Communicating uncertainty in Cost-Benefit Analysis: a cognitive psychological perspective

Abstract

Based on a cognitive psychological theory, this paper aims to improve the communication of uncertainty in Cost-Benefit Analysis. The theory is based on different cognitive-personality and cognitive-social psychological constructs that may help explain individual differences in the processing of uncertain information used for decision making. The most important conclusion that can be derived from this paper is that negative consequences of using heuristics when processing uncertain CBA outcomes can be reduced when CBA practitioners first communicate the uncertainty surrounding welfare effect estimations – such as bandwidths, ranges and chances of outliers – and only then carefully give some indications as to what could be plausible outcomes. This is in sharp contrast to what is the common practice in the Netherlands of primarily presenting welfare impact point estimations. Moreover, this paper discusses the level of uncertainty in regard to travel time savings provided by new rush-hour lanes on the A9 highway in Amsterdam. Uncertainty surrounding the travel times for the considered project are calculated through the application of an advanced Monte Carlo traffic model, called INDY-MC. The findings of this case study unambiguously demonstrate that the uncertainty surrounding estimations of travel time benefits in CBA can be immense. Although a prominent communication of the immense uncertainties reduces the negative consequences of using heuristics in general, for some types of decision makers, new problems will arise when they are confronted with large uncertainties in CBA outcomes. In this study, we developed a cognitive psychological conceptual framework of motivation which was used to find some recommendations for decreasing these new problems. From this framework we derive that increasing personal fear of invalidity might stimulate individuals that process information heuristically to consider uncertain results of the CBA report in a more in-depth way. Another remedy is to enhance the presentation of the results and optimize other environmental characteristics of the message. Lastly, training that enhances the ability of individuals to process CBA reports that communicate an uncertain message might result in a more systematic way of processing the information. The results of our study may enhance insights into the question of how – and how prominently – uncertainty in welfare effect estimations should be communicated in CBA reports so that users with different personality and social psychological characteristics are able to understand the information and still evaluate the information as useful input in the decision-making process.

1. Introduction

Cost-benefit analysis (CBA) has been an important tool for transport planners for several decades, in particular for evaluating and ranking transport infrastructure investments (Eliasson and Lundberg, 2012; e.g. Grant Muller et al., 2001; Hayashi and Morisugi, 2000; Odgaard et al., 2005). Despite its popularity, CBA has often been criticized for several reasons, most of them related to the insolvable limitations when it is applied in practice. The main insolvable limitation is that estimations of future project effects are inherently very uncertain (e.g. Flyvbjerg et al., 2003; Naess, 2006; Naess and Strand, 2012; Salling and Banister, 2009).

Mouter et al. (2012) interviewed key actors in the Dutch appraisal practice for spatial-infrastructure projects. One of the main results was that these actors think that bad management of insolvable CBA limitations could have a negative impact on the decision-making process for spatial-infrastructure projects. An important type of ‘bad management’ mentioned by respondents is poor communication regarding the uncertainty of effect estimations in the CBA report. Some of the respondents interviewed perceive that it is difficult to sufficiently understand the uncertainty surrounding effect estimations as a result of poor communication. The fact that CBA reports tend to present uncertainties surrounding welfare effect estimations in a poor way is endorsed in existing
literature. Naess and Strand (2012) state that the high degrees of uncertainty are often not displayed in Cost-Benefit Analyses. According to Welsh and Williams (1997), CBA outcomes are usually presented as if they are endowed with considerable accuracy, although estimations of traffic models, for instance, are very uncertain. From an analysis of decision-support documents for 78 projects, Nicolaisen (2012, p.7) finds that: ‘uncertainties are often toned down or ignored in the decision support prepared for policy makers. This neglect makes impact appraisals appear more accurate than warranted, which causes distrust towards the results among policy makers’.

At present, uncertainty is sometimes included in Dutch CBA studies by estimating effects with two or more different scenarios that vary in economic growth and demographic development, amongst other things. A finding of Mouter et al. (2012) is that a group of key actors in the Dutch appraisal practice for spatial-infrastructure projects suggests communicating uncertainties more prominently in CBA reports. However, another group of respondents believe that a more prominent communication of uncertainties can be hazardous. These respondents state that politicians prefer certain, plain and easy to comprehend information and will not consider a CBA report that communicates an uncertain message as useful information in the decision-making process. Some of the key actors interviewed believe that this can be the ‘collapse’ of the CBA. Moreover, a Review of the Norwegian Cost-Benefit Analysis Guideline (Hagen et al., 2012, p. 85) advises against the use of more than one estimate of welfare effects: ‘since the approach will not provide one estimate, but several different estimates, for net economic benefits for the entire lifespan of the project, this approach may result in a more complex and equivocal basis for making decisions.’

It is assumed that there are individual differences in attitude towards CBA uncertainties between actors in a decision-making process. To understand these differences, cognitive psychology may provide the right perspectives. Based on insights from cognitive psychology, this research aims to scrutinize the extent to which individuals have different attitudes towards uncertainty. In addition, we address how uncertainty should be communicated in CBA reports so that different types of users have a better understanding of uncertainty. Although the results of our study may not necessarily provide a final answer to the question of how uncertainty should be communicated in CBA reports in an appropriate manner, the results may enhance insights into the question of how – and how prominently – uncertainty in welfare effect estimations should be communicated in CBA reports so that users with different personality and social psychological characteristics are able to understand the information and still evaluate the information as useful input in the decision-making process.

2. Methodology

To attain our goal we developed a cognitive psychological theory about the level of understanding reached by CBA users using various ways of communicating uncertainties. This theory is based on the different cognitive-personality and cognitive-social psychological constructs that may help explain individual differences in the processing of uncertainty. This theory also helped to answer the question about how uncertainty should be communicated in CBA. Moreover, we considered insight into the order of magnitude of uncertainties surrounding effect estimations a necessary input for two reasons. Firstly, it is important to check whether the bad management of uncertainty surrounding effect estimations in Dutch practice is only a perceived problem of the Dutch key actors interviewed about the appraisal practice of spatial-infrastructure projects (Mouter et al., 2012) or that it is an actual problem. (If the uncertainties turn out to be negligible we can conclude that it is only a perception). Secondly, immense uncertainties might need more prominent communication than negligible uncertainties. To create a feeling for the order of magnitude of uncertainties in a real-world case, we consider a case study to estimate the level of uncertainty in regard to travel time savings provided by new rush-hour lanes on the A9 highway in Amsterdam. Obviously, there are more categories of costs and benefits in which there is uncertainty, but the basic reason for considering
travel time savings only is that travel time savings, typically, are the largest benefits from any transport project (Salling & Banister, 2009), amounting to 70-90% of the total user benefits (Mackie, Jara-Diaz, & Fowkes, 2001). Uncertainty surrounding the travel times for the considered project are calculated through the application of an advanced Monte Carlo traffic model, called INDY-MC (see Calvert et al., 2014). Apart from showing the level of uncertainty in travel times, the model also provides information about the shape of the uncertainty distribution, which is needed as an input for different ways of presenting uncertainty.

3 Explanations for controversy about communication of uncertainty from a psychological perspective

This section discusses the dual-process theory of reasoning. This widely recognized theory clarifies how individuals receive and process information and explains that individuals can process information systematically or heuristically (section 3.1). Secondly, we discuss the fact that one result of a heuristic way of processing a CBA report that prominently presents point estimations might be that uncertainties are poorly understood and argue that one should present uncertainty in a very prominent way (section 3.2).

3.1 The dual-process theory of reasoning

The dual-process theory of reasoning basically argues that individuals may \textit{theoretically} employ two modes of thinking when processing information: individuals can process messages via ‘System 1’ or via ‘System 2’.\footnote{‘System 1’ and ‘System 2’ are terms that were coined by Stanovich and West (2000). Various recognized researchers in this domain, such as Kahneman (2011), follow their example. Other labels for this theory and the associated modes of thinking are the ‘Elaboration Likelihood Model’ (ELM), which distinguishes between the ‘peripheral route’ and the ‘central route’ to process information (Petty & Cacioppo, 1986) and the Heuristic-Systematic Model of Information Processing (HSM), which distinguishes between processing messages heuristically or systematically. All these theories refer to the same phenomenon and are conceptualized in similar terms (Evans, 2009). Therefore, it seems justified to assume that findings that apply to ELM, HSM or System 1 and 2 are also applicable to the others.} System 1 is characterized by the reliance on simple inquiries and environmental characteristics of the message (O’Keefe, 2008), such as credibility of the author, appearance of the text or clarity of illustrations, whereas System 2 is characterized by accurate balancing of all specific information before judging, extensively relating the information to knowledge already possessed (O’Keefe, 2008). In other words, System 1 tends to process information heuristically, whereas System 2 tends to process information systematically. System 1 is always active (unintentionally) and is influenced by experiences, emotions and memories, whereas System 2, which is influenced by facts, logic, and evidence, is only active if an individual perceives that System 1 does not reach realistic conclusions and intentionally chooses to employ System 2 (Kahneman, 2011).

Batra and Ray (1986) found that the factors that determine whether individuals will employ System 1 or System 2 (i.e. will follow the heuristic or the systematic route to process information), are \textit{Motivation}, \textit{Ability} and \textit{Opportunity}. \textit{Motivation} refers to “heightening arousal so that inactive audiences are ready, willing, interested, or desire to process a message” (Hallahan, 2000). Accordingly, heightened motivation refers to a tendency or willingness to assign valuable cognitive resources to the task of information processing. \textit{Ability} refers to the necessity to maximize individuals’ competences or skills to accurately interpret and understand a message (Hallahan, 2000). Hence, knowledgeable individuals or individuals who are familiar with the topic, generally can process information more systematically than can individuals who lack the specific expertise. Batra and Ray (1986) indicate that \textit{Opportunity} refers to factors of a message that are beyond the control of individuals, such as exposure time, message length, the number of arguments, and the absence of...
distractions that detract from message processing (cf. Andrews, 1988; Hallahan, 2000). So, whereas Availability refers to factors under individuals’ own control, Opportunity refers to factors beyond individuals’ control. Each of these antecedent conditions – Motivation, Ability, and Opportunity – serve only as an essential, but not sufficient, condition for systematic message processing (Andrews, 1988; cf. Petty & Cacioppo, 1986). In other words, in order for individuals to process a message via the central route, they need to believe that the content of the message is relevant and that carefully assessing all relevant information will actually make a difference (i.e. they need to be motivated), and they need to be able to follow the line of reasoning and to understand specific communication methods (e.g. they need to be able to accurately interpret graphs, tables, texts, jargon), and they need to have the opportunity to pay attention to the content (e.g. they should not be distracted too much; they need to have sufficient ‘exposure’ time.

3.2 When point estimations are presented prominently, individuals will not consider the uncertainty

In this section, the relationship between a cognitive aspect of information processing – that is the use of heuristics – and the communication of CBA uncertainty is discussed. The heuristics that are taken into consideration explain why individuals are not able to understand uncertainties sufficiently when point estimations are presented in a prominent way.

The role of heuristics in individual and group decision-making processes

Kahneman et al. (1982) state that the human cognitive capacity is not sufficient to consider all relevant factors when judging situations or making decisions. Reasons for this could be a lack of time, a lack of prior (background) knowledge, distraction, information complexity or the amount of information, for example. To be able to process information in a satisfactory way, people will typically follow System 1 and minimize the use of System 2, which requires relatively more cognitive effort. System 1 uses heuristics: subconscious cognitive ‘shortcuts’ that act as automatic programs to reduce complex decision tasks to simpler judgmental information (Kahneman et al., 1982; Shah & Oppenheimer, 2008). Although Gigerenzer (1991) describes how cognitive heuristics are indeed very economical and usually an effective means of finding satisfactory or acceptable solutions in familiar situations, literature also indicates that heuristics generate systematic and predictable errors (Tversky & Kahneman, 1974). Moreover, Patt & Dessai (2005) indicate that individuals are susceptible to making biased decisions when using heuristics to evaluate and judge information. It is interesting that Meyers-Levy and Maheswaran (2004) suggest that if decision makers process a message systematically (typical of System 2), there will still always be some heuristic processing, at least (typical of System 1). In other words, even if individuals are highly motivated to thoroughly assess information in a systematic way, heuristic processing will always occur to a certain degree, both in individual information processing and in group processes. Based on this observation and the occurrence of heuristic processing in other fields of research and policy making, it is indeed considered likely that the use of heuristics in the processing of CBA reports is common, even if individuals are highly motivated to thoroughly assess all the information in a systematic way. Letson et al. (2001) states that before risks, uncertainties and limitations can be effectively communicated, scientists need to comprehend the ‘mental models’, which essentially refers to actors’ use of framing and heuristics when they evaluate the information. Therefore, the next passage focuses on the most important heuristics that are relevant to the present study.
Availability and anchoring-and-adjustment heuristics

There are various types of heuristics. Two of the most common and important heuristics are the availability heuristic and the anchoring-and-adjustment heuristic (cf. Tversky & Kahneman, 1974).²

The availability heuristic makes it more likely that people will consider the events which are easier to recall or bring to mind. For example, Tversky and Kahneman (1974) indicate that people tend to overrate the danger of air travel (relative to car travel), because of the dramatic nature of aircraft calamities and the subsequent lasting impressions of these accidents. Next, the anchoring-and-adjustment heuristic is the fundamental decision-making heuristic in events where values need to be estimated (Epley & Gilovich, 2006). In essence, this heuristic refers to starting from an initial value - the ‘anchor’ - which is based on a simple feature and then to adjust this number to arrive at the final answer (Tversky & Kahneman, 1974). But typically, the adjustments made to these anchors are insufficient (Lichtenstein & Slovic, 1971; Epley & Gilovich, 2006), meaning that different initial values lead to different estimates that are biased towards the initial values. For example, when asked to estimate the percentage of African countries in the United Nations, the median estimations were 25 and 45 for two distinct groups that had 10 and 65, respectively, as suggested initial values (Tversky & Kahneman, 1974). The anchor biased their final estimate. Furthermore, Yamagashi (1994) suggested that anchoring-and-adjustment also leads to biases in evaluations of risk and uncertainty, the same as the other heuristics and biases.

The availability heuristic and the anchoring-and-adjustment heuristic may be important causes for ineffective communication of uncertainties when CBA practitioners prominently present ‘point estimates’. Considering the availability heuristic; this heuristic leads individuals to relate the numbers presented to the ease with which they can imagine such outcomes. Since individuals have far less difficulty in imagining a single number as the outcome than in imagining a range or a probability distribution as the outcome, presenting a single number results in an overconfidence in this number. In other words, as soon as individuals are given a single number as the outcome, they are likely to put so much emphasis on this number that they will subconsciously accept that number as decisive, irrespective of the presentation of uncertainties surrounding the estimation. For the anchoring-and-adjustment heuristic: this heuristic leads individuals to assume that the actual effect cannot differ that much from the starting estimation, or the ‘best estimate’. So, individuals would subconsciously underestimate the possibility of different outcomes (outliers) and overestimate the confidence with which outcomes are likely to be close to the initial single point estimation. In other words, if a CBA report communicates a specific value for a social benefit or a social cost of a project, the report may still present uncertainties surrounding the estimations, but CBA users remain relatively unaffected by this ‘late’ presentation of uncertainties.

Hence, we suggest that the goal that CBA users understand uncertainty can only be attained when CBA practitioners first communicate the uncertainty surrounding welfare effect estimations, such as bandwidths, ranges, and chances of outliers, and only then carefully give some hints as to what could be plausible outcomes. In essence, by presenting welfare effect estimations in this typical order (first the uncertainty and only then the slightly more specific outcome possibilities), individuals’ tendency to make use of heuristic inquiries is used against itself: when confronted with uncertainty

² Other important heuristics are the representativeness and the affect heuristic (see e.g. Keller, Siegrist, & Gutscher, 2006; Tversky & Kahneman, 1974). However, the use of these heuristics in the context of processing CBA reports is considered to be less clear than availability and anchoring-and-adjustment heuristics. Since the point that we want to make is that CBA users make use of heuristics to process the information (which is characteristic of System 1), we only discuss the most obvious heuristics.
first, it subconsciously becomes less likely that the outcome can be expressed in a single number. This effective communication of uncertainties will probably result in better understanding of the uncertainties of effect estimations in CBA studies. From Mouter et al. (2012) we derived that sufficient understanding of uncertainties regarding outcomes of the CBA study could improve the use of CBA in the decision-making process (contrary to using CBA as a ‘holy grail’ or as ‘worthless information’

4. Case study

The construction of rush-hour lanes on the A9 highway between the junctions of Diemen and Holendrecht in South East Amsterdam, turning the 2x2 road into a 2x3 road during peak hours (see Figure 1) was one of the thirty projects in the Dutch Roadworks Priority Program. Supplying extra road space should relieve congestion on these highway stretches. The lack of capacity typically caused congestion at the Diemen junction going in the direction of Amstelveen/Schiphol in the morning, and in the opposite direction in the evening.

Figure 1: South East Amsterdam (the Diemen – Holendrecht stretch is colored yellow)

4.1 Application of stochastic variation in modeling the case study’s travel time savings

Traffic flow characteristics depend on many factors. However, only a few are taken into account in traffic modeling. It is obvious that this is reflected in the outcomes of traffic models and in policy reports: single point estimations are given, as opposed to interval results. But if real stochastic dynamics were considered, it would be observed that estimations of travel time savings are far less certain than they are generally presented. Applying variation in the modeling process using stochastic input through Monte Carlo simulation is done in this study via the approach that is introduced by Calvert et al. (2014). Firstly, in this approach, the traffic network is constructed with the associated information about road capacity and traffic demand and the distributions of stochastic variations of capacity and demand, which results in probability distributions of capacity and demand. The

3 Mouter (2012) discusses the drawbacks of using CBA as a ‘holy grail’ or as ‘worthless information’ in detail.

4 Stochastic variation in traffic is a result of weather, lane closures, special events, incidents, and shifting demand patterns, for example. In this study, stochasticity is applied by using probability distributions indicating variations in road capacity and in traffic demand (i.e. adjustments from the average). For example, if the average (‘base’) demand for a particular road section is 1800 vehicles/hour, then an adjustment factor of 1.05 yields a demand of 1890 vehicles/hour, and a factor of 0.80 yields a demand of 1440 vehicles/hour.
underlying information for the probability distributions is derived from real traffic data from the A4 and A12 highways in the Netherlands. Calvert et al. (2014) further indicate that the distributions found can be generically applied to most highways, “as the distributions are constructed as a relative factor rather than absolute capacity values.” The cumulative distribution functions of the road capacity and traffic demand factor are presented in figure 2.

![Figure 2: Cumulative distribution function of the road capacity and traffic demand factor](image)

Secondly, from these distributions a random sample is taken by Monte Carlo simulation, which is used as input for the traffic model. In this study, 100 values are drawn for capacity and 100 values for demand. One important aspect in this study is that, in order to reduce the variance between individual samples and thereby to reduce the number of required sample iterations before an adequate level of performance is reached, Latin Hypercube Sampling (LHS) is applied in the Monte Carlo simulations in this study, in line with Calvert et al. (2014) and Salling and Banister (2009).

Thirdly, a traffic model simulation is run with 100 iterations for both the project situation and the reference situation in 2010, 2020, 2030 and 2040 for two social-economic development scenarios that vary heavily in traffic demand development (Global Economy or Regional Communities; Huizinga & Smid, 2004), in which the samples drawn are applied as adjustment factors over base capacity and demand. The traffic model applied in this study is INDY. INDY is a dynamic macroscopic traffic model (Bliemer, Versteegt, & Castenmiller, 2004), which uses the Link Transmission Model (LTM) implementation by Yperman (2007) for traffic propagation.

The 100 outcomes of the simulation are expressed as total hours of less delay in the project situation compared to the reference situation for each year of the time horizon using linear interpolation. Finally, the travel time savings are expressed in monetary terms and are discounted to the base year (in this case 2010; discount rate is 5.5% in the Netherlands) in order to estimate the Net Present Value (NPV).

### 4.2 Resulting distributions and conclusions

The steps described in section 4.1 result in 100 plausible outcomes for the whole time horizon, in both scenarios. In the Global Economy scenario, the min and max values of travel time benefits are -€ 40 million and € 200 million (price level of 2010). The mean, median and modal values are € 156, € 175 and € 193 million. This implies a strongly left-skewed distribution of outcomes. In Figure 3, the histogram of the distribution is presented.
In the Regional Communities scenario, the min and max values of travel time benefits are € 2 million and € 212 million (price level of 2010). The mean, median and modal values are € 77, € 46 and € 62 million. This implies a right-skewed distribution of outcomes. In Figure 4, the histogram of the distribution is presented.

The findings of this case study unambiguously demonstrate that the uncertainty surrounding estimations of travel time benefits is immense. This is seen between and within the scenarios. Firstly, the difference between the scenarios is substantial. Whereas the min and max range is quite comparable in both scenarios, average benefits in the GE scenario are almost three times higher than in the RC scenario. Secondly, there seems to be much room for uncertainty within each scenario. In the RC scenario, for example, the chance of a € 50-225 million benefit is around 50% and all outcomes in that range are approximately equally probable, with a quite uniform distribution for all outcomes in that range. In the GE scenario the most probable outcome seems to be a bit more obvious (i.e. around € 150-200 million), but the actual outcome might just be four times lower, or even negative.
Moreover, it needs to be kept in mind that the uncertainty considered here results from variations in road capacity and traffic demand only, but obviously there is even more uncertainty in estimations of welfare effects. Although we considered only a single case in this research, we believe that – because we found large uncertainties – it is possible to derive that uncertainties surrounding effect estimations in Cost-Benefit Analysis for spatial-infrastructure projects in the Netherlands are not negligible, at least.

Thus, if we take the message from section 3 (first communicate the uncertainty surrounding welfare effect estimations, such as bandwidths, ranges, and chances of outliers, and only then carefully give some hints as to what could be plausible outcomes), in this A9 highway case, a very wide bandwidth, for example, should be communicated first. However, although very prominently communicating uncertainty may result in more understanding of the uncertainty, it should not be expected that all CBA users perceive this as positive. In contrast, we expect problems for at least two types of individuals. In the next section we discuss these problems, and we propose solutions from a cognitive psychological perspective.

5 Prominent communication of uncertainties: problems and solutions

From section 3.2 we derive that if one wants uncertainty to be understood by users, one needs to communicate the uncertainty in a very prominent way. We assume that this way of presenting uncertainty safeguards the fact that individuals who have a tendency to process information systematically will understand the uncertainty regarding effect estimations in the CBA.

However, we are aware of the fact that communicating uncertainty in a prominent way (and our case study shows that these uncertainties can be very large) can lead to problems for individuals that process information heuristically. A report that truthfully communicates all uncertainties and limitations, does not serve heuristic message processing. Actors are not enabled to reach conclusions immediately, but will have to consider the uncertainties and ambiguous clues. In this study we distinguish two possible types of “heuristic individuals” who we think will have trouble with processing information on uncertainty.5

Firstly, we believe that the communication of an uncertain and equivocal message will be problematic for the ‘flamboyant heuristic individual’. By making decisions, this type of individual will heavily rely on his intuition. Hence, this individual is a priori relatively sceptical towards the added value of research reports. This type of individual will almost exclusively use System 1 to process information. If this individual decides to process the information of a report at all, he will process the information in an extremely heuristic way. When a research report communicates an uncertain message this commands the flamboyant individual to activate System 2. We think that the chance is high that the individual will not decide to activate System 2 and will just focus on information that is possible to grasp using System 1 solely or will rely on his intuition. In conclusion, if a CBA report first communicates point estimations, a ‘flamboyant heuristic individual’ will probably consider the point estimations and not the uncertainties. However, when uncertainties are presented first, it is likely that this individual will not consider the information of the CBA report at all. Hence, prominent communication of uncertainties results in diminishing use of information.

Secondly, we think it is likely that a prominent communication of uncertainties is ineffective for the ‘stubborn heuristic individual’. In spite of the prominent warning that effect estimations are uncertain, this individual still wants to find a definite and unambiguous conclusion in the CBA report.

5 We are aware of the fact that considering a report that communicates an uncertain message can be troublesome for other types of individuals as well. Hence, the two possible types of heuristic individuals should be seen as examples of individuals for whom we consider it certain that possible drawbacks of prominently communicating uncertainty can arise. Further research should clarify which other types of individuals may have trouble with processing information on uncertainty.
This type of individual will consider a report that conveys an equivocal message useful. However, this individual will ignore the uncertainty and eventually find conclusive evidence in the report to support or not support the project.

To enhance our understanding of the two types of individuals’ difficulties to process ambiguous messages, we first need to discuss the relationship between individual differences and motivations to use the CBA report (section 5.1 – 5.3). Moreover, we will discuss psychological characteristics of the so-called ‘stubborn heuristic individuals’ and the ‘flamboyant heuristic individual’ (section 5.4) and provide solutions for managing their problems of processing uncertain messages (section 5.5).

5.1 Different Motivations (orientations)

Individuals can have different motivations for using a CBA report in the decision-making process. For instance, individuals use the CBA to contemplate the usefulness, necessity and design of a project, use it strategically (either to kill or support the project), use it in an Absolute way (“if the score is positive we decide positively and vice versa) or consider the CBA as ‘worthless information’ and do not use it (Mouter et al., 2012). The first three motivations will from now on be called (1) Challenge orientation, (2) Strategic orientation and (3) Absolute orientation. We have conceptualized Challenge orientation as the tendency to view information as being useful or needed to think about the usefulness, necessity and design of the project, and to be likely to question assumptions in the CBA, for the sake of making better decisions. Strategic orientation has been conceptualized as individuals’ tendency to value and apply information according to their own liking, for the sake of serving their political or personal interests. Absolute orientation has been conceptualized as the tendency to overrate or absolutize information because of a conviction that it is imperative to base the final decision on this information. Within this orientation, the accent is not on searching out the limitations and assumptions of the research, which is the case in the Challenge orientation, but on ‘simply’ trusting that the information provides the right (final) answer.

In sub-section 5.3, we discuss a conceptual model for the hypothesized relationships between cognitive styles and the three motivations for processing CBA reports. First (in sub-sections 5.2), we need to explain the cognitive styles that are relevant, related to the processing of uncertainty-related CBA report content.

5.2 Cognitive styles

Cognitive styles are defined as individuals’ “chronic motivations that principally determine the initiation, course, and cessation of information seeking and processing” (Thompson, 2008, emphasis added; cf. Thompson, Naccarato, Parker & Moskowitz, 2001). In other words, cognitive styles are individual differences that directly influence information seeking and processing preferences.

6 Mouter et al. (2012) find that key actors in the Dutch appraisal practice for spatial-infrastructure projects evaluate the first motivation as advantageous and the other motivations as disadvantageous.

7 As – technically – considering the CBA report as worthless information is not a motivation for using CBA, we do not discuss this motivation more in-depth.

8 The outlines of these conceptualizations could be filled in more specifically based on Mouter et al.’s (2012) discussion of actors’ perceptions of the use of CBA in the decision-making process. Furthermore, strong support for these conceptualizations is found in the study of three distinct motivations in the field of religion: it was found that Challenge, Strategic and Absolute orientation are highly similar to ‘Quest’, ‘Means’ and ‘End’ orientation in religion (see e.g. Barrett, Patock-Peckham, Hutchinson & Nagoshi, 2005; Hood, Spilka, Hunsberger & Gorsuch, 1996; Allport & Ross, 1967). It is, however, beyond the scope of this research to discuss the convincing similarities between the motivation to be involved in religion and the motivation to use the CBA report.
Individual differences are defined as psychological traits or chronic tendencies that “convey a sense of consistency, internal causality and personal distinctiveness” (Carver & Scheier, 2000). These individual differences are assumed and demonstrated to be relatively unrelated to situational induced differences: individual differences are considered to “play an elemental role in how people generally react across the situations they encounter” (e.g. Thompson, 2008, emphasis added). In other words, individual differences, as they are understood in psychology, are presumed to describe individuals’ general orientations and motivations across domains.

Three cognitive style variables are discussed which can be related to the processing of uncertainty-related CBA report content. These are: Need for Cognition (NC; Cacioppo & Petty, 1982), Personal Need for Structure (PNS; Thompson, Naccarato, & Parker, 1989, 1992), and Personal Fear of Invalidity (PFI; Thompson, Naccarato, & Parker, 1989, 1992).

5.2.1 Characteristics of Need for Cognition (NC)

Cacioppo & Petty (1982) conceptualized Need for Cognition (NC) as “an individual’s chronic tendency to engage in and enjoy effortful cognitive activities.” To measure individuals’ NC, generally, the scale validated by Cacioppo, Petty, & Kao (1984) is used. This scale consists of 18 items, such as “I would prefer complex to simple problems”; “I find satisfaction in deliberating hard and for long hours”; “I only think as hard as I have to” (reverse scored); “It’s enough for me that something gets the job done; I don’t care how or why it works” (reverse scored). Geuens & De Pelsmacker (1998) found that individuals high in NC tend to watch less television, prefer public over commercial television channels, prefer news and current affairs television programs over game shows and prefer to read magazines and newspapers for news information (See Cacioppo et al., 1996, for a review of studies concerning NC). See et al. (2009) found that situational induced expectations of message complexity work together with NC to determine the level of information processing. In other words, if individuals assume that a message is complex, they will process the information systematically if they are high in NC, but they will process the information superficially or heuristically if they are low in NC. Positive correlations have been found, amongst other things, between NC and Objectivism (the tendency to base one's judgements and beliefs on empirical information and rational considerations, Leary, Sheppard, McNeil, Jenkins, & Barnes, 1986).

Hypothesized relationships between NC and the motivations in the processing of CBA reports

Challenge orientation clearly indicates individuals’ inclination to systematic processing of the more cognitively complex and less explicit content. Consequently, it is hypothesized that there is a positive relationship between NC and Challenge orientation.

Since NC was found to be positively related to Objectivism, indicating that individuals high in NC are more open to change their opinion – perhaps even their strategic (self-centred or political) opinion – if empirical or rational information demands so, it is to be expected that NC and Strategic orientation are inversely related.

Absolute orientation has been conceptualized as the tendency to overrate or absolutize the CBA because of a conviction that it is imperative to ‘simply’ trust the outcomes of the CBA report and base the final decision on its results. Nicolaisen (2012) found that individuals with a higher education tend to perceive results of a research report with more skepticism than people with a low education. From the findings of Spotts (1994) we derive that level of education and Need for Closure are positively related as well. Consequently, it is hypothesized that there is a negative relationship between NC and Absolute (vs. Relative) orientation.
5.2.2 Characteristics of Personal Need for Structure (PNS)

PNS is designed to “assess preferences for structure and clarity in most situations, with ambiguity and grey areas proving troublesome and annoying” (Thompson et al., 1989) and was indicated by Neuberg et al. (1997) to serve “to capture the chronic preference for cognitive simplicity and structure”. Thompson, Naccarato, & Parker (1992) furthermore indicate that PNS “reflects individual differences in preferences for structure and clarity in one’s thinking and one’s life”. To measure individuals’ PNS, generally the scale validated by Thompson et al. (1989) is used. This scale consists of 12 items (11 items in the revised version, Neuberg & Newsom, 1993), such as “I become uncomfortable when the rules in a situation are not clear” “I hate to be with people who are unpredictable”; “I don’t like situations that are uncertain”; “I find that a consistent routine enables me to enjoy life more.” Negative correlations have been found, amongst other things, between PNS and Openness to experience, and Need for Cognition (Neuberg & Newsom, 1993). Furthermore, it should be expected that people high in PNS prefer simple informational messages over complex ones, which require more cognitive effort to understand (cf. Van Hiel & Mervielde, 2003).

Hypothesized relationships between PNS and the motivations in the processing of CBA reports

PNS is expected to be negatively related to Challenge orientation. Basically, this is because high PNS is indicative of rigid or inflexible thought, whereas Challenge orientation is conceptualized as showing flexibility in changing one’s thoughts for the sake of making better decisions. Individuals high in Challenge orientation are likely to start processing a CBA report in an open-minded way.

Strategic orientation is hypothesized to be positively related to PNS. The reason is that high-PNS individuals will need to act strategically more than low-PNS individuals in order to be able to maintain their more circumscribed convictions.

Absolute orientation is hypothesized to be positively associated with PNS. It may be expected that absolutizing a message in the context of a decision-making process requires people to freeze their judgments and then to remain relatively uncritical about their opinions, which are characteristic of high PNS.

5.2.3 Characteristics of Personal Fear of Invalidity (PFI)

Personal Fear of Invalidity (PFI) refers to the tendency of individuals to seek alternatives and avoid making an explicit choice between them because of a fear of being incorrect (Thompson et al., 1992), and to the extent to which individuals are concerned with the cost of committing errors (Thompson et al., 1989). To measure an individual’s PFI, typically, the scale validated by Thompson et al. (1989) is used. This scale consists of 14 items, such as “I prefer situations where I don’t have to decide immediately”; “I rarely doubt that the course of action I have selected will be correct” (reverse scored). Thompson et al. (1992) indicate that individuals high in PFI were found to be concerned about the possible consequences of a choice, that they are indecisive, that they were found to be likely to feel discomfort when they receive feedback indicating that they have made a mistake, and that they are likely to embrace cognitive structures to reduce ambiguity. It can be suggested that there are positive relations between PFI and the amount of information acquired prior to making decisions (Wichary et al., 2008). Negative relations may be expected between PFI and exhibiting primacy effects (the tendency to attribute greater value to the first information presented about something than to information presented later; cf. Webser & Kruglanski, 1994), reliance on incomplete information and confidence in one’s own judgment (Kruglanski & Fishman, 2009).

Hypothesized relationships between PFI and the motivations in the processing of CBA reports

It is conceivable that PFI is positively associated with Challenge orientation. Whereas Challenge orientation refers to a motivation to study the CBA exhaustively, individuals high in PFI are
likely to study reports exhaustively as a result of a fear of making an error harmful to themselves or harmful to society.

Strategic orientation is hypothesized to be unrelated to PFI. Whether individuals have a high or low fear of making errors seems to be orthogonal to using the CBA outcomes strategically in order to serve their personal or political interests.

The relationship between PFI and Absolute orientation is expected to be positive. It might be expected that individuals high in PFI will want to minimize their personal responsibility of being wrong, whereby they are conceivably more likely to rely on the outcomes of underlying research reports. By doing so, in a sense, they absolve themselves of their personal responsibility.

5.3 Conceptual framework

Overall, section 5.2 provides support for the hypothesis that broader cognitive orientations might have a systematic influence on actors’ motivations in the processing and use of CBA reports in decision-making processes. We display the hypothesized relationships between NC, PNS, PFI and Strategic, Absolute, and Challenge orientation discussed in the previous section in a conceptual framework (Figure 7). These relationships have not been examined by researchers before. This study contains the first exploration of these relationships.

Figure 7: A conceptual framework of the hypothesized relationships between Personal Need for Structure, Need for Cognition, Personal Fear of Invalidity and Strategic, Absolute and Challenge orientation in the processing of CBA reports

The conceptual framework results in the following observations:

- Individuals who are high on Strategic orientation should be expected to be low on NC, high on PNS, and either high or low on PFI;
- Individuals high on Absolute orientation should demonstrate high PNS, high PFI and low NC;
- Individuals who are high on Challenge orientation are expected to show high NC, high PFI and low PNS.

5.4 Relate psychological characteristics of flamboyant heuristic and stubborn heuristic

Looking at the conceptual framework (figure 7) we assume that the ‘flamboyant heuristic individual’ will have a low NC and low PFI. The flamboyant individual tends to rely on intuition. For this individual it is not necessary to process research findings to come to a decision. Hence, his NC is low. Moreover, the PFI of a flamboyant individual can assumed to be low. This individual will trust

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We would like to emphasize that the assumed relationships in the conceptual framework need to be tested in further research.
that his intuition is right, even when the outcomes of a research report contrast his intuition. At best, this type of individual will read the top page of a research report and will use the results of the CBA report in a strategic way. When the report supports his intuition, he considers the information in the report as valid. When the report does not support his opinion he might marginalize the validity of the report.

It is likely that the ‘stubborn heuristic individual’ is high on PNS. Although the CBA report prominently communicates that the welfare effect of the project is highly uncertain, this individual wants to know if the outcomes mean that the project should or shouldn’t be supported. It is either black or white. This type of individual will not consider it problematic to process the report systematically (use System 2), as long as he can find conclusive evidence for a ‘go’ or ‘no go’ decision. Although uncertainty is communicated prominently, this individual will not consider the uncertainty.

We hypothesize that the result of the prominent communication of uncertainties (as recommended in 4.2) is that the ‘flamboyant individual’ will not use the CBA report at all, whereas the ‘stubborn heuristic individual’ is likely to ignore the uncertainty, even though the uncertainty is communicated in a prominent way.

5.5 Solutions to enhance systematic processing

In this section we discuss some possible remedies to enhance motivation of the flamboyant heurist and the stubborn heurist to simultaneously understand uncertainty and perceive the CBA report as useful input for the decision-making process. For both individuals it is not easy to achieve our double objective. However, we think that increasing the Personal Fear of Invalidity might help both individuals to consider the results of the CBA report in a more in-depth way. Accordingly, we suggest that decision makers are held personally accountable for their decisions (cf. Bruzelius, Flyvbjerg, & Rothengatter, 2002). When these individuals know in advance that the consequences of a wrong decision will be severe (for his income or reputation), this might be an incentive to process the CBA report more systematically, even though the main conclusion of the CBA report is that the welfare effect of the project is uncertain. Flyvbjerg et al. (2003) propose a number of instruments to improve accountability. There are, however, a number of dangers with the introduction of such a measure, moral hazard being the most important (Cantarelli, 2011).

Another remedy to enhance the motivation to process the information of a CBA report systematically is to enhance the Ability and Opportunity of individuals, by training, for instance. It may be assumed that the Ability of individuals to work with research reports that communicate an uncertain message will be enhanced anyhow when all CBA reports communicate uncertainty. Eventually individuals get more used to it. Opportunity of individuals may be enhanced by customizing the environmental characteristics of the message (O’Keefe, 2008), such as credibility of the author, appearance of the text or clarity of illustrations. This means that it is more likely that the flamboyant individual will process the information of the CBA report in a systematic way when the report (that presents uncertain results) is presented by THE expert in the field and the lay-out of the report is very persuasive. Because the flamboyant individual is forced to use System 2 to process the uncertain message of the CBA report it is paramount to make sure that the individual solely needs to use System 1 to process the rest of the information. More specifically, jargon should be avoided at all cost, the report should be very easy to read, persuasive info graphics should be used etc.

6. Conclusions and discussion

The most important conclusion that can be derived from this research is that the goal that CBA users understand uncertainty can only be attained when CBA practitioners present the uncertainty in a very prominent way. This is in sharp contrast with the common Dutch practice of primarily presenting
point estimations (at best for two or more scenarios). However, it was found that the negative consequences of using heuristics when processing the CBA report can be marginalized when CBA practitioners first communicate the uncertainty surrounding welfare effect estimations, such as bandwidths, ranges, and chances of outliers, and only then carefully give some indications to what could be plausible outcomes. The findings of this case study unambiguously demonstrate that the uncertainty surrounding estimations of travel time benefits is immense.

However, we are aware of the fact that communicating uncertainty in a prominent way can lead to problems for individuals that process information heuristically. Firstly, it is problematic for the ‘flamboyant heuristic individual’. This individual heavily relies on intuition and is likely to completely ignore a CBA report that communicates uncertainty. Secondly, communicating uncertainty is ineffective for the ‘stubborn heuristic individual’. This individual still aims to find a definite conclusion in the CBA report, regardless of the level of uncertainty. In this study, we developed a cognitive psychological conceptual framework of motivation to use the CBA report in the decision-making process. From this framework we derive that increasing Personal Fear of Invalidity might stimulate the flamboyant and stubborn heuristic individuals to consider the results of the CBA report in a more in-depth way. One way of achieving this is by increasing personal accountability for a negative outcome of a decision. Another remedy is to enhance the presentation of the results. It is important that ‘the expert in the field’ presents research reports that communicate an equivocal message to a ‘heuristic individual’. Likewise, optimizing environmental characteristics of the message, such as appearance of the text, clarity of illustrations, less jargon, etc., increases the chance that individuals will make the cognitive effort to understand the uncertainty. Lastly, training that enhances the ability of individuals to process CBA reports that communicate an uncertain message might result in a more systematic way of processing the information.

We would like to emphasize that the aim of this contribution was to develop a theory on communicating uncertainty in Cost-Benefit Analysis from a cognitive psychological perspective. Several items in this study have not been empirically demonstrated. This study contains the first exploration of these relationships and further research is needed to test the validity of the hypothesized relationships. We distinguish three relationships that need further research. Firstly, the fact that CBA users make use of heuristics in the processing of CBA reports has not been tested. Theoretically, it may be expected that this is indeed the case, but the extent to which this is the case for decision makers processing CBA reports remains unclear. Secondly, based on existing literature regarding cognitive psychology, we suggest that uncertainty is better understood if communicated very prominently in the CBA report, but the extent to which the understanding increases has not been tested. Thirdly, the relationships between broader cognitive motivations and motivations in the processing of CBA reports have not been examined before.

In this study we found that – based on cognitive theory – CBA users understand uncertainty better if uncertainty is presented prior to point estimations. However, we did not analyze which format is the most appropriate to present uncertainty in CBA reports (e.g. Monte Carlo analysis, bandwidths, scatter plot, etc.). Further research should demonstrate which format communicates uncertainty in an optimal way.

References


