for appraisal of projects scenarios is NPV. When NPV or another calculative method has been calculated for respective project scenario, it is time to appraise the different scenarios in step five.

The final step of a CBA, the *fifth step*, is thus the appraisal of different project scenarios with the help of net present value and/or other methods. This is the foundation of deciding which project(s) is realised (Transportministeriet, 2015; Transport Canada, 1994; European Commission, 2015).

All the five steps of doing a CBA, arguably contain a large amount of assumptions, estimates and subjectivity. To better understand the underlying factors of these assumptions, estimates and appraisals, it is beneficial to explore decision-making and the decision-making process. The next chapter will address what individuals' base their decisions on, and how this affects decision-making in society.

2.3 Decision-making and the decision-making process

Decision-making is a part of all people's everyday life (Crozier, Ranyard and Svenson, 1997). Individuals are taking daily personal decisions regarding their economy, careers, relationships, health etc. There are also individuals taking decisions on a societal level such as investment-, development-, and political decisions. These individuals are often politicians, which is why it is relevant to explore how politicians make decisions with CBA as a basis.

Politicians are the end-user of CBAs, concerning public infrastructure projects. However, there are studies (Nyborg, 1998; Mouter, 2017) showing that politicians tend to use CBA only as a screening device instead of a method for ranking projects. Both Dutch (Mouter, 2017) and Norwegian (Nyborg, 1998) politicians seem to use CBA as a way of sorting out projects rather than to form an opinion about projects.

Mouter (2017) has identified three different ways Dutch politicians use CBA. The first way is "When forming their opinion about the desirability of transport projects" (Mouter, 2017, p.1131). Most of the interviewed politicians in Mouter's (2017) paper said they could not mention situations where a CBA have changed their opinion from negative to positive or vice versa. The reason is that the politicians already formed an opinion about the project before receiving the CBA. Another reason is that politicians do not trust the CBA fully and thought it was easily prone for changes. However, the interviews showed that CBA could change the desirability of specific projects. For example, if the CBA has a very negative result it can lead to more discussions and investigations before a decision is made. The study also shows that CBA is able to change politicians' views of specific details in the considered project. Lastly, the politicians do not seem to use CBA to rank projects on an ordinary basis, but instead using it for ranking projects during major budget cutbacks, such as the cutback in the Netherlands 2010.

Mouter's (2017) paper brings up 7 barriers hindering politicians to form an opinion regarding infrastructure projects with the help of a CBA. These barriers are explained in the Table 2.

Barrier	Description
Barrier 1: the process of forming an opinion is trivial	Politicians have a limited time to form an opinion. Therefore, they have to be very particular with what they read, and it is unlikely they will use a CBA to form their opinion.
Barrier 2: Politicians prefer to form their opinion via conversation rather than reading reports.	This barrier also alludes to the limited time of politicians. For example, one politician says that reading reports is very inefficient compared to talking to different experts about the result of the CBA.
Barrier 3: Politicians do not trust the impartiality of CBA	Politicians do not trust that the CBA has been carried out in an impartial way and therefore it cannot be trusted.
Barrier 4: Politicians disagree with normative choices made in CBA	Some politicians do not want to form an opinion with CBA as base since they are not fond of the method. For example, a politician says that the CBA does not acknowledge her political view of what she thinks is important and therefore cannot use it to form opinions.
Barrier 5: CBA's explanatory power is limited	Some politicians claim that CBA hold relatively little value when it comes to predict a geographical area's long-term change.
Barrier 6: Politicians receive the CBA too late	The politicians receive the CBA too close to the deadline for a decision. The politician is therefore unable to form an opinion of the project with the help of the CBA.
Barrier 7: Politicians care less about maximizing social profitability of a project when there is enough money	It seems like politicians are more careful with reading CBA's when there are limited resources.

TABLE 2, BARRIERS FOR POLITICIANS USE OF CBA WHEN FORMING THEIR OPINION (MOUTER, 2017)

Mouter (2017) deems Barrier 3 and 6 as most significant. Therefore, they will be developed further.

Barrier 3, politicians do not trust the impartiality of CBA, is obviously a major barrier since the purpose of CBA is to provide an impartial assessment of a project. Mouter (2017) highlights three different groups that distrust the impartiality of CBA. The first being politicians whom believe the CBA has been deliberately manipulated. The second group believes that CBA as a tool is quite impartial but how it is communicated to them is biased by the institution presenting the result. The third group is the group with the most trust in the impartiality of CBA; however, they distrust the assumptions made regarding different parameters in the CBA.

Barrier 6, politicians receive the CBA too late, is also seen as a major barrier. The first reason is that the politicians do not have time to verify the quality and impartiality of the CBA. This is something they want time to verify to minimize the risk of changing their viewpoint on account of incorrect or subjective information. The second reason is associated with the

political manner in which politicians operate. If the CBA report is presented too close to when the decision is made, the politicians will not be able to coordinate with their respective political parties, which is something they need to do.

The second way Dutch politicians use CBA is according to Mouter (2017) as political ammunition. This means that, instead of using CBA as a way to form an opinion about a project, CBA is used as ammunition in political debates and in bargaining processes. An example is in political debates when the CBA does not support a politician's own opinion. The CBA then becomes subject to criticism used to strengthen the politicians own opinion. On the other hand, if the CBA supports the politicians view, it is used as an argument. The interesting thing with this use of CBA is that unlike the first use, late CBAs and CBAs considered impartial are not seen as barriers when using them as political ammunition. When it comes to using CBA in bargaining processes Mouter (2017) states that a positive CBA strengthens the advocate of a project, while a negative CBA strengthens the antagonist of the project. An example of this is drawn in Mouter's (2017) study when the minister of transport and regional politicians try to persuade each other of investing in projects.

The third use of CBA is what Mouter (2017) calls symbolic use. This means that CBA is used as a way of rationalizing arguments and decisions because of rational decisions being more convincing that emotional ones. This use of CBA is also a way to improve the public's opinion regarding projects. If politicians can point to a positive CBA it will be easier for them to justify the project and convince the public about the social benefits of the project. Nyborg (1998) also see this type of usage by Norwegian politicians. She states that "it may be in their [Norwegian politicians] interest to behave as if they were trying to maximize different perceptions of social welfare." (Nyborg, 1998, p.383). This statement is developed by referring to voters being motivated by social responsibility and that vote-maximizing politicians therefore will need to behave as if they always work towards maximizing social welfare.

The decisions for sustainable transitioning are made both on a personal- and a societal level, but ultimately, both levels derive from decisions made by individuals. To better understand why and how individuals make decisions regarding sustainable transitions and decisions in general, one needs to understand on what basis the decision is made. According to Crozier, Ranyard and Svenson (1997) decisions are based on the basic cognitive structure of involvement which includes three different types; value-relevant, impression-relevant- and outcome-relevant involvement.

A decision-maker with a high level of *value-relevant involvement* is described as an individual deciding something aligned with her/his values (Crozier, Ranyard and Svenson, 1997). To showcase a high-level value-relevant involvement decision, Crozier, Ranyard and Svenson (1997) present an abstract example of Christian parents' choice of pre-school for their children. Because of the high level of value-relevant involvement they have, the parents would consider catholic-, protestant and state schools but no other types of schools. This causes the parents to oversee other alternatives but on the other hand the values that comes with being in a Christian school are important for them. A positive aspect with a high-level of this involvement type is that the intuitive screening of alternatives and decision is time efficient. However, deeply rooted values can prompt the decision-maker to manipulate rational information unconsciously to suit their needs. Therefore, value-relevant decision-makers are the ones deemed most likely to be biased when reassessing decisions-alternatives.

The second type of involvement, *impression-relevant involvement*, is described as present when other individuals express an attitude towards the decision being made (Crozier, Ranyard and Svenson, 1997). The level of this involvement type increases if the other individuals' attitudes have consequences for the decision-maker. Using the same example with parents deciding pre-school for their children, impression-relevant parents can disregard schools that have a bad reputation (in their or others' mind) and only consider schools contributing to a good impression. This creates time-consuming decision-processes since the decision-maker wants to make a decision considering the impression of oneself as well as other's impression. However, with this type of involvement, the decision-maker is usually not biased when it comes to reassessing choice alternatives after new information has appeared. This derives from the conflict that can erupt if the decision-maker's decision is based on inaccurate information and the negative impressions this can entail.

The last involvement type is *outcome-relevant involvement* where decisions are made with a specific goal in mind (Crozier, Ranyard and Svenson, 1997). To showcase how this type of involvement matters, the example with parents' choice of pre-school, is once again used. Parents, with outcome-relevant involvement, will choose pre-school based on a specific goal for the children. For example, becoming good at physics or football, learn a lot or make good friends. A positive aspect with outcome-relevant involvement decisions is that decisions are not usually made intuitively since the decision-maker does not want to come short of the desired outcome. On the other hand, this involvement can be a source of bias when reassessing decision-alternatives. If new information is gathered and no decisions fulfill the decision-maker's desired outcome, the decision-maker might choose to consciously manipulate the information, and thus bias can emerge.

As learned from this chapter, decision-makers use CBA for decision-making in three different ways. To form an opinion, as political ammunition and as symbolic use. On a personal level, individuals base their decisions on the cognitive structure of involvement. These are divided into three different types; value-, outcome- and impression-oriented involvement.

2.4 Inaccuracy in cost-benefit analysis

There is often a large discrepancy when comparing CBA appraisals and their actual outcome (Flyvbjerg and COWI, 2004). Flyvbjerg (2007) describes three possible explanations for inaccurate appraisals: technical-, psychological-, and political-economic explanations. Inaccuracy due to technical explanation can be explained by for example insufficient data and imperfect forecasting. Psychological- and political-economic explanations explains inaccuracy by human interaction and assessments, making estimates subject to bias (Flyvbjerg, 2007; Damart and Roy, 2009). The concept of bias is defined as decisions and courses of action made with lack of internal validity (Delgado-rodrı and Llorca, 2004). The lack of internal validity means that decisions or courses of actions are not well-grounded. In this thesis, a well-grounded decision is defined as a decision made to maximize societal benefits. If the decision has been influenced by a judgement which is not well-grounded it is per definition biased.

2.4.1 Technical Explanations

The technical aspects to inaccurate measurements consist of several aspects, such as measurement problems, insufficient data or information, imperfect forecasting techniques, valuation errors, assumptions, and omission errors (Boardman, Mallery and Vining, 1994; Flyvbjerg, 2007; Damart and Roy, 2009; Volden, 2019). These technical aspects are

particularly prevalent in the early stages of a CBA where a lot of assumptions needs to be made, which makes the CBA subject to inaccuracy (Flyvbjerg, 2007; Damart and Roy, 2009)

The technical explanation of omission errors is expanded upon by Boardman, Mallery and Vining (1994), who describe that these errors occur because a parameter is excluded or neglected. The neglection of parameters can be seen when one compares different CBAs (Sælensminde, 2004; Gössling and Choi, 2015) which include different parameters, either due to inclusion of different transportation modes, locations, or simply because of choice.

Damart and Roy (2009) explains how two of the general steps (Figure 2) of the CBA, step one and step three, are more exposed to technical difficulties. The crucial part in step one concerns the reference situation, where the issue lies in choosing the reference situation and time frame, and how the reference situation changes over time. The crucial part in step three concerns assigning monetary measurements to parameters and putting them into costs and benefits. Both these parts include making assessments and assumptions and are further developed.

The crucial part in step one, is the valuation of an accurate reference situation. An accurate reference situation is vital for a correct evaluation of costs and benefits and thus the outcome of the CBA (Damart and Roy, 2009). If the evaluation is off, it could potentially lead to the realization of a project with an outcome that is more costly than beneficial to society. Furthermore, the reference situation needs to account for what will happen in the timeframe of the project and what would occur if no project were built. Investments are needed not only to build new infrastructure, but also to preserve the quality of existing ones, which means that sometimes it is more costly not to build.

Step three, to quantify and valuate costs and benefits, includes several technical difficulties. The first difficulty is to identify costs and benefits to make the parameters physically measurable (Damart and Roy, 2009). Making them physically measurable is required to quantify their effect and put a common monetary unit on all parameters. An example of the first difficulty is shown in a case of noise costs. Increased noise by a certain transportation mode is described in Table 1 as a cause for declining house prices and health-related costs (Gössling and Choi, 2015). However, there are more causes of noise than just transportation, e.g. industrial facilities and construction, which makes it hard to measure how much of the noise is caused by transportation (Damart and Roy, 2009; Gössling and Choi, 2015). Damart and Roy (2009) argue that in order to make a parameter physically measurable and create cost-coefficients, or add a cost, assumptions need to be made. The assumptions are what will make-up the physical measurability. When "The working group on health and socio-economic aspects" (2003) created a paper regarding valuation of noise, they narrowed the benefits of noise reduction into two physically measurable assumptions. These assumptions consider people's willingness to pay for a reduction of noise resulting in increased taxes or rental, and hedonic pricing, i.e. the impact of noise in other markets and especially the housing market.

The second difficulty is to assign monetary values to the physical measurements (Damart and Roy, 2009). For example, how the two assumptions made in "the valuation of noise" (Working group on health and socio-economic aspects, 2003) should be monetized. However, it is hard to quantify these effects and give them an accurate measurement.

The third difficulty is to make an accurate account for how the valuation of the parameters will change in the future (Damart and Roy, 2009). For example, property value will be different in

the future, and in the final phase, there should be an accurate estimate of how noise will affect future property value.

Both of these crucial parts, in step one and three, include making a lot of assessments on parameters and values that causes inaccuracy in the CBA (Damart and Roy, 2009). However, even though much emphasis is put on reducing inaccuracies because of technical explanations it has not improved the accuracy in forecasting (Flyvbjerg, 2008). Thus, Flyvbjerg (2008) argues that more attention should be given to the psychological and political-economic aspects.

2.4.2 Political-economic explanations

To be able to understand the bias created by political-economic explanations there is a need to understand the pressure that comes from political agendas. The pressure comes from that the forecasters receive directions from their superiors and clients to produce modified documents that justify the projects already chosen based on political reasons (Wachs, 1990). Politicians may create incentives for the forecasters to modify the documents by distributing political rewards such as promotions and recognition. This creates a potential bias where forecasters intentionally underestimate costs to increase the chances of project approval (Flyvbjerg, Holm and Buhl, 2002). The bias that comes from political-economic explanation is called strategic misrepresentation and derives from political and organizational pressure.

Political pressure can be created by the competition for grants. The grant system in the United States requires that for local governments to be awarded federal grants they need to provide a forecast for the estimated cost and capacity of the project (Wachs, 1990). The government has limited resources to allocate and there is thus competition for grants forcing local governments to compete against one another. The grant system relies on long-term forecasting which requires a lot of assumptions. This enables the possibility of including procedures that favour certain decisions, and the assumptions can be modified to match the requirements for receiving a grant. Wachs (1990) provides several examples of where engineers have been forced to modify their forecasts to match with their superiors' expectations. This is done to meet the requirements for a grant or receive other political advantages. An example in Wachs' (1990) paper presents a young planner that estimates a forecasted utilization of a railway to two to three thousand passengers per day. However, the planner's superior directed the planner to alter the calculations to 12 to 15 thousand travellers per day in order for them to meet the requirements for a grant. Wachs (1990) concludes that the examples show that forecasts are presented to the public as a justification for the realization of projects, but the reality is that they are merely instruments used to receive public funding. Thus, the political purpose of the forecast is not an honest evaluation of what is most beneficial for society but rather a mean to justify certain political actions and receive political rewards such as grants.

Flyvbjerg, Holm and Buhl (2002) state that it is difficult to prove strategic misrepresentation, since people who perform the bias are unlikely to tell that they have deliberately fabricated an inaccurate cost estimate. Furthermore, the only one able to showcase proof of strategic misrepresentation, prior to Flyvbjerg, Holm and Buhl, was Wachs (Flyvbjerg, Holm and Buhl, 2002).

2.4.3 Psychological Explanations

The psychological explanations to inaccuracy, described by Flyvbjerg, (2008), can be traced to cognitive biases. When human beings try to anticipate and get a cognition of the future, they have a tendency to unconsciously overestimate the likelihood of positive events and underestimate the likelihood of negative events (Sharot, 2011). This phenomenon is called

optimism bias and is defined as the difference between people's expectations and the outcome. Optimism bias can function both ways, i.e. also as a pessimistic bias, when the outcome is better than the expectation. This is by some researchers (Love *et al.*, 2019) deemed as just as likely to occur as people being overly optimistic.

In terms of CBA, optimism bias shows as an unconscious overestimation of benefits and underestimation of costs. Several sources (Mackie and Preston (1998); Flyvbjerg (2002, 2008); Volden (2019)) describe optimism bias, as one of the most prevalent causes for inaccuracy in CBA. When Flyvbjerg, Holm and Buhl (2002) accounts for the inaccuracy in appraisals for infrastructure projects, there is a clear tendency of underestimation of costs and overestimation of benefits, showing an optimistic view to the optimism bias. Flyvbjerg, Holm and Buhl (2002) provides numbers of the underestimated costs showing an average inaccuracy for bridges and tunnels of 33.8% and for roads of 20.4%. Mackie and Preston (1998) argues that optimism bias, or appraisal optimism as they call it, is the greatest problem, since it can be traced to several other biases. For example, unclear objectives lead to an uncertainty, where the cognition tends to favour optimism bias, and non-quantifiable parameters that may be counted either way. The parameters previously described as a source for inaccuracy due to technical explanation, described by Damart and Roy (2009), might also show as a source for optimism bias, since it should favour an optimism towards benefits and the opposite towards costs. On the other hand, there are also researchers who are critical towards the prevalence of optimism bias. Love (2011) showcases an investigation that reveals lower numbers of average inaccuracy in cost estimate than Flyvbjerg, Holm and Buhl (2002). Love (2011) presents that for bridges the cost overrun is 5.5 % and for roads 13.0%. A reason for the discrepancy is explained to be the project size. Love investigates projects with an average contract value of AUD$33 million and Flyvbjerg, Holm and Buhl an average of over US$ 1 billion. In the more recent study by Love *et al.* (2019) they see that 47% of the studied projects were under budget. In this study, the projects were of varying size, ranging from around HK$ 100 million to over HK 2$ billion.

An interesting aspect to optimism bias is people's tendency for selective updating. This describes how people change the way they look upon future probability based upon facts of what happens to others (Sharot, 2011). Sharot (2011) describes results on people's anticipation of likelihood of aversive events, and how they change their anticipation based upon data. For example, individuals who anticipate a lower than actual risk of suffering from cancer, do not revise their anticipation when finding out about the actual risk. However, people who sees a higher estimate than the average were more likely to change their expectation to the average. In the case of CBA, this means that appraisers who tend to perform appraisals with an optimism bias are unlikely to be more realistic in their next appraisal.

2.4.4 Reference Class Forecasting

According to Flyvbjerg (2008) one way to mitigate strategic misrepresentation and optimism bias is the method of reference class forecasting (RCF). This method derives from Kahneman and Tversky's (1979) Nobel Prize winning work about decision-making and uncertainty. Their work laid the foundation for Kahneman and Lovallo's (2003) method of RCF, which is a method for systematically taking an "outside view". Kahneman and Lovallo (2003) found that forecasters tend to take an "inside view", meaning that the forecaster focus on individual elements in the forecast. By taking the inside view while forecasting, each action is seen as unique. This behaviour forces forecasters to make more assumptions and thus leading to more bias. In contrast to the inside view, the outside view emphasizes the use of statistics from similar actions to reduce assumptions. This can be seen as difficult in an industry where projects

are unique. However, Flyvbjerg (2008) claims that projects contains more similarities than what most actors think.

RCF is performed in accordance to three steps described by Flyvbjerg (2008) in Figure 4.

1. Identification of a relevant reference class of past, similar projects. The class must be broad enough to be statistically meaningful but narrow enough to be truly comparable with the specific project.
2. Establishing a probability distribution for the selected reference class. This requires access to credible, empirical data for a sufficient number of projects within the reference class to make statistically meaningful conclusions.
3. Comparing the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

FIGURE 4, THE THREE STEPS OF REFERENCE CLASS FORECASTING, ADAPTED FROM FLYVBJERG (2008)

It is worth to emphasize that the potential for RCF is higher when optimism bias is the main cause of inaccuracy rather than strategic misrepresentation. The reason for this, is that strategic misrepresentation is deliberate and thus there might not be a desire to improve accuracy.

Flyvbjerg (2008) presents several examples of when RCF has been used in practice, where he rates them as successful because of improved accuracy. One of the examples is the forecasting of the Edinburgh tram in 2004, where two different forecasts were made. The initial forecast suggested a cost of approximately £320 million. The second forecast used RCF and estimated that the project had a 50 % likelihood of being within £357 million and an 80 % likelihood of being within £400 million. Thus, the reference class forecast suggests that the initial forecast was likely to be underestimated due to bias.

The effectiveness of RCF has however been criticized by Love and Ahiaga-Dagbui (2018). One of their major critiques of RCF is that the tramline ended up costing in an excess of £776 million, i.e. 194 % of the 80th percentile value of £400 million (BBC, 2017). However, Flyvbjerg *et al.* (2018) respond to the critique by arguing why Love and Ahiaga-Dagbui's (2018) paper used bad practice in their research and Flyvbjerg *et al.* (2018) refutes the critique. In response to the critique regarding the Edinburgh tram cost overrun, Flyvbjerg *et al.* (2018) states that there are several reasons to why RCF should not to be considered an inappropriate method for the tramline project, or in general. For example, RCF highlighted the 20% risk of a cost overrun. What Love and Ahiaga-Dagbui (2018) also failed to acknowledge in their conclusions was the discount value of the initial forecast and thus comparing “apples and oranges” (Flyvbjerg *et al.* 2018, p.187). In response to the critique towards RCF’s efficiency to increase accuracy, Flyvbjerg *et al.* (2018) state that the method actually works to debias estimates and increase overall accuracy. This is supported by several authors and is proved with several case studies (Bordley, 2014; Awojobi and Jenkins, 2016; Batselier and Vanhoucke, 2016).

3. METHODOLOGY

The following chapter presents the context in which the thesis has been written and aimed towards. The chapter continues with describing how the thesis have been conducted in terms of research methodology, design and process as well as how the data collection was performed.

3.1 RESEARCH DESIGN

This thesis has used an abductive process called systematic combining (Dubois and Gadde, 2002). An abductive approach is described especially useful in situations where the scope of explanations is to be expanded and a chance is given to see things that otherwise might be missed (Shank, 2012). A characteristic of systematic combining is the continuous movement and reorganization between the theoretical framework and empirics (Dubois and Gadde, 2002; Mason, 2002). Thus, the theoretical framework and empirical material should be developed simultaneously. Dubois and Gadde (2002) describes this process as beneficial, since theory cannot be understood without the context of empirics and vice versa (Dubois and Gadde, 2002). The systematic combining approach is illustrated in Figure 5.

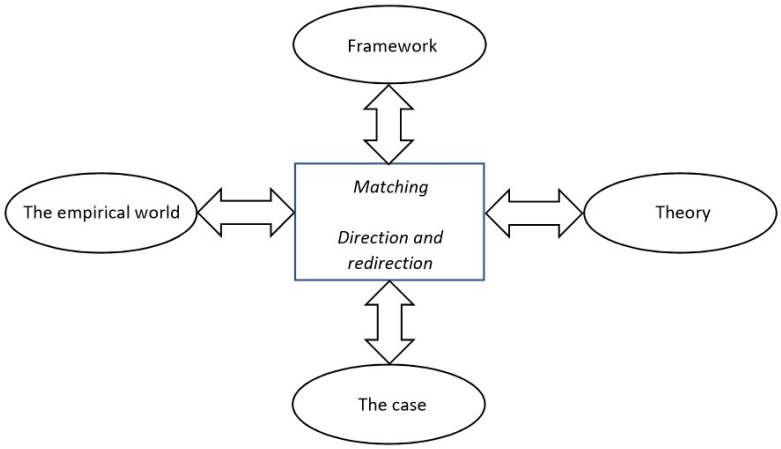

FIGURE 5, THE SYSTEMATIC COMBINING APPROACH, ADAPTED FROM DUBIOS AND GADDE (2002)

With the mentioned benefits, systematic combining was deemed to be an appropriate method for this thesis. At first, some of the collected theory was hard to grasp and to put in a context and required processing to formulate the problematization. Consequently, input from theory and the engineering department of Canmore, altered changes to the research questions and problematization, and required an iterative process to be used. The use of systematic combining was a way for the study to be continuously developed, give room for new perspectives, and create a deeper understanding of the subject.

This study has embraced a qualitative research approach, that has an emphasis on verbal descriptions, as opposed to the numerical focus in quantitative research (Silverman, 2015). To match the qualitative approach and seek an understanding of the subject, the research questions were formulated on a varying degree of explicitness (Silverman, 2015; Bell, Bryman and Harley, 2018). Furthermore, the data was generated by using previously written literature, and conducting interviews to form a holistic approach of the subject. Even though the study uses direct examples from social reality, it is still within qualitative research. Bell, Bryman and Harley (2018) describes that qualitative research frequently uses these examples to get a direct experience from a social setting to provide an understanding.

The report includes a case study of the town of Canmore in their attempt to realize a sustainable transition, implement CBA and the possible biases that they could encounter. A case study is an approach in which one or a few instances are studied in-depth, where the subject of study can be put into a real world context (Blatter, 2012; Yin, 2012). Both Flyvbjerg (2006) and Blatter (2012) emphasizes that case studies have been major sources to strengthen social sciences and for theoretical innovation. However, Flyvbjerg (2006) states that the choice of case is important. Yin (2012) develops on the importance that a relevant case should contain data collection from multiple sources of evidence, that singular case studies are beneficial when why or how questions are posed, and when the researcher has little control over the events. This report uses the singular case approach, which is deemed beneficial since it contains the relevant elements described by Yin (2012). Furthermore, Yin (2012) states that singular case studies with a holistic approach, which is used in this study, are beneficial when questions such as why or how are posed. This study contains research questions which were posed in a why or how manner and the sources of data in the chosen case are from several sources such as interviews, documents and physical artifacts. Furthermore, Dubois and Gadde (2002) emphasize that in systematic combining approach singular cases are beneficial since they allow the researcher to sharpen the theory with empirical examples and verify theoretical findings.

3.2 Research Process

The topic of this study was first suggested by the engineering department of Canmore and developed to better match an academic context. The first draft for the subject of the report was developed in the beginning of December 2019, where the initial plan revolved around a case of developing a cost-benefit analysis together with the Town of Canmore. The topic was further explored in connection to the hand-in of a planning report in January 2020. While the planning report was created, a preliminary literature review was conducted to support the knowledge of the subject. The preliminary literature review led to modifications in the problematization, where focus shifted towards decision-making and inaccuracies in CBA to make the topic more researchable and to be a better match with the academic requirements from Chalmers.

During February and March, the theory and data from spreadsheets and interviews were simultaneously developed and collected, using iterations, to match the abductive approach of the thesis and to seek an understanding of the subjects. Then, the interviews were transcribed and reviewed to collect relevant empirical data. This was later combined in the analysis chapter, where a CBA also was conducted. During April, the discussion was generated by searching for correlations and disparity between the analysis and the theoretical framework. The focus in the discussion was to answer the research questions formulated in the problem statement, ultimately leading to achieving the aim of the thesis. In May, the last parts of the thesis were generated and completed. Here, the conclusions and limitations and further research were developed, as well as several iterations of adjustments. In June, the thesis was presented and opposed. The critique was reviewed, and adjustments were made where necessary, prior to the final hand-in in the middle of June.

3.3 Data collection

The data in this report was collected by using a qualitative approach and includes a case study. Thus, the data was collected by using multiple sources of information that comes from both primary and secondary sources. The methods for inquiring primary data were mainly in the form of semi-structured interviews and observation of participants. The secondary data was obtained mainly by performing an extensive literature review for the theoretical framework but

also by studying Canmore's Integrated Transportation Plan, collecting data from the engineering department, and documents on Canmore Town's website. Bell, Bryman and Harley (2018) argues that it is beneficial for students, who carry out a research project, to include a secondary analysis due to time limitations and the availability of high-quality data at University databases.

3.3.1 Literature review

To outline the theoretical framework, a literature review was conducted. According to Bell, Bryman and Harley (2018) a literature review is the next step after the identification of research questions. However, since the study follows an abductive approach the literature review was conducted using an iterative approach that is suggested by Dubois and Gadde (2002). The literature research was mainly obtained by searching for keywords relevant to the subjects of CBA, sustainable transitions, and inaccuracies and bias in CBA. The research was carefully carried out by using Google Scholar and the University database with critical evaluation of the sources. Even though research was focused towards contemporary literature, there were few changes in the literature from the 90s until today, especially regarding the steps of CBA.

3.3.2 Interviews

In qualitative studies, interviews are presumably the most common method and can act as a source of primary data (Bell, Bryman and Harley, 2018). There are two main types of interviews in qualitative studies; unstructured interviews, and semi-structured interviews. Since the topic of the thesis includes research questions with varied explicitness, this study has embraced the semi-structured method. Semi-structured interviews follow an interview guide with pre-made questions but allows the interviewer to follow up on topics which are relevant for the study or the interviewee shows more interest or emotions in.

In this study four interviews, with people employed in different roles in the town of Canmore, have been conducted. Three interviews were conducted with council members in Canmore, this makes up half the town council excluding the mayor. The three council members have been a part of the council for one- to three terms. The council members are a part of different committees, such as the Bow Valley Regional Transit Commission and one member served as deputy mayor by the time of the interview. The council members will henceforth be referred to as decision-makers. One interview was conducted with the head of the engineering department in Canmore, the person responsible for infrastructure appraisals in Canmore Town. The interviews followed two different interview guides depending on the interviewee's role. The interview guide for decision-makers can be found in Appendix A – Interview framework Decision-Maker and the guide for the engineer can be found in Appendix B – Interview framework Engineer. The interviews were recorded with permission from the interviewees for transcription purposes and to enable a free dialogue, where the researchers have the possibility of formulating follow-up questions. Two interviews were conducted in-person but due to the pandemic outbreak of the Covid-19 virus, the following interviews had to be conducted over Skype. An overview of the interviews is shown in Figure 6.

Interview Subject	Date of interview	Time of interview (min)
Decision-maker	2020-03-04	1:08:17
Decision-maker	2020-03-11	1:02:17
Engineer	2020-03-25	28:59
Decision-maker	2020-03-25	31:51

FIGURE 6, OVERVIEW OF CONDUCTED INTERVIEWS

3.3.3 THE CONCEPTUAL CBA

The conceptual CBA was created with the two scenarios, based on information and data from Canmore's Integrated Transportation Plan. The CBA was created with Canmore's goal in mind. Data was provided by the engineering department of Canmore, as well as data obtained from other CBAs. The steps for the CBA follows the same steps as the European Commission uses in their *Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020* (2015) and the Danish Ministry of Transportation (2015), which both were crosschecked with Transport Canada's *Guide To Benefit-Cost Analysis in Transport Canada* (1994).

The CBA also includes a sensitivity analysis, which has the purpose of showcasing the difference in outcome when parameters are neglected or assigned different values. The purpose of the sensitivity analysis is to study how alterations to parameters, with a high degree of uncertainty, can change the outcome of the analysis. Doing a sensitivity analysis is said to be beneficial when carrying out an analysis such as a CBA (Saltelli *et al.*, 2006).

3.4 QUALITY OF STUDY

The following chapter identify and develops strengths and weaknesses of the study. This has been done to mitigate and take precautions and ultimately ensure a high quality of the study.

One aspect of the quality of this study, and studies in general, is the number of qualitative interviews performed. As mentioned in 3.3.2 Interviews, four qualitative interviews have been performed. At first glance, this could seem insufficient and sloppy. However, since the three decision-makers constitute 50% of the town council in Canmore, this is seen as sufficient. That is, half of those who make societal decisions in Canmore. The interviewed engineer is head of office and in charge of approving justification sheets. Thus, the engineer constitutes 100% of executive decision-makers in the engineering department. Worth emphasizing is that the interviews is only one part of the empirical data and as stated in 3.3 Data collection, other sources of empirical data have also been used.

However, this does not remove the aspect of possibly angled interviews. To mitigate making conclusions based on angled or inaccurate data, certain precautions have been made. Firstly, no conclusion is based on only the interviews. Secondly, the findings from the interviews have been thoroughly analysed with literature together with the other sources of empirical data. This have ensured trustworthy conclusions based on numerous sources.

Another aspect of the quality of this study is the knowledge base the interviews are based on. Prior to interviews, an extensive literature study was carried out, and the other sources of empirical data had been analysed. This made it possible to direct and moderate the interviews to get as clear and accurate data as possible.

A graduation thesis focused on bias must naturally address the fact that the authors ultimately have the goal of finishing the thesis and graduate. This goal can possibly give rise to bias in the empirical findings since that part leaves more room for assumptions and are thus more prone for bias. For example, Yin (1994) is critical of some case study research, stating that ''too many times the case study investigator has been sloppy and has allowed equivocal evidence on biased views to influence the direction of the findings and conclusions.'' (1994, p.2). This phenomenon can be dived into conscious and/or unconscious manipulation of data. The degree of conscious manipulating of data is correlated with the ethical and moral code of the researcher(s). Regarding the degree of unconscious manipulation of data (for example,

optimism bias), the degree is largely dependent on the researcher(s) knowledge base of the subject. A thesis regarding bias is hence arguable less prone to unconscious bias because of the great knowledge base of the subject.

3.5. Ethical Considerations

The thesis have been written according to *Riktlinjer för bedömning av kvalitet på examensarbete vid Chalmers civilingenjörs-/arkitekt- och masterprogram* (Chalmers Univeristy of Technology, 2016). The guidelines emphasize the importance of conducting research with the perspective of sustainable development, as well as having a discussion of possible ethical dilemmas of the conducted research. To fulfil these goals and guidelines, and ensure ethical research, the thesis has been carried out according to the following ethical principles.

The thesis has been carried out without causing any harm, i.e. physical harm, psychological distress, social disadvantage etc. This has been achieved by obtaining informed consent from interviewees prior to conducted interview. The informed consent has included to clearly state the purpose of the thesis and what the research requires of them. All interviewees have voluntarily accepted to be a part of the research and to further minimize the risk of harm, the interviewees' anonymity have been protected. This is achieved by erasing the recording of the interviews after the thesis is approved as well as ensuring all interviewees being named anonymously in the thesis. Lastly, the thesis has been conducted with honesty, objectivity, integrity and carefulness.

4. Analysis

This chapter starts with exploring the background of the town of Canmore and their values and vision. Later, a CBA is developed to showcase how the method is used as well as how sensitive the method is to change of assumptions. The chapter ends with an analysis of how Canmore's decision-makers appraise projects, and how Canmore's engineers estimate costs.

4.1 The town of Canmore and its values & vision

To understand the context in which this thesis is written and aimed towards, a brief presentation regarding the Town of Canmore and its surroundings will be presented in this chapter.

The town of Canmore is a mountain town in Bow Valley, one hour west of Calgary (Stantec consulting; Mobycon corp, 2018). The town is situated at an altitude of about 1400 meters above sea level, with cold winters and temperate summers. Canmore, originally a mining town, has during the last fifteen years rapidly transformed by a strong population growth and increase in tourism. The town currently has a permanent resident population of around 14,000 and a total population including non-permanent residents of around 18,000. The vision for the town is the following: "Canmore is a resilient and vibrant community socially, economically, and environmentally. Its strength is in its resourceful and engaged citizens, who thrive together on the strength of the community's heritage, long term commitment to the diversity of its people, and health of the mountain landscape" (Stantec consulting; Mobycon corp, 2018, p.6). Canmore's vision is built on a society aiming to be sustainable, which does not accord with the current modal-shares in town. Thus, the Town of Canmore has set the goal of reducing the automobile share, and by 2030, they aim to reach a 40 % non-vehicular mode-share during the summer months. Figure 7 shows a vision for what the modal-shares could look like if Canmore succeeds in reaching the goal. To ensure the goal is reached, an integrated transportation plan has been constituted by Stantec Consulting and Mobycon corp. (2018). The plan aims to provide guidance for transportation decisions so that Canmore can realize their vision of economic growth, while also considering sustainability principles. The plan takes an integrated approach to ensure Canmore align investments with the role of the transportation system in town. This includes a reshaping of the multi-modal transportation network. Thus, the transportation plan aims at providing increased opportunity and safety for non-vehicular transportation, such as cyclists and pedestrians.

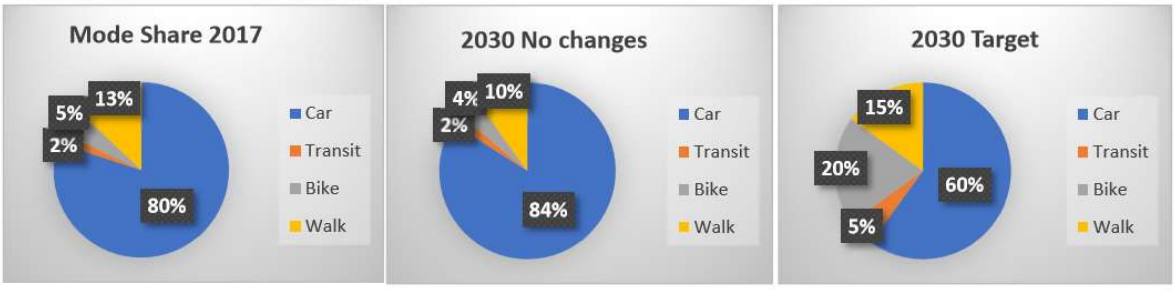

FIGURE 7, DIFFERENT SCENARIOS FOR THE DISTRIBUTION OF MODAL-SHARE, ADAPTED FROM CANMORE'S INTEGRATED TRANSPORATION PLAN (STANTEC CONSULTING; MOBYCON CORP, 2018)

4.2 Decision-making in Canmore and appraisal of Projects

To understand the decision-making process in Canmore, interviews with decision-makers and an engineering manager were conducted. Canmore's Town Council consist of seven people, elected based on personality by the citizens of Canmore (Town of Canmore, 2020). The task of the Town Council is to lead the municipal government, establish policies, and budget for civic and capital expenditures.

The decision-making process for investments in Canmore works the following way. Every four years the town council comes together to create a strategic plan for the municipality. This plan is based on material provided by the Corporate Strategic Group, which consists of members from the council's administration. This material highlights different needs of the community and is reviewed by the council to see if the needs align with the values of Canmore and if funding is realistic. Community needs are raised by members of public, the council, operations, or by safety concerns. Investments in infrastructure can also be based on long-term planning documents, such as the Integrated Transportation Plan. After the strategic plan is set, each department of the municipality provides justification sheets of what they deem to be relevant investments and prioritize them according to how urgent they think they are. From these requests the town council creates a five-year capital plan (Town of Canmore, 2015a). This plan dictates what projects should be realised and how they should be funded.

4.2.1 Appraisal of Investments

The appraisal of general investments in Canmore are based on two aspects. The first one being availability of funding. The second one, how well the project align with the values of the community. These aspects also apply for infrastructure investments, but with this type of investments, the funding aspect becomes more complicated. To understand why, one needs to know how the funding situation for infrastructure investments in Canada works. The funding for infrastructure projects is shared between the municipal-, provincial- and federal levels of government but most infrastructure is owned by the provincial- or federal government. This complicates things since around 60-70% of the funding for infrastructure investments usually comes from provincial and federal grants. For example, according to their Capital Planning Summary (Town of Canmore, 2015b) the total expenditures for engineering works in Canmore from the years 2015-2019 is 30,369,000 CAD. Out of this cost, 18,100,000 CAD is predicted to be funded by grants, which corresponds to 60% of the total cost. The current and future size of local infrastructure investments are hence dependent on grants and on the economic situation of the province or/and the country. One of the interviewees brings up the example of the current economic situation in Alberta. Alberta does not currently have a strong economy and it is therefore difficult to receive funding for infrastructure investments. The other interviewee emphasizes that they can never truly rely on receiving the funding from provincial and federal grants. Furthermore, the funding is limited by a debenture limit set by the provincial government, meaning that municipalities are only allowed to have a certain amount of debt.

The funding situation creates a climate with a high political pressure, as municipalities are dependent on provincial- and federal funding via grants, and thus are forced to compete against each other. Because of this dependency it is very important for municipalities to win grants, hence forcing decision-makers into a climate with high political pressure. For example, one interviewee says, "We get as many [grants] as we can because that is helpful to us and our tax base, if it is paid by a grant, that's a bonus." this statement does not only showcase the strong competition for grants, it also shows that a grant not applied for, is seen as opportunities lost. Moreover, the provincial- and federal decision-makers who decide the distribution of funding

are, in contrast to the municipal decision-makers, actually affiliated to a political party. The municipal decision-makers know of which political party the provincial- and/or federal decision-makers are a part of, thus knowing their agenda. This is also confirmed by one of the interviewees who says that they need to follow what the provincial and federal government wants to invest in. All of the above are factors creating a climate with a high level of political pressure. Even though the climate in Canmore initially seems free of a high level of political pressure, decision-makers in Canmore are forced into a climate which is not.

The second important aspect, the council takes in consideration when appraising infrastructure investment, is the alignment with the community's values. The values of Canmore is to be "a resilient and vibrant community socially, economically, and environmentally." (Stantec consulting; Mobycon corp, 2018, p.6). The decision-makers claim this is the foundation of what all investment decisions should be based on. An example given by one of the interviewees is the awareness of land-use and long-term thinking in decisions connected to the sustainability part of Canmore's vision. When asked about how the mode-share goal of 40% non-vehicular mode share is taken into account in decisions, a decision-maker claims that the shift in mode-share is something incorporated in every investment decision. It is not necessarily the only purpose of the investment, but the outcome should help push towards that particular goal.

4.2.2 Estimation of Cost

Because of the importance of available funding when looking at investments, the decision-makers need to form an idea of the expected cost of a project. These expected costs are compiled as estimates, carried out by different departments in the Canmore administration, where infrastructure cost estimation is carried out by the engineering department. They start with a functional plan, where they state the purpose and goal of the project. The next step is a concept design from where the cost estimate is developed. This cost estimate is the basis for the requested budget shown on the justification sheets. Since justification sheets are the basis for decisions, it is important that the estimate is as accurate as possible. Otherwise, the decision-makers will make decisions based on inaccurate information, which could lead to the realization of less beneficial projects for the community.

However, the engineer states that it is difficult to carry out accurate estimates, especially when it comes to complex projects. The complexity entails more contingencies, which aggravates the estimation process. Previously, the engineering department's estimates have been inaccurate, which seems to be based on an underestimation of costs. For example, in the concept design stage, the costs can be underestimated by 50 % or more. While detailed design is more accurate, the costs can still be underestimated by 20 %. As a result, the engineering department has to ask town council for additional funding. This can create an issue where council has to come up with funding that they might not be able to afford.

An interesting aspect to the estimation of cost, is that even though estimates have continuously been underestimated, the decision-makers of Canmore trust the decision-making material to be correct. For example, two of the decision-makers describes that they have to trust the material to be correct, since they do not have the expertise to validate the information themselves. One of them is a bit sceptical towards the data the engineers receive when the information comes from external developers. The interviewee believes that these developers can have agendas and be biased towards realizing their projects. Another decision-maker discovers the issue with trust when asked about it. This decision-maker also trusts the data to be correct and claims that

the data is used as justification for decisions. Furthermore, all decision-makers agrees that the material is received in time.

4.3 The Five Steps of cost-benefit analysis

A CBA is developed for Canmore to support the engineering department and provide them with a template to reach the 2030 Target-scenario. The CBA follows the first three steps described by Transport Canada (1994), the European Commission (2014), and Transportministeriet (2015) elaborated upon in section 2.2 Cost-benefit analysis . The CBA is created by using numbers from other CBAs carried out in similar settings, as well as numbers given by the engineering department of Canmore regarding the movement of people using different mode-shares shown in Figure 7.

The first step is to define the purpose of the project. Canmore's overall purpose is to perform a sustainable transition in order to become more sustainable and to manage the increasing congestion levels in the city centre. Canmore's goal of reaching a 40% non-vehicular mode-share is set to deal with these issues and reach the overall purpose. The reference situation is defined by the current mode-share depicted in Figure 7. The current congestion level in Figure 8 from Canmore's Integrated Transportation plan (Stantec consulting; Mobycon corp, 2018), showcases why there is a need for a sustainable transition.

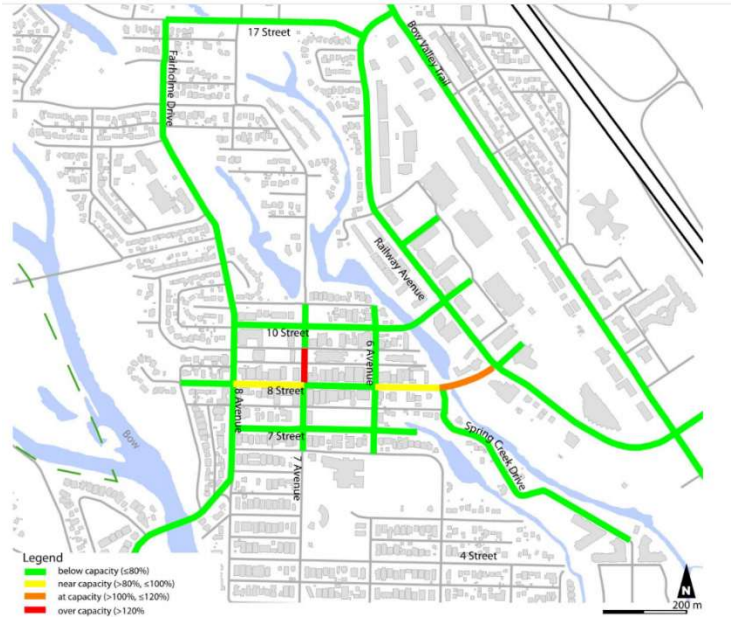

FIGURE 8, CONGESTION LEVELS IN CANMORE AS OF 2017 (STANTEC CONSULTING; MOBYCON CORP, 2018)

The second step is to identify different project scenarios, thus ensuring the aim is reached. The base-scenario of status-quo would mean that the 2030 no-changes alternative in Figure 7 and the congestion levels in Figure 9 are realized. The second project scenario is that the 40% non-vehicular mode-share goal is reached. This would result in the distribution mode-share depicted in Figure 7 and congestion levels according to Figure 10. These scenarios have been chosen since the Town of Canmore have deemed these to be two possible and realistic scenarios during 2030. Some statistics and figures also exist for these particular scenarios. There are of course several other realistic scenarios for the town of Canmore in 2030, but for the purpose and scope of this thesis, the status-quo and no-change scenarios are sufficient.

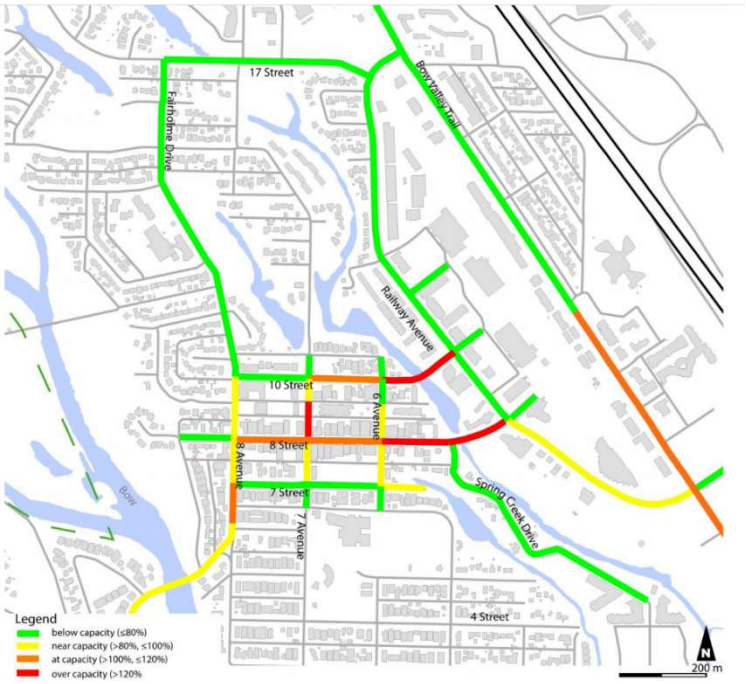

FIGURE 9, CONGESTION LEVELS IN CANMORE BY 2030 IN BASE SCENARIO (STANTEC CONSULTING; MOBYCON CORP, 2018)

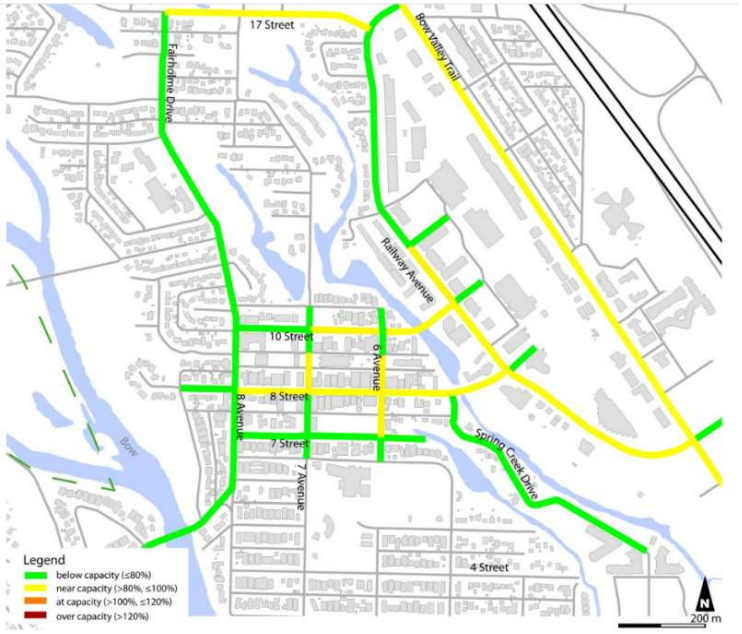

FIGURE 10, CONGESTION LEVELS IN CANMORE BY 2030 IF GOAL IS REACHED (STANTEC CONSULTING; MOBYCON CORP, 2018)

The third step is the quantification and valuation of costs and benefits in the different project scenarios. An example of a quantification of parameters for Canmore is shown in Figure 11, which is based on data provided by the engineering department of Canmore. The parameters chosen for the conceptualized CBA is based on Gössling and Choi's (2015) CBA from Copenhagen where a non-vehicular transformation has been carried out. Since Canmore has not previously carried out CBAs, there is a shortage of data to cover all parameters. Thus, we have collected data and values from literature used in other contexts and regions, which has entailed a number of assumptions.

Type of Parameter	Car		Bicycle		Walking	
	Private	Social	Private	Social	Private	Social
Operating Cost	0,20139		0,06468		0	
Time Costs	0,31605		0,98784		3,1605	
Prolonged Life	0		-0,52626	0,01176	-0,62222	0,00463
Health	0		-0,57477	-0,35574	-0,13162	-0,08147
Accidents		$0,04	0,04998	0,10731	?	
Perceived safety and discomfort	?		0,28		$0,28	
Branding tourism	?		0	-0,00441	?	
Air pollution		0,0059	0		0	
Climate Change		0,0074	0		0	
Noise		0,0706	0		0	
Road Deterioration		0,0015	0		0	
Congestion		0,0911	0		0	
Parking savings			-0,67995		-0,99726	
Total Cost per km	**$0,73794**		**-$0,63956**		**$1,61256**	

Conversion rates

EUR → CAD	$1,47
NOK → CAD	$0,14

FIGURE 11, ASSUMPTIONS BASED ON LITERATURE, PARAMETERS

All values are collected from Sälensminde (2004) and Gössling and Choi's (2015) papers. Gössling and Choi's paper does not include values for walking, hence an additional source to cover walking is required. Sälensminde (2004) was chosen since the CBA covers a town with a similar size as Canmore. In the papers', Gössling and Choi's values are given in EUR (conversion 1,47 EUR/CAD) and Sälensminde's (2004) values in NOK (conversion 0,20 NOK/CAD), both values are converted to CAD.

For some parameters, little or no data exists. According to the theoretical framework, it is important to estimate a 'likely value' for these parameters and rank them based on how uncertain the estimate is. The assumptions deemed most uncertain in the CBA framework are the parameters where no direct data could be found. Examples of such parameters are health and prolonged life for walking. For these parameters, Sälensminde's (2004) has combined the values for cycling and walking, but since the CBA framework have a source for cycling, these values had to be separated into pedestrians and cyclists. By taking the ratio between the mode-share of pedestrians and cyclists in Sälensminde's (2004) paper, we could separate the values and use them in the CBA. Additionally, these values have been converted from a total yearly cost to cost per kilometer and person. This was done by dividing the given value from Sälensminde (2004) by the number of days in a year and the average walking distance in Canmore. Similar assumptions were made regarding the benefit of not having to park when cycling or walking. The value for this parameter was divided by the average days in a month and the average distance walked/cycled. Another example where assumptions were made is the parameter of time cost for pedestrians. The value is based on the ratio between average walking speed and the average speed for a car. This means the time cost is only based on the speed of travel and does not take distance into consideration.

The values with a '?' are deemed too uncertain, by both Gössling and Choi (2015) and Sälensminde (2004), to be assigned a monetary value and will remain unquantified. According to Transportministeriet (2015), Transport Canada (1994) and the European Commission (2015) these parameters should not be excluded from the analysis since they still affect the CBA but to an unknown extent.

To understand the degree of how assumptions of this kind changes the outcome of the CBA, a sensitivity analysis of three cases was conducted. *Case 1* is the base assumptions where values

from literature have been used without changes in regard to the context of Canmore. Figure 12 presents the result of *Case 1*.

Result						
	Car		Bicycle		Walking	
	Goal Reached	Goal not reached	Goal Reached	Goal not reached	Goal Reached	Goal not reached
Total Cost per km [$/km]	$0,73794		-$0,63956		$1,61256	
Avg Trip length [km]	2,2		2,2		1,5	
Cost per Day [$/km]	$1,62		-$1,43		2,39	
Total travellers [In 2030]	679 294	807 694	136 566	29 960	141 709	86 531
Cost per year [2030 in CAD]	$2 426 188	$2 884 784,64	-$437 271	-$95 930	$500 538	$305 642
Savings in 2030 if goal is reached [CAD annually]	**$605 041**					
Savings in 2030 if goal is reached [% annually]	**19,6%**					

FIGURE 12, CASE 1, ASSUMPTIONS BASED ON LITERATURE, RESULT

Case 1 shows a saving of about 605,000 CAD the year 2030 if the goal of 40% non-vehicular mode share is reached, which corresponds a saving of almost 20%. Figure 13 presents *Case 2,* where the assumption regarding time cost for each travel mode have been modified. In Case 2, time cost has been reduced to zero for each mode share, which in Canmore is not an entirely unrealistic scenario. This assumption can be argued as reasonable because of the short average trip length in the area. To bike or walk 2,2- respective 1,5 km takes about the same time as starting the car, drive it to the destination, and find a parking lot. One decision-maker and the engineer found this assumption reasonable and they both stressed that time should not be considered important in a town of Canmore's size.

Type of Parameter	Car		Bicycle		Walking	
	Private	Social	Private	Social	Private	Social
Operating Cost	0,20139		0,06468		0	
Time Costs	0		0		0	
Prolonged Life	0		-0,52626	0,01176	-0,62222	0,00463
Health	0		-0,57477	-0,35574	-0,13162	-0,08147
Accidents		$0,04	0,04998	0,10731	?	
Perceived safety and discomfort	?		0,28		$0,28	
Branding tourism	?		0	-0,00441	?	
Air pollution		0,0059	0		0	
Climate Change		0,0074	0		0	
Noise		0,0706	0		0	
Road Deterioration		0,0015	0		0	
Congestion		0,0911	0		0	
Parking savings			-0,67995		-0,99726	
Total Cost per km	**$0,42189**		**-$1,62740**		**-$1,54794**	
Conversion rates						
EUR → CAD	$1,47					
NOK → CAD	$0,14					

FIGURE 13, CASE 2 - NO TIME COST, PARAMETERS

Result						
	Car		Bicycle		Walking	
	Goal Reached	Goal not reached	Goal Reached	Goal not reached	Goal Reached	Goal not reached
Total Cost per km [$/km]	$0,42189		-$1,62740		-$1,54794	
Avg Trip length [km]	2,2		2,2		1,5	
Cost per Day [$/km]	$0,93		-$3,64		-2,29	
Total travellers [In 2030]	679 294	807 694	136 566	29 960	141 709	86 531
Cost per year [2030 in CAD]	$1 387 084	$1 649 269,31	-$1 112 665	-$244 100	-$480 478	-$293 392
Savings in 2030 if goal is reached [CAD annually]	**$1 317 836**					
Savings in 2030 if goal is reached [% annually]	**118,5%**					

FIGURE 14, CASE 2 - NO TIME COST, RESULT

As shown in Figure 14, a saving of almost 120% can be made if the target goal is reached. That corresponds to about 1,318,000 CAD for the year 2030. Compared to Case 1, this is a considerably higher number and percentage saved.

In *Case 3*, the assumed health and prolonged life benefits for cycling and walking have been reduced. This alludes to the fact that not all pedestrians and cyclists are walking or cycling all year around. Many travelers, only bike or walk during summer months, which does not give them the full health and prolonged life benefit. Therefore, this parameter has been reduced to match the month with the fewest cyclists and pedestrians, assuming they are the only ones walking and cycling all year round. Figure 15 shows the change in parameter values and Figure 16 the result.

Type of Parameter	Car		Bicycle		Walking	
	Private	Social	Private	Social	Private	Social
Operating Cost	0,20139		0,06468		0	
Time Costs	0,31605		0,98784		3,1605	
Prolonged Life	0		-0,16313	0,00365	-0,22308	0,00060
Health	0		-0,17817	-0,11027	-0,04719	-0,02921
Accidents		$0,04	0,04998	0,10731	?	
Perceived safety and discomfort	?		0,28		$0,28	
Branding tourism	?		0	-0,00441	?	
Air pollution		0,0059	0		0	
Climate Change		0,0074	0		0	
Noise		0,0706	0		0	
Road Deterioration		0,0015	0		0	
Congestion		0,0911	0		0	
Parking savings			-0,67995		-0,99726	
Total Cost per km	**$0,73794**		**$0,35752**		**$2,14436**	
Conversion rates						
EUR → CAD	$1,47					
NOK → CAD	$0,14					

FIGURE 15, CASE 3 - HEALTH AND PROLONGED LIFE BENEFITS REDUCED, PARAMETERS

Result						
	Car		Bicycle		Walking	
	Goal Reached	Goal not reached	Goal Reached	Goal not reached	Goal Reached	Goal not reached
Total Cost per km [$/km]	$0,73794	$0,69384	$0,35752	$0,40102	$2,14436	$2,11738
Avg Trip length [km]	2,2		2,2		1,5	
Cost per Day [$/km]	$1,62	$1,53	$0,80	$0,90	$3,17	$3,13
Total travellers [In 2030]	679 294	807 694	136 566	29 960	141 709	86 531
Cost per year [2030 in CAD]	$2 426 188	$2 712 387,15	$244 436	$60 151	$665 607	$401 324
Savings in 2030 if goal is reached [CAD annually]	**-$162 369**					
Savings in 2030 if goal is reached [% annually]	**-5,1%**					

FIGURE 16, CASE 3 - HEALTH AND PROLONGED LIFE BENEFITS REDUCED, RESULT

Case 3 shows a loss of around 162,400 CAD for the year of 2030, if the goal is reached. The change of assumptions regarding health and prolonged life gives a loss compared to Case 1, and Case 2, and shows that it is better for Canmore to not reach their goal.

All examples and cases highlight the difficulties with carrying out a CBA for the first time and in a specific context. Values and data are gathered from similar but not identical contexts and thus assumptions need to be made. The small adjustments of assumptions can create major changes in the result of the CBA and show how sensitive CBAs' are to the impact of assumptions.

The fourth and fifth step is to calculate the net present value of all project scenarios and make a decision based on that. However, the last two steps are not considered relevant for the purpose of the thesis. This sensitivity analysis should act to showcase the sensitivity of assumptions rather than as a basis to form a decision.

5. Discussion

The purpose of this chapter is to answer the research questions from chapter 1.2 Aim and Problematization by an extensive discussion based on the material from chapter 4. Analysis and chapter 2. Theoretical framework. Firstly, this chapter explores the sources of inaccuracy in CBA. Secondly, how to mitigate inaccuracies in CBA is answered by bringing up the seriousness of each cause of inaccuracy and presenting a method for mitigating them. Thirdly, we discuss whether CBA has a role to play in sustainable transitions.

5.1 The sources of inaccuracy in cost-benefit analysis

According to (Flyvbjerg, 2008), the three major sources of inaccuracy when doing CBAs are technical errors, strategic misrepresentation and optimism bias. All three sources of inaccuracy could either be identified in Canmore or be seen as potential issues in their future use of CBA.

5.1.1 Technical Error

Technical explanations have been explained by several researchers as a source for inaccurate CBAs (Boardman, Mallery and Vining, 1994; Flyvbjerg, 2007; Damart and Roy, 2009; Volden, 2019). However, Flyvbjerg (2007) claims that technical explanations should not be a major explanation of inaccuracy anymore because forecasting models and experience with CBA have developed and increased. He argues that even with better forecasting models and experience, the accuracy of assumptions in CBAs are still as bad. This would indicate other reasons of inaccuracy than technical explanations. However, in this statement, Flyvbjerg (2007) assumes the forecaster have used CBA for some time and accumulated experience and technological advancements.

For Canmore, this is not the case. As stated, Canmore has not previously used CBA, meaning they have little experience with the model and less available data for their parameters compared to for example Copenhagen. This creates a need for more assumptions since they need to adapt and refine their current information to suit the parameters used in CBA.

An example of this is shown in the CBA in 4.3 The Five Steps of cost-benefit analysis. The values for the parameters are collected from CBAs carried out in a large town in Denmark (Copenhagen) and a small town in Norway (Hokksund). This entails that the values are not entirely accurate for a small Canadian town, since some parameters, such as cost of fuel, are different in Canmore. The discrepancy between Copenhagen, Hokksund and Canmore's actual values might be small and can be considered a trifle in the result of the CBA. However, from the sensitivity analysis, it can be concluded that small changes in values influences the result of the CBA to a great extent. Canmore's lack of experience can thus make them more prone to carry out inaccurate CBAs because of technical explanations.

5.1.2 Strategic Misrepresentation

As explored in chapter 2.4.2 Political-economic explanations, strategic misrepresentation derives from political and organizational pressure (Wachs, 1990; Flyvbjerg, Holm and Buhl, 2002). In chapter 4.2.1 Appraisal of Investments it is concluded that investments are made according to Canmore's community values. The decision to align community values and investments creates organizational pressure and thus opens to the possibility of strategic misrepresentation. However, since the community values are developed by the people of Canmore it increases the legitimacy of decisions made according to these values. These decisions will be the most beneficial for the community and hence can be considered well-grounded. This is per the definition in section 2.4 a non-biased decision.

In chapter 4.2.1 Appraisal of Investments it is concluded that the funding situation in Canmore creates a climate with high political pressure. Parallels can be drawn between Canmore's funding situation and Wachs (1990) example from the United States, presented in 2.4.2 Political-economic explanations. The funding situation with dependency on grants was proven to create strategic misrepresentation in the United States. In contrast to the situation with Canmore's community values, decisions based on grants does not necessarily maximize community benefits. The reason is that decisions based on grants are not formed by what the community wants, but rather what the available grants are. Since the grants are on a provincial- and federal level, they are not necessarily aimed at what is best for Canmore. Hence, there is a risk of decisions not being well-grounded, i.e. biased decisions.

It is worth noticing that in chapter 2.4.2, Flyvbjerg, Holm and Buhl (2002) claim that strategic misrepresentation is very difficult to prove. The reason for this is that people are unlikely to tell that they are deliberately fabricating inaccurate data. This thesis shows no proof of strategic misrepresentation in Canmore. But to prove if strategic misrepresentation exists in Canmore has never been the goal of the thesis. Instead this thesis focus on the more long-term solution, to depict the source for potential strategic misrepresentation.

With the discussion above, it is concluded that the source of potential strategic misrepresentation is rooted in what the decision-makers appraise projects based on. Decisions based on the funding system via grants could be ill-grounded and thus a source of bias. However, we do not consider decisions based on community values to be considered ill-grounded and thus not a source of bias.

5.1.3 Optimism Bias

It is worth repeating that in contrast to strategic misrepresentation, optimism bias is an unconscious behaviour where humans have a tendency to overestimate the likelihood of positive or negative future events (Mackie and Preston, 1998; Flyvbjerg, Holm and Buhl, 2002; Love, 2011; Love *et al.*, 2019; Volden, 2019).

Even though Canmore has not started to use CBAs, it does not mean that optimism bias cannot exist and be an issue in their current cost estimation method, as well as their future use of CBA. In chapter 4.2.2 Estimation of Cost, it is concluded that cost estimates are continuously underestimated with between 20-50% of the actual cost of infrastructure investments. The inaccuracy of 20-50 % corresponds to Flyvbjerg, Holm and Buhl's (2002) findings regarding cost overruns, rather than Love's (2011, 2019) more optimistic sight on the matter.

This study sees two possible reasons to why forecasters in Canmore tend to underestimate costs. Either the forecasters have a belief that the estimate will become more accurate the next time, even though the estimate is conducted the same way. Sharot (2011) see this as a normal behaviour, and people who tend to underestimate the likelihood of negative events are unlikely to change their next estimate. This can thus be seen as an unconscious bias towards an optimistic future, i.e. optimism bias.

Another explanation could be that cost estimation is connected to the issue of gaining approval and funding for a project. This phenomenon is emphasized by Flyvbjerg and COWI (2004, p.44)

"A planner said that: 'You will often as a planner know the real costs. You know that the budget is too low but it is difficult to pass such a message to the counsellors and the private actors. They know that high costs reduce the chances of national funding.'"

If this is the case, what was first seen as optimism bias should be revised to a conscious bias, i.e. strategic misrepresentation. This shows that the line between optimism bias and strategic misrepresentation can sometimes be quite blurry, and the difference is whether the inaccuracy is conscious or not. The reason why technical error is not considered is because of the non-normalized inaccuracies, with 20-50 % underestimation of costs. If technical error would have been a valid explanation, the inaccuracies should be normalized around zero, i.e. both under- and overestimated.

We thus suggest that the primary source of potential optimism bias in Canmore's future use of CBA derives from the engineers' estimates of project alternatives that are optimistic, and can be attributed to the optimistic nature of humans (Sharot, 2011). However, the optimistic estimates could potentially also be attributed to strategic misrepresentation, stemming from the particularities of the funding system.

5.1.4 Involvement type and Bias

The three involvement types described in 2.3 Decision-making and the decision-making process are those of value-relevant, impression-relevant, and outcome-relevant involvement. These cognitive structures explain how individuals make decisions on a personal level, and it is therefore plausible that involvement can correlate to bias.

Value-relevant involvement means that individuals make decisions aligned with their values (Crozier, Ranyard and Svenson, 1997). These individuals tend to make intuitive decisions based on what they consider important. As seen in 2.4.3 Psychological Explanations optimism bias comes from an unconscious over- or underestimation. The correlation between value-relevant involvement and optimism bias can be found in the definition of intuition. According to Lexico (2020) intuition is "Using or based on what one feels to be true even without conscious reasoning". This correlates with how the definition of optimism bias alludes to unconsciousness. Worth emphasizing, is that the values in value-relevant involvement are those of the individual and not necessarily societal values. For Canmore, this would mean that making value-relevant decisions is not the same as taking Canmore's community values into account. Instead, it is rather the forecasters personal values that could cloud the judgement of the estimate. This could be exemplified by seeing the community as a monolithic block of rational thinking and if the forecasters' values deviate from the community's, the assumptions have to be considered ill-grounded. Hence, individuals with a high-level of value-relevant involvement are more prone to be a source of optimism bias.

Impression-relevant involvement can be prevalent when other individuals express an attitude towards the decision being made (Crozier, Ranyard and Svenson, 1997). Individuals with a high-level of impression-relevant involvement tend to make decisions, which match the expressed attitude of others. This makes them prone to thoroughly screen project alternatives before a decision is made to make sure others approves. By having this process, the individual is making conscious decisions, which are less likely to contain optimism bias. Furthermore, these individuals also tend to reassess decisions, which are not received well by others. This means that an ill-grounded decision can be changed to a well-grounded one, i.e. a biased decision revised to an unbiased one. However, since these individuals are more inclined to change decisions because of expressed attitudes, their decisions might be coloured by loud opinions. These loud opinions do not necessarily have to represent the opinion of the masses or be well-grounded in any way. Thus, the individual's decision can be consciously modified to appease the opinion, i.e. perform strategic misrepresentation.

Individuals with the third involvement type, outcome-relevant involvement, are making decisions with a specific goal in mind (Crozier, Ranyard and Svenson, 1997). Individuals with a high-level of outcome-relevant involvement, screen decision alternatives with their goal in mind and are thus less likely to make an intuitive decision. However, with a high internal pressure to reach the goal, the individual can be prone to modify the decision consciously. If the individual's goal does not correspond to the societal goals, it could lead to ill-grounded decisions by performing strategic misrepresentation. Ill-grounded decisions can also be made when reassessing decisions. Even though these individuals do not make intuitive decisions when screening project alternatives, they may be more intuitive when reassessing decision alternatives. This could come from what chapter 2.4.3 Psychological Explanations describes as selective updating, the tendency of sticking with future events deemed positive. The possible reason for why these individuals' are prone to selective updating is their strong will to reach their goal. Hence, they may anticipate their initial project as most beneficial even though new information shows other alternatives as more beneficial. This makes the decision unconsciously ill-grounded, i.e. optimism bias.

By understanding how involvement types correlate with the inaccuracies of CBAs we contribute and expand upon previous research of CBAs. This knowledge will potentially support the work in mitigating inaccuracies in CBAs.

5.2 Mitigating Inaccuracies in cost-benefit analysis

From chapter 5.1 The sources of inaccuracy in , it is to be concluded that three possible sources of inaccuracy in CBA were found. The source of technical error will come from Canmore's inexperience with the use of CBA and the lack of a realistic reference situation. Optimism bias already has its source in forecasters' estimates, and it will remain when Canmore transfers to using CBA. It is also concluded that the source of any eventual strategic misrepresentation stems from the way decision-makers appraise investment projects, i.e. the funding and alignment of community values.

To mitigate these inaccuracies, it is beneficial to discuss to what degree each respective source influences the CBA in terms of cost overruns. However, according to Love (2019) no successful attempt to quantify optimism bias and strategic misrepresentation has been done. This means that it is not possible to allocate the cost-overruns to a specific explanation, and thus it is not possible to rate how serious each respective explanation is. Nevertheless, since all sources of inaccuracy seem to exist in Canmore, it is relevant to discuss their seriousness and efforts in mitigating them.

What has been stated, both in chapter 2.4.1 Technical Explanations and chapter 5.1.1 Technical Error, is that technical error is mainly prominent in early phases of CBAs, due to the lack of prior measurements. As concluded, this is the reason why technical error will be a challenge in Canmore, and if they do not acknowledge this, the very purpose of CBA can be compromised. However, with experience, and the will and ability to improve, technical error may be reduced. To accelerate the process, Canmore can learn from the many CBAs, which has been carried out elsewhere with the same purpose. Thus, it is recommended that Canmore makes an early effort in learning from others and hence reduce technical error. This requires a small amount of energy compared to the improvements it could entail.

As stated in 5.1.2 Strategic Misrepresentation, the existence of strategic misrepresentation has not been proved in Canmore. However, there seem to be potential for strategic misrepresentation,

due to how the appraisals are done, and the funding situation in Canada. It is therefore important to acknowledge. Mitigation of strategic misrepresentation raises complex questions of ethics. In contrast to technical error, which only results in negative impacts of maximizing societal benefits, strategic misrepresentation could potentially increase societal benefits. For example, as seen in 4.2.1 Appraisal of Investments Canmore's engineering budget is largely funded by grants. These grants have certain prerequisites, which needs to be fulfilled in order to receive them. If Canmore do not meet the prerequisites, they could be left with smaller projects or no project at all. By performing strategic misrepresentation, Canmore can meet the prerequisites, receive the grants, and realise larger projects. In this case, strategic misrepresentation would prove beneficial for Canmore. However, would it be ethically correct to perform strategic misrepresentation if it results in more benefits for the town of Canmore but prevents another town from realising their projects? This question is even more complex if looking at maximizing benefits on a global scale. Due to the ethical dilemma, the question will not be answered in the thesis. However, it is recommended that Canmore's engineers and decision-makers have the ethical dilemma in mind when making decisions based on CBAs and carrying out CBAs.

If there is an intention to mitigate strategic misrepresentation, Flyvbjerg (2008) claims that Reference Class Forecasting (RCF) helps to mitigate any type of human bias, including strategic misrepresentation. However, since strategic misrepresentation has been defined as a conscious manipulation there is no intention to improve the accuracy. Thus, taking the outside view is not considered to be an efficient way to mitigate the bias. Flyvbjerg's (2008) other suggestion of aligning incentives in order to reward accurate forecasts is seen as a more efficient way of mitigating strategic misrepresentation. If accurate forecasts have a higher yield than what the entity earn from performing strategic misrepresentation, there is no longer an incentive to perform strategic misrepresentation. For Canmore, it would mean that incentives to not use strategic misrepresentation, as a way to receive grants, must come from the federal- or provincial level of government.

What has been found in chapter 5.1.3 Optimism Bias is a current prevalence of optimism bias in Canmore's estimates. Just like technical error, the result of optimism bias in Canmore's future use of CBA can cause decisions, which does not maximize societal benefits. Thus, it is recommended that Canmore makes an effort in mitigating optimism bias. The bias can be mitigated by the method of RCF described in 2.4.4 Reference Class Forecasting. This method is deemed efficient in mitigating optimism bias, due to its ability to bypass unconscious manipulation and thus making the forecast more accurate.

As understood in 5.1.4 Involvement type and Bias, individuals with a certain involvement-type towards a decision are more or less prone to perform strategic misrepresentation and/or optimism bias. This knowledge enables the individual to choose an efficient method for mitigating the most prevalent bias. Thus, the knowledge regarding involvement have the potential to increase accuracy in CBAs.

5.3 The role of cost-benefit analysis in Sustainable transitions

According to Sheldrick, Evans and Schliwa (2017), sustainable transitions is defined as the process of steering society towards becoming more sustainable. To make the transition, Jensen, Cashmore and Elle (2017) argue, it has to be politically attractive, which is also confirmed by the decision-makers of Canmore. The decision-makers state the importance of having a calculative method for motivating their decisions and use it as basis for argumentation. Jensen,

Cashmore and Elle (2017) conclude that calculative methods is an efficient tool to generate visibilities by having a common unit and thus visualize the outcome, leading to a more politically attractive narrative.

However, with Canmore's values connected to sustainability and their vision of becoming more sustainable, it is relevant to investigate if a calculative method really is necessary. In Canmore there seem to be a discrepancy between their values and vision compared to the will to transition and how people in town actually behave. An example of this discrepancy is the perceived necessity to drive a car. This is showcased by the current mode-share (Figure 7), which does not reflect the values and vision, people of Canmore claim to have. Another example is the public opinion of the soon-to-be paid parking in town. According to one of the interviewees, this change was poorly received since the perceived necessity to drive is so strong. However, another interviewee claimed that the public received it quite well. This interviewee claimed they did a good job at communicating why they needed paid parking and thus reducing the rumble of the decision. At the same time, the interviewee also admitted that there is some discontent with the decision and expectancy of rumble once it implemented the coming summer.

It is also relevant to investigate how big of a step it would be for Canmore's decision-makers to start using CBA. This can be achieved by comparing the current state of Canmore's decision-making process to how well it corresponds with how CBA is used by politicians today and how easily they can overcome the barriers. From theory, it is understood that CBA is used by decision-makers in three different ways. To form an opinion, as political ammunition and in a symbolic way. All interviews show clear indications that the current decision-making material (justification sheets, reports and recommendations from their administration) is used to form opinions. These indications are evident in the interviews regarding important aspects of decision-making, and what the interviewees personally look for when appraising projects. However, in chapter 2.3 Decision-making and the decision-making process two major barriers for using CBA to form opinions are brought up. The first one is that the decision-maker do not trust the material to be impartial. The second one is that the decision-maker do not receive the decision-making material in time. All interviewed decision-makers agree that they trust the material's impartiality and that they receive it in time. Thus, these barriers should not be an issue in Canmore's implementation of CBA.

The second way politicians use CBA is as political ammunition, i.e. in political debates and in bargaining situations. This behavior could also be found among the decision-makers of Canmore. For example, one of the interviewees states that the information received from different departments is used to defend and motivate decisions. This tie into the example from the literature where politicians use CBA to support their decisions, and in that regard, CBA will be useful for Canmore's decision-makers.

The third way of using CBA is as symbolic use. This is done to increase public opinion of decisions by rationalizing arguments. One example in Canmore is how one of the interviewees described their strategy of reducing discontent when implementing paid parking. Their strategy was to make the public understand, with rational arguments, why paid parking brings more benefits for society than what it costs. The argument was that visitors will pay for parking as well, which means the income can be used for the free public transit in town. However, to what extent the actual decision-making material was used for this purpose is not revealed from the

interviews. Nevertheless, a conclusion can be made that Canmore community has a need for rationalizing decisions to make the decisions more accepted among the public.

To conclude, CBA is according to theory efficient in realizing sustainable transitions. However, it is worth to emphasize the need to be critical towards calculative methods claiming to be neutral. This thesis has contributed by locating the sources of inaccuracy and bias in CBA, and thus emphasized the need to be critical and aware of the subjective nature of calculative methods. With this in mind, we still see CBA as a useful method in Canmore, since they have a need for a calculative method that can communicate decisions connected to their sustainable transition. This will enable the decision-makers in Canmore to change the perception of decisions perceived as negative and thus they can create an attractive narrative of the sustainable transition.

6. Conclusion

Sustainability is of growing concern both on global- and local scale. Thus, the construction industry needs to take responsibility and transition to become more sustainable. This thesis has contributed by researching the method of cost-benefit analysis (CBA), and how it can be used to create incentives for sustainable transitions. Furthermore, the study has addressed the issue with inaccuracy in CBA and possible ways of improving accuracy. The Canadian town of Canmore intends to implement CBA in order to realize the sustainable transition. Hence, the aim of the thesis has been to support the town of Canmore in their implementation of CBA.

Below follow the answers to the research questions:

What a cost-benefit analysis entail

CBA is a calculative method with the purpose of maximizing the net value for society. The method achieves this purpose by assigning a common monetary unit to all parameters included in the analysis. A CBA is performed in five steps; define purpose and reference situation, identify project scenarios, quantify and valuate costs and benefits, calculate net present value, and appraisal of project scenarios. The outcome of the CBA is the project that is most profitable to society.

The potential sources of inaccuracy in Canmore's future use of CBA

In theory, it has been stated that there are three possible explanations to inaccurate CBAs; technical-, political-economic-, and psychological explanations. Each respective explanation of inaccuracy can be explained by different sources. Technical explanations of inaccuracy include many sources, for example; measurement problems, insufficient data or information, imperfect forecasting techniques, valuation errors, assumptions, and omission errors. All sources for technical explanations can be prevalent in Canmore's future use of CBA due to their inexperience with the method and lack of historical data suited for the method. The political-economic explanation is strategic misrepresentation, a bias where conscious manipulation of data is created by political- or organizational pressure. The funding situation in Canada makes Canmore's current funding to be dependent on grants. The situation with grants creates political pressure and thus promotes strategic misrepresentation. Hence, strategic misrepresentation can be a source for inaccuracy in Canmore's future use of CBA. The psychological explanation of inaccuracy is optimism bias, the unconscious underestimation of costs. Since Canmore's current estimates are continuously underestimated by 20-50%, it indicates that optimism bias is prevalent in their estimates. It is therefore reasonable to assume that the issue of optimism bias will persist in Canmore's future use of CBA.

In addition to previous research regarding sources of inaccuracy in CBA, this thesis has taken a step further in locating the sources. This has been achieved by connecting research in individual's decision-making with research on CBA. What has been found is a likely correlation between the cognitive structure of involvement and inaccuracy in CBA. Individuals with high-level of value-relevant involvement are more prone to be a source of optimism bias. Decisions where individuals have a high-level of impression-relevant involvement entail a possibility of strategic misrepresentation. Individuals with a high-level of outcome relevant involvement are inclined to perform strategic misrepresentation in the initial decision and be a source of optimism bias when reassessing decisions.

How Canmore can mitigate the inaccuracies in their future use of cost-benefit analysis

The inaccuracies in Canmore's future use of CBA can be mitigated by different means. The technical error can be mitigated ahead of Canmore's implementation of CBA, by making sure they obtain sufficient knowledge. This can be achieved by learning from other CBAs and thus they gain experience prior to implementation. Once Canmore has implemented CBA, the most efficient way to mitigate technical error is to make an effort in the post analyses of early CBAs. The effect of obtaining sufficient knowledge and doing extensive post analyses in early CBAs is that the process of mitigating technical error will be accelerated. The second source of inaccuracy, strategic misrepresentation, can be mitigated by aligning incentives with accurate forecasts. However, since the possible strategic misrepresentation in Canmore comes from political pressure created on a federal- and provincial level, incentives needs to be put in place by these levels of government. Worth emphasizing is that Canmore still has the opportunity to mitigate potential strategic misrepresentation by creating their own incentives for increased accuracy, but this might leave them with fewer grants. The third source of inaccuracy, optimism bias, can be mitigated by using the method of Reference Class Forecasting (RCF). By using RCF, i.e. taking the outside view, the unconscious bias of optimism bias can be bypassed. Previous research has proven the method efficient in mitigating optimism bias, and there is no reason to doubt why RCF would not work in Canmore.

As concluded, involvement types have a correlation with bias. Hence, it should also have a part in the mitigation of bias. If individuals become aware of what type of involvement they base their decisions on, the individual can also predict what type of bias their decision is most likely to contain. Thus, it is possible to choose the most suitable method to improve the accuracy in CBAs. For individuals making decisions with a high-level of value-relevant involvement, the most efficient way to improve accuracy is to use RCF. Regarding decisions containing a high-level of impression-relevant involvement, the most efficient method is aligning incentives. For the third type of involvement, outcome-relevant involvement, both methods for improving accuracy are recommended. This is due to both types of bias being prevalent in high-level outcome-relevant decisions.

How cost-benefit analysis can support decision-making in sustainable transitions

A CBA has the ability to include sustainability in decision-making by assigning monetary values to all parameters, including those connected to sustainability. But firstly, for CBA to support decision-making in sustainable transitions, there must be a will to become more sustainable. It is only then the CBA actually support a sustainable transition.

By assigning monetary values to parameters, where sustainability parameters are highly valuated, a politically attractive narrative for sustainable investments can be created. This narrative is created by decision-makers using CBA to; form an opinion, use the CBA as political ammunition, and as symbolic use. Hence, CBA is considered an efficient method to support sustainable transitions, such as Canmore's.

Final thoughts

It can be concluded that Canmore has a good chance of mitigating the possible inaccuracies in their future use CBA. This can be achieved by reviewing the research questions and the in-depth explanations to the answers. Thereby, Canmore can use CBA to perform a sustainable transition and reach their goal.

6.1 Further research

Four major points of further research has been found. Firstly, this thesis is delimited to solely study the method of CBA, whereas other methods to achieve a sustainable transition could also be studied. This enables a comparison between CBA and other methodologies and how efficient each respective method is in supporting a sustainable transition. Secondly, further research into other types of community investments could be studied. These investments might entail other inaccuracies than the ones found in this study. It might also show that the same sources of inaccuracy are prevalent in other investments, which would indicate these to be multi-faceted issues. Thirdly, the involvement-types' correlation with different types of bias lack empirical evidence and is thus a gap that needs to be filled. Lastly, the efficiency of RCF has been questioned. It has been proved to improve estimates but not to what degree. Hence, there is a need for more extensive empirical testing of the method.

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APPENDIX A – INTERVIEW FRAMEWORK DECISION-MAKER

Introductory question:

1. Could you introduce yourself and your role in the town of Canmore?

Decision-making in Canmore:

1. How do you prioritize investments in Canmore?
    a. How highly does Canmore prioritize infrastructure investments?
2. How do you presently make decisions regarding infrastructure investments?
    a. Do you have an example of when it has been difficult to choose between different infrastructure projects?
        i. How did you and the decision group reason about the investments?
    b. How has the decision to implement paid parking been received?
    c. Why do you make the decision you make?
        i. Can you give an example of that?
        ii. What are the most important aspects in decision-making of infrastructure investment?
        iii. Why are these aspects important?
    d. What do you personally look for when appraising projects?
        i. Why do you consider this important?
    e. How do you handle other people's' opinions regarding your decisions?
        i. How do you handle criticism?
    f. How do you make decisions in regard to the 40% non-vehicular mode-share goal in mind?
        i. If the decision goes against the public opinion but is the best decision for the goal, how do you deal with that?

Political situation

3. Do you think politicians sometimes make decisions according to political agendas?
    a. If yes, why do you think that is?

Decision-making material

4. Is the decision-making material given to you sufficient?
    a. Is the material well communicated? Easily understood?
    b. Do politicians trust the material to be impartial?
        i. If not, why?
5. Do you receive decision-making material in time to thoroughly go through it?
    a. If not, why do you think that is?
6. What do you need from a decision-making tool?
    a. What improvements can be done?

APPENDIX B – INTERVIEW FRAMEWORK ENGINEER

Introductory questions:

1. Could you introduce yourself and your role in the town of Canmore?
2. When a need for "something" arises, how do you currently screen between different solutions/project alternatives? For example, to reach the 40% non-vehicular mode-share
    a. Why is the chosen alternative the most beneficial for Canmore?

Funding:

3. How much do you look into available grants when choosing projects?
4. Do you feel political pressure to match available grants with your project alternatives?
    a. Is there any other situation where there is pressure from the politicians to achieve something?
    b. Is there competition between different departments over funding?

The process of estimation costs:

5. What is the general process when estimating project costs?
6. How accurate is the appraisal generally?
    a. Does the appraisal require a lot of assumptions?
    b. What is the most difficult aspect with doing an accurate assumption?
    c. If there is a discrepancy in estimation/appraisal, is it usually positive or negative?

General questions:

7. How important is time cost for the community of Canmore?
8. Do you think Canmorians act according to the community values?
    a. If Not, Why?
9. Why do you think CBA is a good appraisal for Canmore?