THE IMPACT OF INACCURATE COST INFORMATION ON MANAGERIAL DECISION-MAKING IN PURCHASING

DISSERTATION

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Contents

1 General Introduction

Purchasing decisions are interesting and exciting topics to study. These decisions are difficult as each sourcing alternative has many different attributes which are important to take into account. For example, a purchaser may focus on the initial purchasing price, uptime, quality, environmental friendliness, lifetime, or service level of the supplier. These attributes may cause conflicting results when using different alternatives. Uptime of machine A may be higher than for machine B, but machine B may produce products of a higher quality than machine A. Different stakeholders (e.g., operators, financial managers, operations managers, sales representatives) may also have different interests and attach different weights to the same attribute. An operations manager, whose performance is measured by machine availability, favors alternative A, while a service manager, whose performance is measured by the number of customers' complaints, favors alternative B. Another purchasing conflict may arise between the research and development manager and the financial manager; after all, the goal to design the best product possible often contradicts the goal of cost minimization (Noble and Tanchoco 1990). A purchaser has to decide how to weigh the different product attributes and come to a sound decision that will satisfy all stakeholders. One way to do this is by making a total cost of ownership (TCO) calculation for each sourcing alternative. That is, calculating and adding all costs (initial purchasing costs, operating costs, maintenance expenses, disposal cost, etc.) that result from a purchasing decision for each alternative. Subsequently, alternative selection is easy: a purchaser should select the least expensive alternative.

Alternative selection by using total cost numbers has several advantages, compared to selecting a sourcing alternative by the initial (unit) price (Monczka and Trecha 1988; Ellram 1994, 1995a). First, TCO analyses make decision makers aware of the relative value of different performance indicators. Special attention can be paid to these activities and attributes where costs may be reduced significantly. It also helps decision makers to concentrate on the important few purchases. Secondly, TCO analyses force decision makers to make performance evaluations explicit. Explicitly transforming qualitative performance measures into cost numbers makes it possible to arrange clear performance evaluations: a lower TCO number is better. Buyers can compare alternative suppliers or products, and suppliers can demonstrate how competitive their products are, and underpin the selling price. TCO information makes it possible to compare suppliers with each other and one self over time. TCO numbers can be used to drive supplier improvement, measure ongoing supplier performance and identify priorities and subsequently award suppliers for excellent performance. Thirdly, TCO numbers force decision makers to adopt a long-term strategy. Decision makers have to think about future activities and subsequent events (e.g., maintenance activities) that influence the costs resulting from a sourcing decision. Summarized, calculating and using TCO numbers is beneficial in decision-making. Besides, using TCO information may be tempting; cost numbers support alternative evaluation, are easy to communicate, suggest objectivity, etc. However, to perfectly accurate calculate costs is difficult; not all information can be translated into its financial impact. As a result, the calculated TCO numbers are very likely inaccurate. Therefore, it may be wise to review the accuracy of the calculated cost numbers and not follow these cost numbers blindly. Does a decision maker take information which is not included in the TCO numbers into account or is TCO information too tempting and the main and overriding decision criterion in purchasing?

In this thesis, we want to describe the impact of financial information on decision-making in the context of organizational purchasing decisions. More precisely, the aim is to research the weight decision makers attach to attributes that are not (or inaccurately) included in TCO numbers in sourcing decisions. Sometimes it is especially difficult to calculate the costs of attributes. Some attributes (or specific information about certain attributes) may be excluded from a TCO calculation. We research how aggregating multiple attributes in TCO numbers affects the weight of any attribute omitted from, or inaccurately included in TCO numbers in a purchasing decision. By that, we research a question that goes down to the core of management accounting research: the cost and benefits of aggregating information and of financial versus non-financial information. We study purchasing decisions where we provide decision makers with inaccurate TCO information (e.g., see Carr and Ittner (1992) and Ellram (1993) for a discussion about TCO, and Galbraith (1973) and Chapman (1997) for a discussion about inaccuracy in cost numbers). We apply judgment and decision-making literature (e.g., Tetlock 1992; Payne et al. 1993) to understand purchasers' judgment and decision-making. This is somehow different from research on consumers' judgment and decision-making, which is, for example, more emotionally driven, compared to judgment and decision-making in business. We do not aim to prescribe the decision-making process (like for example De Boer 1998) or apply TCO to reduce purchasing transaction costs (see for examples to apply mathematical models to reduce purchasing costs Degreave and Roodhooft 1999; 2000 or Degreave et al. 2000; 2005). Furthermore, we do not build or improve accounting models to calculate accurate cost numbers. We conducted three experiments (N = 2,097 participants) to investigate the weight decision makers attach to information that is not, or inaccurately, included in TCO information. The experiments were conducted with individual decision makers who were involved in a particular sourcing decision.

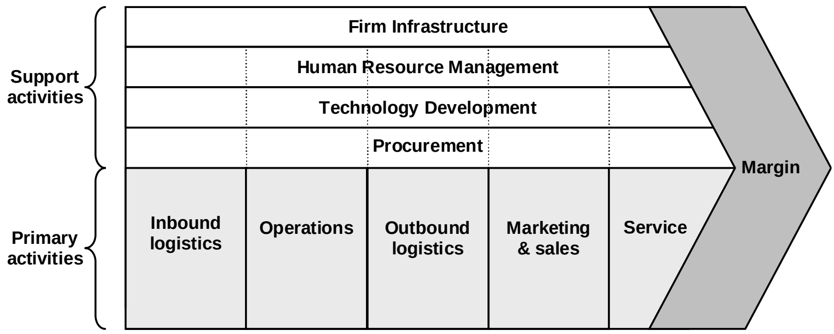
The structure of the remainder of this first chapter is as follows. Firstly, we place our research problem in the context of the purchasing process. Secondly, we will discuss total cost of ownership in detail. Then, we will elaborate on prescriptive and descriptive decision-making. Finally, we will discuss the research design and give an overview of the chapters in this thesis.

1.1 The purchasing process

Purchasing decisions in a business setting (e.g., buying machines for production, buying transportation vehicles, or computer systems) are the scope of this thesis. Purchasing is an important activity within business; on average, sourcing costs form the greatest part of a company's total costs; ranging from 90% in petroleum industry to still 25% for a non-manufacturing firm (Ellram and Siferd 1998; Degraeve and Roodhooft 2001). The purchasing decision cannot be seen in isolation. In this paragraph, we pinpoint the position of our research in the context of purchasing and business studies.

As can be seen by Porter's (1985) model of the value chain (Figure 1.1), the purchasing process is only one of many activities in an industrial organization. Porter distinguishes five primary activities (inbound logistics, operations, outbound logistics, marketing and sales, and service) and four support activities (firm infrastructure, human resource management, technology development, and procurement). Porter points out that all these activities interact and should be in balance to operate effectively and create value. Procurement's aim is to provide the organization with the necessary resources to produce and maintain the organization. Procurement does not only provide resources to primary activities, but also to supporting activities. Most often, purchasing can be split in two processes, one focusing on the sourcing of support activities and one on the sourcing of primary activities.

Figure 1.1 Porter's value chain

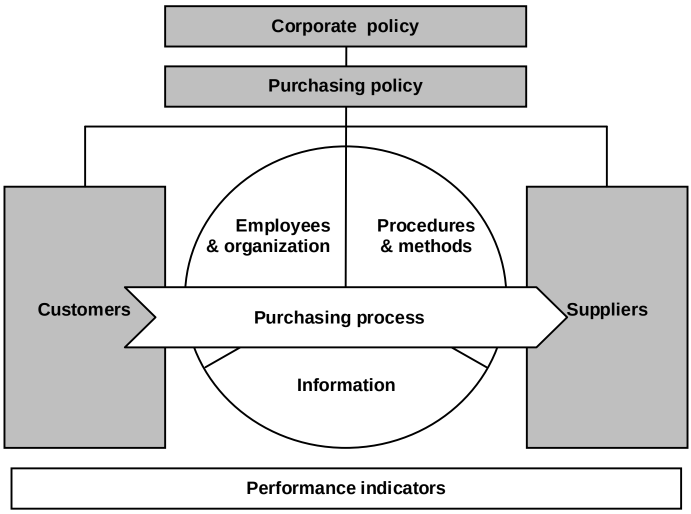


Veeke and Gunning (1993) present a more specific framework for purchasing (Figure 1.2). Their framework indicates the elements interacting with the purchasing process (see also Harink 2003):

- *Corporate policy:* Keynotes for the purchasing policy are described in this element.
- *Purchasing policy:* The mission of purchasing is described in this element. Using the mission, goals and objectives for the purchasing department can be set.
- *Customers:* Goals and recommendations to handle customers are described in this element. It is important to know the customers, the customers' wishes and their influence on the purchasing process.
- *Suppliers:* Objectives to approach the market and handle suppliers are described in this element (e.g., maintain a close partnership with a limited number of suppliers). It is important to know the suppliers because they determine largely the company's ability to fulfill the customers' wishes.
- *Employees and organization:* In this element, activities and positions are described and related to each other. In addition, positions are related to each other, employees are appointed to certain activities, etc. Often, employees from different departments are involved in the sourcing process. Attention should be paid to the education of employees and to the creation of a fit between the corporate culture and policy.
- *Procedures and methods:* Procedures and methods to execute activities are described in this element. Procedures and methods should guarantee a complete and meticulous execution of the purchasing process.

- *Information:* Information (systems) to provide information necessary to execute the sourcing process are described in this element. For example, an ERP system may provide purchasers with information necessary to calculate costs.
- *Performance indicators:* Performance indicators are important to investigate the effectiveness of the purchasing organization (e.g., reduction of purchasing costs).

Figure 1.2 The purchasing organization, elements of the purchasing function



The purchasing process is sometimes described as a sequential procedure of six steps[1] (Van Weele 1994):

Initial purchasing process steps:

1. *Purchase and order specification:* The aim of this step is to arrive at a clear and unambiguous specification of the product the company wants to buy.

[1] Rietveld (1997) describes six similar steps while Botter (1999) adds the "orientation stage" before Van Weele's (1994) purchasing and order specification step. In the orientation stage, purchasers search (and aim to build a database) for superior suppliers which might bring new possibilities and technologies to the organization. Again, other researchers frame different models (e.g., De Boer 1998). Van der Heijden et al. (2006) provide practitioners' with a guidebook on several purchasing models.

Important steps are describing the functions the product has to fulfill for its users, describing the technical properties and characteristics of the product, and defining the logistic and maintenance specifications.

2. *Supplier selection*: The aim of this step is to make a balanced selection of suppliers and find the best supplier. To do this a company has to develop criteria to evaluate and select suppliers, and decide how to weight all criteria.
3. *Purchasing agreement*: The aim of this step is to appoint and record the terms and conditions between supplier and buyer in sound contractual agreements.

Operational purchasing process steps:

4. *Ordering*: The aim of this step is to order the product.
5. *Expediting and evaluation*: The aim of this step is to monitor the process after the product has been ordered (e.g., checking delivery times, the bill, the quality of the ordered product).
6. *Evaluating the sourcing process*: The aim of this step is to monitor the relationship between buyer and supplier after the product has been delivered. TCO numbers may be used to measure ongoing performance and identify activities that should be improved.

To conclude, the outcome of the purchasing decision is the result of a combination of many different interacting elements and activities. The research in this study is concentrated on the selection decision made in the second step in the purchasing process: Which product/supplier to choose, given a set of alternatives? This is an important decision; the selection of a supplier is one of the most important decisions taken in the sourcing process (England and Leenders 1975; Leenders and Fearon 1993). We study the choice of an alternative and do this for decision where TCO information is available to support the decision maker in evaluating and selecting one alternative. Therefore, in the next paragraph we will elaborate on TCO.

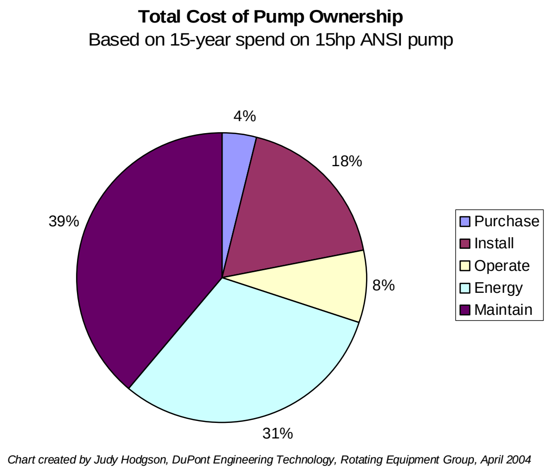
1.2 Total cost of ownership

It should go without saying that nowadays purchasers should take costs into account above and beyond the purchasing price (Ellram and Siferd 1993). However, the practitioners' literature indicates that the main and overriding criterion for many purchasers still is the purchasing price (Milligan 2000, Wessels 2005, Moser 2006, Graham 2007). Then again, focusing on the acquisition price may be short sighted. For example, the purchasing price of a certain pump turned out to be only four percent of the total costs of use over 15 years, making price differences between vendors almost irrelevant (Smith 2005). Also, the initial purchasing price of a type of lathe ended up being only 14% of its total life cycle costs over ten years (Moser 2006). These numbers stress the importance of looking beyond the initial purchasing price. Figure 1.3 shows two examples of how TCO costs are represented in business.

Although sometimes called differently (e.g., total life cycle costing, life-cycle cost, total cost analysis), the value of making a total cost analysis to support decision-making is recognized in many different fields. Examples are: information technology (Bradley and Dawson 1999; Dugan 2002; Whelan and McGrath 2002), marketing (Rust et al. 2001), space research (Sellers et al. 1998), aircraft industry (Sandberg and Stömberg 1999), transportation (DeCorla-Souza et al. 1997), architecture (Minami 2004), environmental studies (Tsagarakis et al. 2003), and medicine (Begley et al. 1999; Mark et al. 2001).

The following paragraphs will elaborate on total cost of ownership. The first section will present several definitions of TCO and discuss activities that should be taken into consideration when calculating TCO numbers. The second section will describe the many different characteristics of TCO models. Thereafter, we present our own definition of TCO. The remaining sections describe advantages of using TCO, explain for what sourcing decisions TCO should be used, and finally how a company can use TCO.

Figure 1.3 Two examples of TCO in business (Source: Smith 2005)



Total Cost of Ownership		
	Pump A	**Pump B**
Pump Cost $	$3,890	$3,300
Installation Cost $	$450	$100
Lifetime - Yrs.	10	8
Energy Cost$/kw-hr.	0.1	0.1
brakehorse power	7.55	8.25
motor horse power	10	10
Hours of Service - yr.	8000	8000
Total Energy Cost	$45,119	$49,302
Seals and Elastomers	185	145
Replacement Intervals - yr.	2	1
Time Needed to Replace - hr.	1	1
Maintenance Cost/Hr.	$20	$20
Cost of Regular Maint.	$1,125	$1,320
Major Components	1150	950
Replacement Intervals - yr.	5	4
Time Needed to Replace - hr.	2	2
Cost of Major Maint.	2380	1980
Total Maintenance Cost	$3,505	$3,300
Reduced CIP Time of 10 min. per day		
Operational Factors	-$9,466	0
Total Cost of Ownership	$43,498	$56,002
Total Annual Cost	$4,350	$7,000

1.2.1 Definitions and characteristics of TCO models

As can be concluded from reading the following quotations, the aim of a TCO calculation is to financially quantify all the consequences of a purchasing offering:

"Total cost of ownership (TCO) is a purchasing tool and philosophy which is aimed at understanding the true cost of buying a particular good or service from a particular supplier." … "Total cost of ownership is a complex approach which requires that the buying firm determines which costs it considers most important or significant in the acquisition, possession, use and subsequent disposition of a good or service." (Ellram 1995a page 4)

"Total cost of ownership tries to quantify the costs associated with the purchasing process. It determines the costs associated with purchasing activities in the company's value chain before, during, and after the purchase." (Degraeve and Roodhooft 1999 page 44)

"The TCO of an information system is defined here as: …all the costs associated with owning and using the information system throughout its life cycle. The TCO of an organization can be defined as: …all the costs associated with owning and using IT by the organization over a certain period of time. TCO models force to consider IT expenditures beyond the initial investment i.e. throughout the life cycle of information systems." (Van Maanen and Berghout 2002 page 167)

"We define the total cost of ownership (TCO) as the sum of purchase price plus all expenses incurred during the productive lifetime of a product or service minus its salvage or resale price. Such expenses fall into three categories: acquisition, conversion and disposal." (Anderson and Narus 2004 page 98)

We see TCO as a management accounting tool that aims to support decision-making by transforming, as accurately as possible, the multi-dimensional sourcing problem into a one dimensional cost number that can be used to evaluate sourcing alternatives. We use the following definition for TCO:

Total Cost of Ownership (TCO) is a management accounting tool to support the selection and evaluation of alternative products (suppliers), at a certain point in the sourcing process, on the basis of accurately monetarily quantifying and aggregating all relevant attributes of a product into comparable cost numbers over its relevant life time.

Central in this definition is the monetary quantification of all the relevant attributes in comparable cost numbers; attributes with different dimensions (e.g., percentages, hours, kilowatt-hours) are transformed to monetarily numbers (e.g., euros, dollars). We study the weight decision makers attach to the attributes that are not, or inaccurately included in cost numbers (i.e., the monetarily quantified attributes). Therewith it is different from traditional multi-criteria analyses applied in purchasing (see De Boer 1998 for an overview of multi-criteria methods applied in purchasing[2]):

- Within TCO, attributes, with all kind of different dimensions, are transformed to one monetary dimension (e.g., euros or dollars). Within multi-criteria analyses the "original" dimensions of attributes (e.g., percentages, kilowatt-hours) are used to evaluate suppliers (see for an example Analytic Hierarchy Process (AHP)).
- Within TCO, the weight of an attribute is objectively determined by applying management accounting methods (e.g., Activity Based Costing). Within most multi-criteria methods (e.g., categorical models, AHP, Multi Attribute Utility Theory) attribute weights are determined by asking the purchaser to attach a weight to attributes. The weight assigned to attributes is much more subjective in case purchasers have to assign a weight to the attributes, compared to determining the weight of attributes by using management accounting method like Activity Based Costing.
- In this thesis, uncertainty is different from uncertainty as defined in operations management; in the context of operations management, "uncertainty" typically means that there is uncertainty about what will happen in future periods. This is different from how accurately costs can be measured, which is central to this thesis.

To clarify the conceptualization of TCO further, we will discuss TCO variations. Although the aim of a TCO calculation is to calculate all costs associated with purchasing a product, a single TCO model or generally accepted method of calculating TCO numbers does not exist. The TCO models companies use vary widely, not only between companies but even within companies (Ellram 1995a). Table 1.1 shows several characteristics we will describe in the following paragraphs (see also Morssinkhof et al. 2005; Wouters 2006).

[2] De Boer (1998) also mentions TCO and cost ratio methods to select a supplier. However, the inaccuracy in cost numbers is ignored, which is central in this thesis. De Boer (1998) investigates the application of decision-support tools in a number of cases; however, no empirical findings concerning the use of TCO are reported (although some of the case companies mention total costs as important purchasing criteria).

Table 1.1 Total cost of ownership characteristics

Ex-ante	↔	Ex-post
Support purchasing	↔	Support sales
Formal model	↔	Informal model
Cost based	↔	Value based
Unique model	↔	Standard model
Exclusive revenues	↔	Inclusive revenues
Accrual based	↔	Net present value
No contract implications	↔	Contract implications
Single firm model	↔	Interfirm model
Decision supporting	↔	Decision influencing

TCO calculations can be made to support ex-ante or ex-post decisions (Morssinkhof et al. 2005; Wouters 2006). The aim of an ex-ante calculation of TCO numbers is to estimate future costs by doing a cost calculation before making a purchasing decision. Ex-post calculations are made on the basis of historical information. Ex-post information may be used to evaluate whether the best decision has been made.

TCO information can be used to support decision-making in purchasing or in sales. Most TCO models are presented as a sourcing method, where a purchasing company calculates the total cost of buying and using a product (e.g., Carr and Ittner 1992; Degraeve and Roodhooft 1999; Wouters et al. 2005). To calculate TCO numbers the purchasing company needs product information from the vendor. However, TCO numbers can also be used to market products and services (Anderson and Narus 2004, Anderson et al. 2006). Practitioners' literature also recommends this strategy to ensure a long lasting supplier-purchaser relationship (Wessels 2005). In this case, the sourcing company needs to supply information to the vendor.

TCO models may be formal or informal (Ellram 1993). Within a formal model there is a structured method for calculating cost numbers. A purchaser who adopts an informal TCO strategy takes the purchasing price and naively considers a number of other characteristics without explicitly evaluating these characteristics. In general, decisions made by a formal method are better verifiable, compared to decisions made by an informal method.

TCO models can be divided into cost based and value based models (Ellram 1995a). In a cost-based model the aim is to calculate costs accurately by using a management accounting method like activity-based costing. In a value-based model, the total costs are calculated by multiplying the purchasing price by a "cost-factor". This cost-factor depends on the difference between the attributes target values (set by the decision maker) and the actual value of the attributes. For example, if the quality department finds that only 90% of deliveries passes the quality check, instead of the targeted 99%, then the TCO number may be calculated by multiplying the purchasing price by a cost-factor of: 1 + (99% – 90%)/99% = 1.09. Calculating a cost-factor may make it easier to include attributes that are difficult to quantify monetarily, compared to using a cost-based model. It is also possible to blend a cost-based model with a value-based model; Monczka and Trecha (1988) and Smytka and Clemens (1993) give examples of models where they blend a cost-based model with a more qualitative value-based rating system to also include attributes that are difficult to quantify into cost numbers. However, neither a value-based model, nor a blended model solves the problem of accurately quantifying information into easy comparable (cost) numbers. After all, the problem of accurately quantifying information is not solved by (a combination of) these models.

A unique versus standard model is another distinction made (Ellram 1995a). A unique model is a model that is specifically designed and used for a special purchasing occasion. A 'standard' model is designed and used for regularly returning sourcing decisions. In general, less frequent decisions and, or ones with a greater impact on business require unique models. Standard models can be applied in situations where evaluations are more repetitive and have less impact on business progress. Survey results by Ferrin and Plank (2002) indicate that a generic TCO model may not be appropriate for calculating TCO numbers. Their results indicate that most TCO models can be based on a core set of 'general' cost drivers, but should be made situation specific with a set of auxiliary cost drivers.

Total costs can be analyzed by solely looking at the total costs or they can be taken into relation to the revenue made with a product. For example, a fancy colored children's lunch box can be sold for a much higher price compared to a black one. The color does not add anything to the lunch box's function; however, children may prefer fancy colored lunchboxes. Therefore, although the raw material for a colored box may be more expensive (making it unattractive in a 'pure' TCO analysis), the additional revenue made with a colored one may compensate for these costs.

The costs beyond the purchasing price can be added to the total price (accrual based), or the net present value of alternatives can be calculated. A TCO calculation is an example of an aggregating of all relevant costs in to one number. Within a net present value (NPV) calculation, not only the costs but also the incoming cash flows are taken into consideration. Another difference between accrual and NPV concerns the discounting of future cash flows. Within a NPV calculation, future cash flows are corrected with an interest rate, a correction not made in accrual based models.

Total cost calculations can be made with or without contract implications between companies. For example, a supplier and purchaser may agree that the vendor compensates the purchaser for overrunning the calculated TCO numbers.

A TCO model can be used in a single firm or in a value chain model. A TCO model can be used internally to calculate the sourcing costs for one firm.

However, a value chain analysis may reduce total costs in a value chain by investigating the cost relations between companies (Shank and Govindarajan 1992). TCO may then be used as a communication tool to evaluate and optimize costs over several companies (see also Van den Abbeele 2006).

TCO numbers may support decision makers by reducing the decision complexity. In this case, TCO numbers may support purchasers in making a deliberate decision. TCO numbers may also be used to influence decision makers. TCO numbers are not unintentionally produced, and certain attributes may be excluded from a TCO calculation on purpose. As costs are important selection criteria in business, purchasers may interpret the exclusion of certain attributes from the TCO numbers as a signal of the unimportance of these attributes.

To summarize, TCO models can be distinguished by many different characteristics (see Table 1.1). Most often, several characteristics are brought together in a TCO model. It is important to know what characteristics are used in a model, to understand and use a TCO model properly.

1.2.2 The scope of a TCO calculation

As a TCO calculation aims to calculate all the cost consequences of a purchasing offering, many different activities may be included in such cost calculations (see also Carr and Ittner 1992 or Ellram 1993). Depending on the person calculating TCO numbers and on the scope, different decision makers may calculate different TCO numbers for the same decision problem. In social decision-making studies, cost-benefit analyses are made to support investment decisions and reach a more efficient allocation of society's resources. See also Boardman et al. (2001) for a discussion about concepts and theory behind cost-benefit analyses. By calculating the costs (and benefits) for alternatives, the best alternative can be chosen. By that, it is close related to selecting the best alternative by using TCO numbers. The steps needed to conduct a cost-benefit analysis are more or less similar to the first two steps in the purchasing process described earlier. A cost-benefit analysis can be broken down in the following nine major steps (Boardman et al. (2001):

1. Specifying alternative projects
2. Deciding whose benefits and costs count
3. Catalogue the impacts and selection of measurement indicators
4. Predication of the impacts over the project's lifetime
5. Monetary quantification of all impacts
6. Discount the benefits and costs to obtain present values
7. Compute the net present value for each alternative
8. Perform a sensitivity analysis

9. Recommendation of an alternative, based on the previous two steps

Below we will shortly discuss two examples to highlight the impact of the person and the scope on decision-making when using TCO (we ignore benefits in these examples). First, TCO can be used to compare several alternatives for the construction of a new road (see also Boardman et al. 2001 for a comparable cost-benefit analysis). The owner of the road will calculate "his" TCO by summing the costs for constructing, maintaining, street lighting, etc. Using TCO, the road owner may decide to construct a two-lane road with a specific road surface. Traffic using the road may calculate a different TCO number for the same road, and prefer another alternative. Traffic may calculate the TCO of using this road by aggregating costs for delays (e.g., traffic jams resulting from the decision to construct a two-lane road or because of maintenance), driving comfort (resulting from the road surface), toll, etc. Traffic may prefer another alternative (e.g., more lanes, another road surface, more parking facilities, a tunnel instead of a pass) compared to the road owner. Another example is an energy company buying a new turbine for its coal-fired power station. The company may calculate the total costs resulting from buying and using the machine to produce electricity. It may do so by aggregating the initial purchasing price and all the costs during its lifetime (e.g., energy consumption, maintenance costs, labor costs, scrap costs). The company may exclude externalities like environmental pollution resulting from using coal. However, it will include these costs if they have an economical value to the company. Government may calculate the costs of coal-fired power stations for society by including costs that are ignored by the energy company (e.g., air pollution, illness, disasters). Emission rights for carbon dioxide sold by the government are examples of costs ignored by companies unless an economical value is given to it.

To conclude, depending on the person calculating TCO numbers and on the scope of the activities and costs that are included in a TCO calculation, different decision makers may calculate different TCO numbers for the same decision problem. In this thesis, we focus on settings in which the scope of the purchasing decision is given and the same for all decision makers.

1.2.3 Calculating TCO numbers

Accurately calculating cost is important; failure to calculate and allocate costs accurately may result in high costs and probably even "devastate business" (Roehm et al. 1992; Ellram and Siferd 1993). Survey results in the practitioners' literature indicate that many companies face difficulties in calculating TCO numbers (Milligan 1999; Milligan 2000). Although most companies are able to calculate the costs that occur prior and during purchasing, they fall short when it comes to calculating costs of an item when it is in use (Ellram 1993). When calculating total costs, an important difference is made by splitting the purchasing task in two broad categories: the purchasing of components for production, and the purchasing of services (Degraeve et al. 2004). Examples of components (and related costs) that may be included in a TCO calculation are:

1. Equipment and other “one-time” investments, such as:
   - Purchase price and other initial payments directly related to it. For example, these may be transportation, installation, spare part inventory, or tools needed.
   - Operating costs, such as: education and training, maintenance, use of spare parts, energy, operating supplies (e.g., lubricants, packaging materials, tools), and rejection, scrap, rework, or downtime.
2. “Continuously” sourced materials, components, etc. that become part of the final product. For example:
   - Purchase price and related payments
   - Production costs (e.g., when a material requires more energy or labor in manufacturing)
   - Inventory holding costs (such as storage, insurance, obsolescence, mark down, financing)
   - Costs of poor quality (such as rejection, scrap, rework, downtime, warranties)
   - Costs of delivery failure (such as expediting, premium transportation, lost sales)

Degraeve et al. (2004) and Hurkens et al. (2006) are, to our knowledge, one of the few researchers who studied TCO in a service environment. The calculation of TCO numbers in a service environment forces purchasers to focus on: intangible activities and performance indicators that are difficult to see (e.g., the performance of consultancy), the moment of consumption of the service (after all, the consumption and production of services cannot be separated), and the time service is needed (after all, services cannot be stocked) (Degraeve et al. 2004). Wynstra et al. (2006) provide a classification of different business services and address the importance to evaluate the impact of different types of services in the purchasing decision process carefully. Nevertheless, even if a company purchases products, there are also costs related to services that are less directly related to the organization’s goods and services. For example:

- Purchasing transaction costs related to purchasing activities:
- Supplier identification and certification costs
- Writing specifications and contracts’ costs

- Management of materials, ordering costs
- Quality control costs

Selecting an alternative is easy after carefully evaluating what activities and services should be included in a TCO calculation and subsequently calculating the costs of all these activities and services; the alternative for which total costs are lowest becomes the best choice. However, accurately calculating costs is difficult; in a sourcing decision, many important factors are difficult to quantify (e.g., service levels, assistance in product development costs) and may require many subjective judgments when assessing the overall value (Carr and Ittner 1992). Also problematic is that initially not all information is expressed in a (comparable) financial metric; attributes may have a financial or non-financial metric (e.g., energy consumption in kilowatt-hours, setup time in hours). Finding the information and subsequently translating all these different metrics into a comparable cost number may be complicated. Another calculation problem is that not all information is available at the relevant level. For example, some information may be available at company level (e.g., logistic performance indicators), or at business unit level (e.g., downtime levels of a production line). In these cases, extracting (cost) information that is relevant to be able to accurately calculate TCO numbers may be difficult.

Purchasers may use activity-based costing (ABC) to calculate TCO numbers. Total Cost of Ownership is a management accounting tool to support decision-making, but does not prescribe how to calculate cost numbers. TCO can be seen as an application of ABC (Wouters et al. 2005).[3] ABC is a structured

[3] Both ABC and TCO aim to support decision-making by computing costs accurately (Ellram 1995b). TCO and ABC focus on relevant costs in decision-making and recognize the diminishing return of accurately assigning cost (Ellram 1995b, Roodhooft and Konings 1996). ABC helps managers to distinguish between low-cost and low-price suppliers (Ellram 1995b). Roodhooft and Konings (1996) mention several advantages of using ABC. Firstly, ABC gives the buying company an objective measure to evaluate impact (and problems) caused by the vendor. Secondly, ABC is, like TCO, an alternative approach for a complicated multi-objective optimization problem. Thirdly, the relative importance of costs components can be identified and used to design a strategy to reduce these costs. Like TCO, ABC is also useful for vendors; ABC provides vendors with an objective measure of customer's satisfaction and the importance of the different criteria in the sourcing process. Roehm et al. (1992) found case based evidence that ABC is beneficial to (1) identify cost drivers that affect (significant) sourcing department expenses, (2) stress several cost allocation options, and (3) support accurate costs calculating. Although the benefits of using ABC for TCO calculations have been demonstrated (e.g., Roodhooft and Konings 1996; and Degraeve and Roodhooft 2000), Ellram (1995b) found that none of the eleven case companies in her study used ABC for TCO calculations.

However, there are also several differences between ABC and TCO (Ellram 1995b). ABC generally focuses more on internal costs associated with purchasing, while TCO tries to take all costs that are associated with purchasing into account. TCO focuses more on the interface with suppliers to support sourcing, while ABC focuses at internal activities in a company (Wouters et al. 2005). TCO aims to group costs that are driven by a particular supplier for a particular item or method to calculate cost numbers (e.g., Horngren et al. 2003). Nonetheless, even with the use of ABC, the calculated total cost numbers are still likely to be inaccurate. This is also recognized in practitioners' literature; although ABC helps to calculate cost numbers more accurately, it is still difficult to produce accurate cost numbers (Porter, 1993).

These difficulties in calculating TCO numbers may result in inaccurate cost numbers. Accounting information may not fully represent operational processes and decision problems in organizations; accounting information is an abstract representation of highly complex situations and decisions (Galbraith 1973; Chambers 1996; Chapman 1997; Lillis 2002,). Hence, decision makers have to deal with uncertainty about the accuracy of the TCO numbers; not all information is (accurately) included in the TCO information. Therefore, in both cases it is short-sighted to use only accounting information as a basis for decision-making; decision makers should not only use abstract accounting numbers which do not give definite answers, but use the original operational considerations and information as well (Chapman 1997).

1.2.4 A purchaser's influence on the total costs

The difficulty to calculate costs accurately may be relaxed by involving a purchaser in the product development process. A purchaser's ability to influence (purchasing) costs is largely determined by the moment he is involved in the decision-making process. A purchaser's knowledge about available technologies, materials, suppliers' expertise, et cetera, may reduce costs, reduce the time to market, and improve product quality (Van Weele 1994, O'Neal 1993). If specifications are set and suppliers are selected, than no other choice than the prescribed alternative is possible. As a result, a purchaser will not be able to influence the costs resulting from purchasing this alternative.

Involving a purchaser in a product development process rises several opportunities to influence the TCO numbers. The further a product is developed, the more rigid its specifications, the more difficult and costly it becomes to change the product design. As a result, the latitude and freedom of a purchaser are reduced as the design of a product is further developed (Van Weele 1994). In general, purchasers are much more frequently in contact with suppliers, products and technologies than engineers and developers. A purchaser may be able to oversee the consequences of buying a product, and help to distinguish the organizational costs resulting from buying. Therefore, purchasers should be involved early in the product development process to manage (purchasing) costs. This is also recognized in practitioners' literature, sourcing decisions drive many

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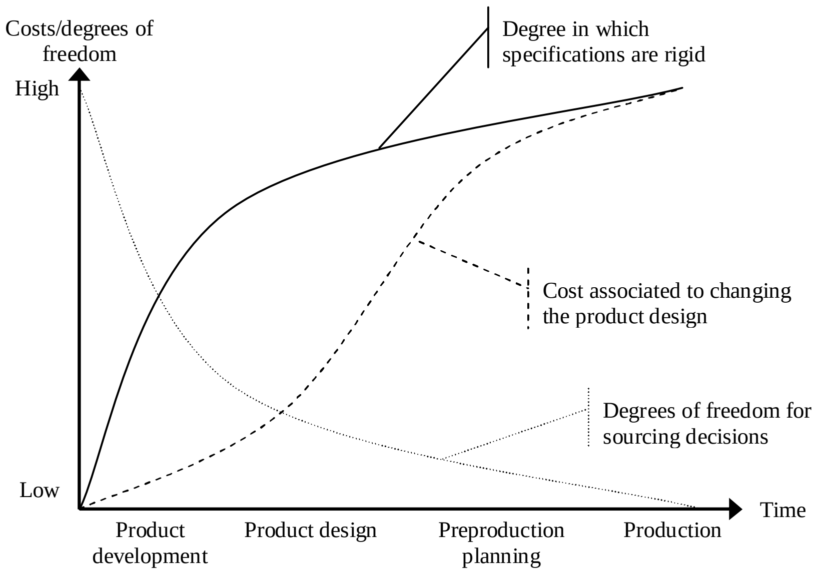
service, while ABC tries to allocate costs to the product, customer, or distribution channel that causes the costs to be incurred.

costs downstream (Porter 1993). Figure 1.4 shows that purchasers' ability to influence cost is strongly decreasing the later they are involved in the product design.

Figure 1.4 Degrees of freedom for purchasing in relation to the product development process (From: Van Weele 1994, p.146)



1.2.5 For which sourcing decisions does one calculate TCO numbers?

Developing accurate TCO models can be time-consuming, and the potential cost reductions by using TCO models should outweigh the costs off developing and introducing TCO into the organization (Ellram and Siferd 1998). The smaller the fraction the initial purchasing cost is, in comparison to the total cost of buying and using a product, the more important it is to focus on costs beyond the purchasing price. Companies should pay attention to the after sales costs. Especially the costs beyond the purchasing price can be controlled by companies (David et al. 2002). Nonetheless, particularly these are the costs companies seem to lose track of (Ellram 1993).

Information Technology (IT) is an example of a field where TCO calculations may be very valuable in supporting purchasing decisions. After all, establishing and maintaining IT is one of the most expensive activities in an organization (Barthélemy 2001). Nevertheless, most IT-costs are hard to quantify, intangible, costs, that go far beyond easily identifiable direct costs like the initial purchasing price (Hinton and Kaye 1996; Barthélemy 2001; Irani and Love 2001; Opfer 2001). A case study by Van Maanen and Berghout (2002) revealed that missing information and lack of knowledge made it complicated for most (case) companies to calculate and allocate the cost for their IT systems. Examples of other 'hidden' IT costs are maintenance and support, misuse of the computer systems or costs because users do not know how to use the IT-systems optimally (Conti and Zollikofer 1998; Opfer 2001). Estimating the cost of outsourcing IT is also problematic; the benefits of outsourcing are often lost because managers do not take the real total costs of IT outsourcing into account (Barthélemy 2001). In addition, costs associated with e-commerce are hard to estimate. A survey by The Gartner Group showed that none of the 20 midsize companies in the survey were 'on budget' for their projects (Hillam and Edwards 2001). A major problem is formed by the "intangible", "hidden" costs; traditional cost accounting and appraisal methods are centred on physical assets, thereby underestimating the actual costs (Irani et al. 1997; Conti and Zollikofer 1998; Irani and Love 2001; Opfer 2001). The fact that IT gets more and more interwoven with all kinds of activities in companies (Opfer 2001) also makes it more complicated to calculate and allocate costs accurately. Managers may use 'rough' heuristics to 'solve' cost calculation problems. For example, one manager doubled the calculated costs, arguing that in his experience that this was a good estimate of the total cost (Hillam and Edwards 2001). To summarize, calculating TCO numbers for IT is complicated, but the high cost of buying and using IT-systems demand a thoughtful evaluation of the total cost.

1.2.6 Introducing TCO in the organization

Successfully introducing TCO in an organization is challenging; companies will face several hurdles and difficulties when introducing TCO (e.g., Carr and Ittner 1992; Ellram 1993; Ellram and Siferd 1998). Below we will discuss several hurdles in greater detail and describe how companies may implement TCO in their organization.

Firstly, companies face difficulties finding information necessary to calculate TCO numbers. Information is often situation-specific; for each sourcing decision purchasers have to search over and over again to find the relevant information (Schmenner 1992). Finding and evaluating which information is important is especially difficult when a company wants to buy new products or, for example, calculate TCO numbers for a new production process. In these cases, no (or only limited) information is available about relevant product characteristics, cost drivers, failure costs, etc. In addition, information is often diffused through the entire organization, making it hard to find the necessary information (in time) (Carr and Ittner 1992). Hence, a purchaser depends on information provided by others to calculate TCO numbers; it is unlikely that a purchaser is able to survey the full impact of a sourcing decision without contacting others (Ellram 1994). In its most progressive form, a TCO calculation is a non-trivial, challenging and boundary-spanning concept that asks to quantify all costs that are executed at different places within the customer's organization and across the value chain with suppliers (Wouters et al. 2005). Most information technology (IT) systems are not designed to support the complex calculations in TCO, often there is very specific internal and external case information required (Ellram and Zsidisin 2002).[4] To conclude, gathering relevant information is difficult. However, a purchaser's knowledge and understanding concerning the gathering of relevant information is most important; there is almost no common knowledge available about logical and consistent data gathering beyond the purchasing price available (Ellram and Siferd 1993).

Secondly, there is no standard method available prescribing how and for which decisions to calculate TCO numbers. Case research indicates that TCO models do not only vary widely between organizations, but may even vary within one company (Ellram 1994; Ellram 1995a). ABC (see previous section) may support the calculation of TCO numbers, but it does not prescribe how to make an accurate TCO calculation. Calculating TCO numbers may be time-consuming; therefore, companies should carefully consider for which sourcing decisions they want to develop and use a TCO model.

Thirdly, the existing corporate culture may need to change. It is important for companies to move away from price orientation to total cost orientation. Potential users should be convinced of the benefits of using TCO. It is important to convince employees of the benefits; successful implementation of TCO depends on the collaboration of many different people from within the company. A complicating factor is that the implementation may eliminate jobs; TCO may be used to improve the purchasing process and may be used to eliminate or outsource cost inefficient processes.

Given the advantages of using TCO, purchasers should be motivated to use TCO numbers. Purchasers may be motivated to use TCO as a decision tool by rewarding them on the basis of reducing the TCO for the organization. Measuring purchasers' performance by their ability to reduce TCO numbers forces purchasers to cooperate with colleagues from other departments. After all, purchasers are not able to oversee all the consequences of purchasing by

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[4] Dunk's (2004) findings suggest that improved quality of an information system positively influences the adaptation and use of product life cycle analysis in companies as more and better information is available. Nevertheless, the use of IT to support TCO may be limited; companies may find it difficult to commit the resources for development and maintenance of cost data files that are needed to support accurate cost calculations and consistent supplier selection (Smytka and Clemens 1993).

themselves. Measuring purchasers' performance by their ability to reduce the initial purchasing price may reduce the initial purchasing cost, but increase the cost of using the product as purchasers' performance does not depend on the impact of the purchase decision on the organization.

To conclude, introducing TCO in a company is complicated. Many companies face difficulties in gathering relevant data and calculating cost numbers. Consolidating necessary information and making it usable has even been described as 'a daunting activity' in the practitioners' literature (White 2006). The general implementation of TCO in business may be limited as a result of the complexity of calculating TCO numbers and may also limit its general implementation in business (Ellram 1995a).

1.3 Decision-making

Deliberate sourcing implies that decision makers do have to evaluate and judge the available alternatives before selecting a preferred alternative. Decision-making can be studied from different points of view. On the one hand, you have prescriptive and normative studies that aim to calculate which strategy is preferable or solution should be chosen (see Hwang and Yoon 1981 for a review). On the other hand, empirical studies research how people make decisions (see Payne et al. 1993, or Plous 1993 for reviews). The selection of a sourcing alternative can be studied using normative, prescriptive or descriptive decision-making theory. The aim of normative theory is to study the best method to make a decision. Within prescriptive research the aim is to stipulate how the decision maker should make best decision possible; that is, support the decision maker in making the best decision possible (e.g., De Boer 1998). Within descriptive research researchers study questions like *who, what, when, where*, and *how*. The studies in this thesis are empirical and aim to describe causal relations in a purchasing decision.

Different purchasers may use different criteria to select an alternative. Each purchasing alternative has many attributes that can be used to evaluate its suitability (e.g., purchasing price, energy consumption, lifetime, maintenance costs). Therefore, sourcing decisions are examples of multi-criteria decisions. The selection and weight decision makers attach to certain attributes may depend on their background, the products they are buying, the persons to whom they are accountable, or, for example, legal safety requirements; that is, decision-making depends on many situational conditions (Payne et al. 1993). As a result, many different selection criteria are available, for example:

- *Qualitative characteristics*: Hard to quantify characteristics, like brand name, trust, feeling or service provided, may be important selection criteria in the purchasing process. For example, a certain brand name may be associated with high quality, high service levels, or ease of handling.

- *Quantitative characteristics (non financial)*: Quantitative product characteristics (e.g., the production speed or the cutting precision) may be important criteria when evaluating and selecting alternative offers. These characteristics are important to technically orientated decision makers, like engineers and operations managers. Quantitative characteristic are also important for high-tech companies searching for suppliers who can offer some special component (Davila and Wouters 2000, 2004). Purchasers will ask themselves whether a supplier will be able to fulfil the high technical requirements asked for.
- *Financially quantified characteristics to minimize offered resources*: Purchasers may evaluate and select alternatives on the basis of the lowest cost numbers. For example, they may select the alternative for which the initial purchasing price is lowest, still an important selection criterion (Milligan 1999), or choose the alternative for which the total life cycle costs are lowest.
- *Financially quantified characteristics to maximize possible revenues*: Purchasers may select the alternatives that will add the most value for their customers. A more advanced tool may for example be highly appreciated by customers—resulting in a higher selling price—although the product would also work with a less advanced tool. Anderson et al. (1993) define value in a business market as "the perceived value of economic, technical, service and social benefits received by a customer firm in exchange for the price paid for a product offering, taking into consideration the available alternative suppliers' offering and prices."

Nevertheless, other selection criteria may also be important. For example, ethical dilemmas and moral values may also influence the outcome of the purchasing process. A purchaser in a social responsible organization attempts to take public consequences of organizational buying into account or attempts to create positive social change by adopting a certain sourcing strategy (Drumwright 1994).

To conclude, many different criteria are available to assist in evaluating alternatives, and different decision makers may use different criteria. In this thesis, we focus at how a purchaser selects one alternative from a set of sourcing alternatives. We do this for sourcing decisions where total cost of ownership (TCO) is used as a method to compare and evaluate alternative purchasing offerings. In the next paragraph, we will elaborate on total cost of ownership. Nevertheless, as explained in the previous section, not all information can be accurately included into TCO numbers. Therefore, decision makers do have to take a multi-attribute decision to make a trade-off between the cost information and the information not or inaccurately included in the costs. In the following paragraphs, we elaborate on judgment and decision-making from a normative point of view, and subsequently from a human judgment and decision-making point of view.

1.3.1 Multi-criteria decision-making

Purchasing decisions are examples of multi-criteria problems. After all, decision makers have to evaluate several options on many different attribute dimensions. Even if TCO information is available, the decision is still a multi attribute decision. Multi-criteria problems share a number of characteristics (Hwang and Yoon 1981):

- *Multiple attributes*: Alternatives have multiple attributes (e.g., production speed, purchasing price, maintenance schedules). These attributes make it possible to evaluate the performance of alternatives.
- *Conflict among attributes*: One attribute (e.g., electricity consumption) may be in favorable in alternative A, while another attribute (e.g., purchasing price) is better in alternative B. Decision makers have to decide how to weigh the pros and cons among attributes and alternatives.
- *Incommensurable dimensions*: Attributes often have different dimensions (e.g., euros, percentages, hours) that are difficult to compare.

In this paragraph, we discuss normative methods to solve multi-criteria problems and thereafter focus on descriptive methods about how human decision makers actually make decisions.

Normative methods are used to calculate which option is best. De Boer et al. (2001) review different normative methods which can be used in purchasing (see also De Boer (1998) for an overview of decision models used in purchasing). They split up the sourcing problem into three steps: (1) decision methods for problem definition and formulation of criteria, (2) pre-qualification of suitable suppliers, and (3) decision models for the final choice-phase. De Boer et al. (2001) distinguish five different methods for selecting a sourcing alternative:

1. *Linear weighing models*: In these models, the available information is transformed into one single number for each supplier. Each attribute receives a certain weight, with a bigger weight indicating a higher attribute importance. The weights for each attribute are multiplied by the attribute rating and summed. Subsequently, the supplier with the highest overall rating can be selected as most preferable alternative.
2. *Total cost of ownership models*: The aim of these models is to calculate the total cost by quantifying all costs associated with selecting a supplier or product (see previous paragraphs for a more extensive discussion of TCO).

3. *Mathematical programming models*: A mathematical programming model allows the decision-maker to formulate a mathematical objective function that can be optimized (e.g., maximized for revenues/minimized for costs). Although these models may be assumed to be more objective (decision makers have to formulate the objective function) these models do often mainly focus on more quantitative criteria. See also, Degraeve and Roodhooft (1999), Degraeve et al. (2000), and Degraeve et al. (2004) for examples of mathematical programming techniques to select and evaluate suppliers and products with the help of TCO numbers.
4. *Statistical models*: These models take stochastic uncertainty related to vendor choice into account. However, only very few supplier choice models do use of this.
5. *Artificial intelligence based models*: These models improve by using historical data or by being trained by an expert in how to make sourcing decisions. These models are not widely used in purchasing, however, there is potential for further development of these models. Artificial intelligence based models can cope better with complexity and uncertainty than traditional models as formalization of the decision-making process is not required.

An example of a normative method can be found in Lowe et al. (2000). They give an example of a selection method to evaluate the suitability of a production method. The first step is the selection of important process and product characteristics. After putting all selected product and process features into a matrix, the decision-maker can attach a value to each interrelationship. An interrelationship receives a higher score if the match between product and process is better. The relative weight of each product characteristic is taken into account by multiplying each interrelationship with the relative importance of a value. The total sum of all interrelationship values forms the overall result for a production method. By repeating this evaluation method for several production methods, it is possible to select the one that forms the best alternative available.

Although these methods aim to calculate as objectively as possible what alternative should be selected, quantifying all attributes is complicated. Layer et al. (2002) review three quantitative approaches to calculate life cycle costs for product development. Nevertheless, none of these three advanced approaches results in satisfactory accuracy of cost numbers. And although information technology makes it possible to make more and more data available, the increasing amount of data that can be made available during development is not considered when calculating cost numbers.

As discussed, quantifying attributes into numerical form can be complicated and arbitrary. For example, qualitative attributes (e.g., service quality, trust) are hard to transform into variables with a ratio scale (e.g., cost numbers) (Hwang and Yoon 1981). Many qualitative attributes have no “natural” point zero, or measuring the relative distance between two variables is hard (e.g., supplier’s X service is twice as good as Y’s). To overcome these problems, some TCO models use combinations of total cost calculations and weighing methods to take attributes that are difficult to quantify into account (e.g., Monczka and Trecha 1988; Smytka and Clemens 1993; Ellram 1995a). However, these methods have important shortcomings as well (Roodhooft and Van Den Abbeele 2005). For example, weights for attributes may be arbitrarily appointed, and this method still has difficulty taking all the relevant (costs) information into account. Therefore, it is important that a decision maker understands how information is transformed into cost numbers. Subsequently, the decision maker can decide whether or not to focus solely on the calculated numbers or to take other information into account as well. In the following paragraphs, we will discuss how people handle these problems.

1.3.2 Adaptive decision-making

Decision makers use multiple decision strategies in different situations. Their response depends on many contingency variables and can be seen as an adaptive response of a limited-capacity information processor to the demands of complex decision tasks (Payne et al. 1993). Payne et al. (1993) distinguish three major factors which may influence the strategy adopted by a decision-maker: (1) characteristics of the problem, (2) characteristics of the person, and (3) characteristics of the social context. These three major types of factors affect the availability, accessibility, processability, and perceived benefits of various decision strategies. Decision makers generally prefer to use as little effort as necessary to solve a problem (Payne et al. 1993). Human decision makers have even been qualified as ‘cognitive misers’ who prefer to minimize cognitive effort (Fiske and Taylor 1984, p.12). However, cognitive effort may be strengthened under certain conditions. For example, reflective thinking may increase the cognitive effort (e.g., Tetlock, 1985). Therefore, decision-making is situational dependent; the same decision maker will use different decision strategies to deal with different problems (Payne et al. 1993).

In this thesis we focus on how people use TCO in dealing with multi-criteria purchasing decisions. Multi-criteria problems are exciting research topics; most people will struggle to solve these problems. Multi-criteria problems are difficult for human decision makers, because of a number of factors including: (1) as the amount of information increases, (2) as attributes are measured on a greater number of dissimilar dimensions, as the degree of conflict among attributes increases (the degree to which differing attributes indicate that different alternatives are the most desirable), as the number of shared attributes describing the options is smaller, as the amount of missing information increases, as the time available for processing the information decreases, and as the information display format becomes more complex (Bonner 1994; Bettman et al. 1998). All these situational variables may influence the way decision makers evaluate the multi-criteria problem. For example, a higher decision complexity (e.g., Bonner 1994) may result in decision makers who are more likely to adopt a heuristic approach to judging and deciding.

Decision makers can adopt many different decision-strategies to evaluate information. However, the properties of these strategies can be described by the following six general characteristics (Payne et al. 1993):

1. *Compensatory versus non-compensatory decision-making:* Decision makers who adopt a compensatory strategy trade off attributes against each other; an attribute (e.g., long lifetime) can compensate for a less attractive attribute (e.g., a high purchasing price). Decision makers who adopt a non-compensatory strategy do not make these trade-offs. For example, a decision maker eliminates an alternative if the purchasing price is too high, no-matter the lifetime. A non-compensatory strategy is (in general) less cognitive demanding; decision makers do not need to make trade-offs between conflicting attributes. TCO can be seen as a compensatory strategy where low costs for one attribute can compensate for high costs of another attribute.

2. *Consistent versus selective processing*: Consistent processing of information means that a decision maker compares and evaluates the same information for each alternative (e.g. the lifetime for all alternatives). Selective information processing means that a decision maker does not necessarily evaluate the same information for all alternatives. For example, a decision maker may take three attributes into account when evaluating one alternative and only two when evaluating another alternative. TCO information makes it easier to evaluate alternatives consistently. Comparing the total cost for each alternative supports a consistent evaluation process (assuming that the same information for each alternative is equally accurately transformed into costs).

3. *The amount of information processed*: A decision maker is only able to process a limited amount of information. Depending on each specific situation and necessity to process information, the amount of information examined may vary from cursory to exhaustive. TCO numbers may encourage decision makers to process more of the available information. After all, TCO numbers transform all information available into one cost number that makes it easier to evaluate (many) sourcing alternatives.

4. *Alternative based versus attribute based decision-making*: Decision makers may adopt an alternative-based (i.e., multiple attributes of an alternative are considered before evaluating a second alternative), or on attribute based

(i.e., the values of several alternatives of a single attribute are processed before information on a second attribute is processed) process. TCO supports alternative based decision-making; alternatives are easily comparable by the total costs of ownership information.

5. *Formation of evaluations*: Decision makers can explicitly formulate an overall evaluation for each alternative, or they can evaluate alternatives without coming to an overall evaluation (e.g., an elimination-by-aspect strategy). Total cost of ownership information supports overall evaluations per alternative; the total cost information forms an explicit overall evaluation for each alternative.

6. *Quantitative versus qualitative reasoning*: A decision maker can adopt a more quantitative method by transforming (most) information into numbers and calculating which alternative is optimal, or adopt a more qualitative method where not all information is transformed into numbers. Total cost of ownership calculations are examples of quantitative methods; information is financially quantified and summed to one total cost number.

Which strategy a decision makers adopts depends on many variables, for example experience, cognitive development, formal training, task characteristics, the response mode (choosing or matching problems), information display, or agenda effects (restrictions on the order in which alternatives are evaluated) (Payne et al. 1993). However, decision makers seem to adopt strategies that help them to evaluate and decide efficiently (Payne et al. 1993). For example, decision makers prefer non-compensatory strategies as these are cognitive less demanding.

TCO numbers may help decision makers to evaluate sourcing alternatives; the transformation of attributes with many different dimensions into cost numbers reduces the difficulty to compare the sourcing alternatives. However, calculating costs is complicated and TCO numbers are likely to be inaccurate. Thus, although TCO numbers reduce the complexity of a sourcing problem, the decision is (very often) still a multi-attribute decision.

Decision makers may be convinced by TCO numbers and tempted to ignore the information not included in the TCO numbers. Furthermore, TCO numbers are not unintentionally produced. Purchasers may interpret the presented TCO numbers as a signal of the importance of the attributes that are translated into TCO numbers and ignore the attributes not included. Besides this, decision makers are generally assumed to prefer cognitive less demanding decision strategies. If most information seems to be translated into cost numbers it may be tempting to ignore the few attributes not included. To conclude, the weight decision makers attach to TCO numbers may depend on many contingency variables like the complexity of the decision, the pressure to justify decisions, or the ability to concentrate on the information available.

1.4 An extension of current research

Despite the widespread attention for costing systems that include costs beyond direct costs, such as activity-based costing (ABC) or total cost of ownership (TCO), the interaction of such information and managers' cognition has received little consideration (Lipe and Salterio 2000). Previous TCO studies focus on technical issues and potential benefits of TCO but ignore human decision-making characteristics (e.g., Carr and Ittner 1992; Ellram 1995a; Roodhooft and Konings 1996; Ellram and Feitzinger 1997; Degraeve and Roodhooft 2000; Degraeve et al. 2004). We apply insights from the theoretical field of decision research to a decision problem faced by managerial decision makers confronted with cost information. The formal characteristic of the problem we are studying (decision information that is 1) translated into a common, monetary unit of measurement, 2) aggregated into a summary number, 3) however, only partially translated and aggregated) may exist in other applied fields besides accounting, although we are not aware of them. We extend current research knowledge by investigating the persuasiveness of monetarily quantified attributes in managerial decision-making. As far as we know, no researchers have investigated the impact (and persuasiveness) of inaccurate cost information on the weight decision makers attach to the information that is not or inaccurately included in the cost numbers because certain cost numbers are especially difficult to "financialize".

Completeness of accounting information has received considerable attention, but primarily in the context of performance evaluation (Hartmann 2000; Lillis 2002, Mol and Beeres 2004). Ittner and Larcker (2001) stress the importance of focusing on the impact of reliability of performance information on judgment and decision-making, an important management accounting characteristic ignored by researchers. Related to this topic is the question what weight managers attach to financial information. In a survey among managers Ittner and Larcker (2001) found the perceived importance of financial performance information to be much higher than the perceived quality of this information. Lingle and Schiemann (1996) came up with corresponding results; the perceived value of performance indicators is (much) higher than the perceived quality of the performance information. Managers seem to put a lot of trust in financial performance information. Also other studies (e.g., Ittner et al. 2003; Reck 2001; Schiff and Hoffman 1996) found that decision makers tend to value financial information more highly than non-financial information. Finally, Kadous et al. (2006) indicate that financially quantified information is tempting to use, and suggests that a highly competent person produced these numbers. Although these studies give an indication of the perceived importance of (financial) performance indicators, these studies do not indicate how decision makers handle cost information that was initially non-financial.

To summarize, we add to current knowledge in management accounting by investigating the impact of inaccuracies in cost numbers on the weight decision makers attach to information excluded from financially quantified numbers. Although research is never finished, the findings in the following chapters help us to get more insight in judgment and decision-making in management accounting.

1.5 Research design: Experimental research

In this thesis, we use experimental research to investigate the impact of inaccurate cost information on decision-making in organizations. Seeing that an organization's success depends largely on managerial accounting, it is vital to understand the influence of managerial accounting information on decision-making. In particular, experimental research is useful to study whether and how managerial information, which plays a key role in motivating employees and improving their judgment and decisions, affects the behavior of individuals in organizations (Sprinkle 2003); experimental research offers the possibility to investigate causal relations between variables that influence decision-making. To our knowledge, only a few experimental studies in a field study were conducted to investigate decision making in industrial buying (e.g., Qualls and Puto 1989; Anderson et al. 2000; Mantel et al. 2006). One of the main reasons for the lack of experimental research in operations management may be the difficulty to include practitioners in laboratory experiments (Mantel et al. 2006). However, other research methods like archival studies or survey studies are difficult to apply to the study of the effects of management accounting information on individual decision makers in an organization (e.g., Sprinkle 2003, Ittner and Larcker 2001).

1.5.1 Design of the experiments

The key question to answer is: How is an attribute weighted when it is inaccurately (or not at all) included in TCO numbers? The TCO numbers in this study are ex-ante (i.e., they indicate future costs). TCO implies the monetary quantification of attributes, which may be initially expressed in monetary terms (e.g. purchasing price), or as a quantitative non-financial metric (e.g., lifetime), or as a qualitative non-financial metric (e.g., service level). In all cases, the 'original' metric has to be transformed to be able to calculate the total cost. Four different methods of representing inaccuracy within TCO numbers are included in this thesis. Firstly, information which is hard to quantify (accurately) may be excluded (Chapter 2, 3 and 4). Secondly, for some attributes it may be possible to give an indication of the costs, but it may not be possible to produce accurate cost numbers. For example, costs for logistics may include the cost of transportation; but the cost of not meeting delivery schedules is much harder to calculate and may be excluded from the logistic cost numbers. Alternatively, in the worst-case scenario all possible costs may be included in the logistic cost numbers if delivery schedules are not met. In these cases, minimum or maximum cost numbers may be calculated (Chapter 3). Finally, attributes for which costs are difficult to include accurately may be presented as a range (e.g., costs range between € 4 and € 6) (Chapter 4).

In all experiments, participants are required to make sourcing decisions in a business market context: buy a new machine for the production department. Participants receive information about several sourcing alternatives and are asked to choose the one they would buy. The decision maker's choice (*Choice*) is the dependent variable in all experiments. For each machine, between four and ten attributes are given per alternative. These attributes are a mixture of financial and nonfinancial features. In most experiments, the availability of TCO information (*TCO info*) and uptime percentage of one of the alternative machines (*Uptime*) are two of the manipulated, independent variables. For example, Figure 1.3 shows two tables. Both tables show sourcing information for two brands, brand A and brand B. Decision makers are provided with the sourcing information shown in Figure 1.3a (no costs per hour information is available) or the information in Figure 1.3b (cost per hour information is available). The uptime of machine B (*Uptime B*) is manipulated as well. In some conditions the uptime is low (e.g., 96% in Figure 1) while in other conditions it is high (e.g., 99.5%).

A total number of 2,097 students and practitioners have participated in the experiments in this thesis. Student participants were undergraduate students from the University of Twente (the Netherlands) and the Catholic University of Leuven (Belgium). All students were familiar with the basic concepts in cost accounting. We contacted practitioner participants at professional trade fairs in the Netherlands. They were interested in technology and users of cost accounting information in organizations.

Figure 1.3 Sourcing information

1.3a no TCO info available

	Brand A	Brand B
Life time (hours)	2,900	2,800
Uptime (%)	99.0%	96.0%
Purchasing price (€)	€ 1,280	€ 1,020
Energy per hour (Kwh)	2.0	2.2

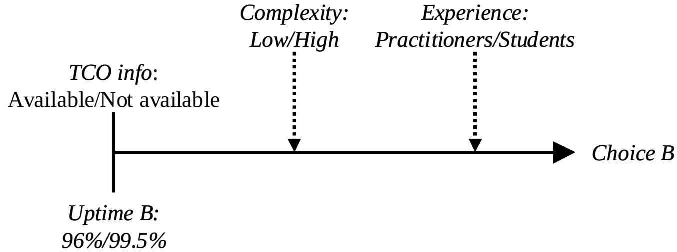
1.3b TCO info available

Energy cost (Kwh) € 0.13

	Brand A	Cost per hour	Brand B	Cost per hour
Life time (hours)	2,900		2,800	
Uptime (%)	99.0%		96.0%	
Purchasing price (€)	€ 1,280	€ 0.44	€ 1,020	€ 0.36
Energy per hour (Kwh)	2.0	€ 0.26	2.2	€ 0.29
Total cost per hour		€ 0.70		€ 0.65

In the experiments, reported in chapter 2, *Complexity* was added as a third independent moderating variable (besides the independent variables *TCO info* and *Uptime B*). Complexity of information was manipulated by providing participants with more or less detailed TCO information about the purchasing price of the machine. Both students and practitioners (N = 1,028) participated in this study. Therefore, *Experience* was included as a fourth measured variable. Figure 1.4 gives a schematic representation of the variables.

Figure 1.4 Dependent, independent and moderating variables in Chapter 2

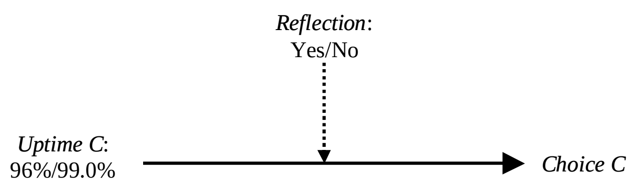


A second study (Chapter 3) was conducted to investigate the impact of reflective thinking (*Reflection*) on the weight decision makers (N = 358) would attach to the information not or inaccurately included in the TCO numbers. *Uptime C* was an independent variable measured at two levels, and *Choice C* was the dependent variable. We conducted an experiment to investigate the impact of reflective thinking on the weight participants would attach to cost numbers that were estimated to be minimum costs (Figure 1.5a). A similar experiment was conducted to investigate the impact of reflective thinking on the weight decision makers would attach to cost numbers that were estimated to be maximum cost numbers. *Reflection* was manipulated by asking the participating students to reflect on their decision strategy before choosing between one of the three sourcing alternatives. Decision makers in the no-reflection condition were only asked to make a choice.

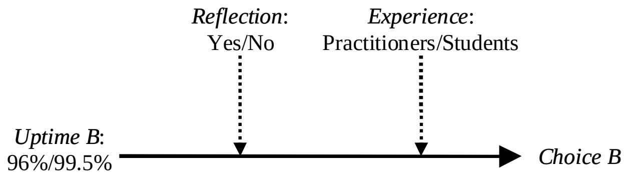
Another experiment was conducted to investigate the impact of reflective thinking on the weight decision makers attach to information that is not included in TCO numbers. In this experiment, *Reflection* was manipulated by making participants believe that they would have to justify their decisions afterwards. Participants who were not encouraged to reflect were only asked to choose between the alternative sourcing options. This experiment was conducted with students and practitioners. Therefore, *Experience* was included as a measured variable. Figure 1.5b gives a schematic representation of the variables.

Figure 1.5 Dependent, independent and moderating variables in Chapter 3

1.5a Variables to investigate the impact of reflective thinking



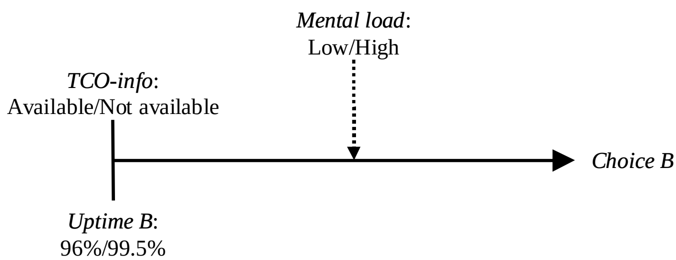
1.5b Variables to investigate the impact of reflective thinking and experience



The impact of mental load was researched in Chapter 4. A total number of 711 students participated in these experiments. We investigated whether mental load influenced the weight decision makers would attach to information not included in TCO numbers (Figure 1.6a). We manipulate mental load by increasing the cognitive load participants were experiencing during the sourcing decision (e.g., by asking them to remember a number that was difficult to memorize). Furthermore, another experiment was conducted to investigate whether presenting TCO numbers as a range or as a point (*Estimation*) influenced the weight decision makers would attach to inaccurate cost numbers. Again, mental load was a moderating variable to investigate the interactive effect between cost numbers and a decision makers' cognition (Figure 1.6b).

Figure 1.6 Dependent, independent and independent variables in Chapter 4

1.6a Variables to investigate the impact of mental load



1.6b Variables to investigate the impact of mental load and the estimation method of TCO numbers

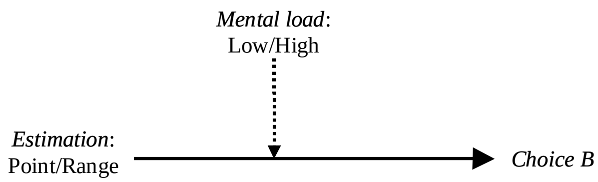


Table 1.2 shows the methods of conceptualizing inaccuracy in each of the chapters. The table also shows the level of participants' experience in each experiment.

Table 1.2 Conceptualization of inaccuracy and the level of participants' experience

Conceptualization of inaccuracy in TCO numbers	Complexity experiments, Chapter 2	Reflective thinking experiments, Chapter 3	Mental load experiments, Chapter 4
Excluded	Students & Practitioners	Students & Practitioners	Students
Minimum		Students	
Maximum		Students	
Range			Students

In the following three chapters, we present and discuss the three experimental studies. Chapter 2 and Chapter 3 are written as papers that will be submitted to accounting journals. As a result, both chapters partly cover the same literature.

2 Decision Complexity

In this chapter, we investigate how the provision of Total Cost of Ownership (TCO) information affects attribute weights in sourcing decisions, and how this effect is moderated by decision complexity. TCO quantifies the costs of each decision alternative for purchasing decisions, from the perspective of the buying organization. We consider incomplete TCO information, in the sense that some nonfinancial attributes are not included in the TCO calculation, and we investigate effects of providing decision makers with such information.

We conducted experiments with 1,028 participants, both students and managers. We found mixed support for the hypothesis that when complexity was low participants gave a higher weight to the attribute that was excluded from the TCO information. Student participants' results supported this hypothesis, but practitioner participants' results did not. We found support for the hypothesis that when complexity was high, practitioner participants gave less weight to the excluded attribute, and within this group this result was found for the most experienced subgroup of managers. Due to the provision of TCO information, the most experienced decision makers were more likely to follow an evaluation process in which less attention was paid to attributes that were not part of the TCO calculation. This may suggest that experienced decision makers could be less mindful of the incompleteness of TCO information.

2.1 Introduction

In this study we investigate the use of accounting information for sourcing decisions and how this is affected by decision complexity and experience. Sourcing decisions are multi-attribute decisions, whereby decision makers must consider several attributes of different purchasing options, and make tradeoffs among these attributes and alternatives. Total Cost of Ownership (TCO) accounting information aims to quantify the impact of all attributes on the total costs for the buying organization (Carr and Ittner 1992; Degraeve et al. 2005; Ellram 1995a). As purchase prices are easy to compare, TCO information particularly aims to quantify the impact of other-than-price differences (such as quality, lifetime, or energy use) on costs.

TCO simulates a compensatory decision-making process, which would lead to optimal decisions with rational decision weights that are proportional to their impact on total cost. In other words: TCO information converts a multi-attribute decision into a single-attribute decision. Such information has the potential to reduce decision complexity, to correct biases in multi-attribute decision-making, and to make sure that the weight that each attribute receives in the overall decision is based on objective procedures. Not only in sourcing decisions, but also in settings of capital budgeting, or cost-benefit analysis for public policy, much supporting information consists of qualitative information and quantitative, non-monetary information, making it difficult to decide which alternative is best overall. Different attributes are non-comparable, because their measurement units are not commensurable. The translation of qualitative and non-monetary attribute information into monetary units of measure, and the aggregation into a summary measure facilitates cross-functional comparisons of alternatives.

However, not all attributes can be translated to their financial impact. Something gets lost in the translation to a common financial dimension, and some information is not translated at all (Galbraith 1973; Chambers 1996; Chapman 1997; Lillis 2002). Yet, the benefits of quantitative financial summary data—they draw attention, are persuasive, suggest accuracy and objectivity, are easy to communicate, reduce the amount and diversity of information, make tradeoffs easy—could lead to loosing sight of nuances, paying less attention to subtle elements that are not included in the financial calculation, or making the nonfinancial information less credible. This could be a drawback of providing financial summary information. In other words: there could be unintended effects of providing better—but not perfect—costing information.

In this study, we will investigate what happens when some attribute information is included in the overall cost number, while other attribute information is not included. What is the effect on decision weights of these excluded attributes? We are particularly interested in the question whether information that is not compounded into aggregate financial information receives more or less weight as a result of providing such information. Decision makers can follow different strategies, which are likely to affect decision weights. They may focus on the overall TCO number, rather than on the individual attributes that are represented by that number, and tradeoff the TCO number against the attributes that are not part of it. Categorization would reduce the weight of the included attributes and would increase the relative weight of the excluded attributes (Lipe and Salterio 2002). However, when the decision task becomes more demanding, applying this compensatory heuristic may be too difficult. Rather, decision makers may focus primarily on the TCO number and avoid making the difficult tradeoff with the nonfinancial attributes that are not compounded into the TCO number. As a result, the weight of the excluded attributes would reduce.

Both a reduction and increase of the weight of these excluded attributes would be unintended effects of providing the decision maker with TCO information. We will investigate complexity and experience as moderating variables. Despite the widespread attention for costing systems that include costs beyond direct costs, such as activity-based costing, customer profitability analysis, or TCO, the interaction of such information and managers' cognition has received little consideration (Lipe and Salterio 2000).[5]

We use TCO data to address the intersection of two fundamental issues in accounting: the costs and benefits of aggregation financial versus nonfinancial measurement. We raise the specific question how aggregation of multiple attributes into TCO will affect the weight of any attribute omitted from TCO because it is especially difficult to "financialize". On the one hand, aggregating attributes in one TCO number may be helpful as it reduces decision complexity. On the other hand, decision makers may tend to "ignore" attribute information not included in TCO. We apply insights from the theoretical field of decision research to a decision problem faced by managerial decision makers confronted with cost information.

Experiments were conducted with students and managers, 1028 participants in total. The decision involved making a choice between two brands for a similar product. We found mixed support for our hypothesis H1: when complexity was low, providing decision makers with TCO information increased the decision weight of the excluded attribute, but only for student-participants. We found support for hypothesis H2: when complexity was high, the weight of the excluded attributes decreased as a result of providing TCO information, but only for the practitioner-participants. This differential support for H1 and H2 for students versus practitioners is consistent with H3b. In sum, these results suggest that providing incomplete TCO information has a significant impact on decision weights, moderated by the complexity of the decision task and, more clearly, by the level of business experience of the decision maker.

The remainder of this chapter is structured as follows. In the next section, the background of this chapter is introduced in more detail and our hypotheses are developed. Subsequently, the research method is described, and results are presented. Discussion and conclusions are in the final section.

2.2 Hypotheses development

Monetary quantification is the key element of TCO. Attributes that are initially not expressed in a financial metric are "translated" into financial numbers, and financial data are aggregated into a summary measure (such as the cost per hour, cost per unit, or net present value). These costs may include transaction costs related to purchasing activities (e.g., ordering, freight, quality control), inventory-holding costs (e.g., capital, storage, handling, insurance, obsolescence), costs related to poor quality (e.g., rejection, rework, downtime, and warranties), or costs related to delivery failure to customers (Carr and Ittner 1992;

[5] Some early studies on how decision makers use financial and nonfinancial information include Blocher et al. (1986), Iselin (1988), Shields (1980, 1983), Shields et al. (1981).

Ellram 1995b). Activities that are part of the scope of TCO should involve not only routine activities of the purchasing department (such as ordering items and making payments) but extend to more strategic activities of purchasing (such as supplier selection, developing relationships with important suppliers, participating in new product development). Furthermore, TCO activities occur within the purchasing department as well as in other departments (Armstrong 2002). As in activity-based costing, cost drivers can be at various levels, such as unit level (e.g., purchase price, quality control cost when each item must be inspected), batch level (e.g., costs of creating a purchase order, inspecting an order received), supplier sustaining level (e.g., cost of identification and certification of a supplier), and product or part sustaining level (e.g., cost of maintaining technical information on purchased parts).

Like all costing information, TCO is almost always an imperfect representation of the underlying decision problem, since not all aspects involved can be quantified perfectly in formalized, financial numbers (Galbraith 1973). Accounting information is an abstract and incomplete translation of real life processes and decision problems into numerical form (Chapman 1997). Some of the attributes of alternative offerings are not included in TCO systems, or are inaccurately included. For example, it may be that choosing a better quality supplier leads to lower costs for scrap, labor, inspection, and warranty, but the cost accounting system may not be able to accurately trace all these cost savings to that particular offering. It could be that, for example, only material, scrap, and labor costs savings are traced to products, while lower costs for inspection and warranty are shown at a higher level, such as overhead costs for the total plant. Previous studies have investigated, for example whether more accurate product costing information improves production output decisions (Briers et al. 1997), and whether more accurate customer profitability analysis reports are useful in a marketing resource allocation task, even if managers have access to other information (Cardinaels et al. 2004).

In this chapter we investigate the effect of providing TCO information on decision weights in a multi-attribute sourcing decision when some attribute information is compounded (versus not compounded) into the TCO number. Consider the example in figures 2.1a and 2.1b, which will also be used in the experiments. A sourcing decision requires choosing between two alternative machines. For each, information on four attributes is provided: lifetime, uptime, purchase price, and energy consumption. The total cost of ownership calculation (in terms of total cost per hour) is straightforward for purchase price and energy consumption. The cost implications of downtime are typically much harder to determine and may very well be left out of the TCO calculation, as shown in Figure 2.1. Will the attribute that is not included in the TCO calculation—uptime in this example—receive more, equal, or less weight when the TCO calculation is provided, compared to when no such information is provided?

Figure 2.1 Information provided for multi-attribute decision-making in experimental task

2.1a no TCO info provided, complexity low

	Brand A	Brand B
Life time (hours)	2,900	2,800
Uptime (%)	99.0%	96.0%
Purchasing price (€)	€ 1,280	€ 1,020
Energy per hour (Kwh)	2.0	2.2

2.1b TCO info provided, complexity low

Energy cost (Kwh) € 0.13

	Brand A	Cost per hour	Brand B	Cost per hour
Life time (hours)	2,900		2,800	
Uptime (%)	99.0%		96.0%	
Purchasing price (€)	€ 1,280	€ 0.44	€ 1,020	€ 0.36
Energy per hour (Kwh)	2.0	€ 0.26	2.2	€ 0.29
Total cost per hour		€ 0.70		€ 0.65

2.1c no TCO info provided, complexity high

		Brand A	Brand B
Life time (hours)		2,900	2,800
Uptime (%)		99.0%	96.0%
Purchasing price (€)	Component A	€ 760	€ 560
	Component B	€ 170	€ 190
	Component C	€ 250	€ 160
	Component D	€ 100	€ 110
Energy per hour (Kwh)		2.0	2.2

2.1d TCO info provided, complexity high

Energy cost (Kwh) € 0.13

		Brand A	Cost per hour	Brand B	Cost per hour
Life time (hours)		2,900		2,800	
Uptime (%)		99.0%		96.0%	
Purchasing price (€)	Component A	€ 760	€ 0.26	€ 560	€ 0.20
	Component B	€ 170	€ 0.06	€ 190	€ 0.07
	Component C	€ 250	€ 0.09	€ 160	€ 0.06
	Component D	€ 100	€ 0.03	€ 110	€ 0.04
Energy per hour (Kwh)		2.0	€ 0.26	2.2	€ 0.29
Total cost per hour			€ 0.70		€ 0.65

The effect of TCO information on decision weights may depend on the decision strategy that decision-makers follow. We will discuss two different strategies: one implying that decision weights of the excluded attributes will increase as a result of providing TCO information, and the other implying that the weights will be reduced. We will then discuss complexity and experience as moderating variables.

Accounting numbers, such as TCO, are often a meaningful basis for categorization. Consequently, a first possible decision strategy could be to categorize the attributes that are compounded in the TCO number as one perceptual unit, and to make a tradeoff with the excluded attributes. Categorizing information reduces information load and information diversity by combining information in categories that are meaningful to the decision maker. Ignoring the compounded attributes reduces information load, while the combined TCO number is obviously still meaningful to the decision maker. This allows decision makers to focus on the category as a whole, rather than on the individual items within the group (Lipe and Salterio 2002). Accounting numbers, such as TCO, are often a meaningful basis for categorization. Within the category of attributes that are included in the TCO calculation, the provision of TCO information closely simulates a compensatory evaluation process. The few attributes that are not included will stand out and be more salient. At the extreme of such an evaluation process would be the equal weight heuristic (Dawes 1979; Einhorn and Hogarth 1975) giving the lone nonincluded attribute about the same weight as the TCO number compounding all other attribute information. The implication is that the relative weight of the attributes that are not included in the TCO number increases, compared to a situation of not providing the TCO information.

A second, alternative, evaluation process would be if decision-makers evaluate the relevance of attribute information on the basis of their inclusion in the "bottom-line" TCO number. Consequently, they would use primarily or exclusively the TCO number to compare the options. This decision strategy makes comparison and choice easy, because it avoids making a tradeoff between attributes on different dimensions. There is only a tradeoff between attributes that are on the same financial dimension, and this tradeoff is captured in the TCO information and readily provided to the decision-maker. This is a "tempting" heuristic, because it is cognitively less demanding and because it is based on financial quantification, which is a particularly persuasive type of analysis (Kadous et al. 2005) and carries much weight in decisions (Schiff and Hoffman 1996; Schiff and Bento 2000; Reck 2001; Ittner et al. 2003). If decision makers focus on the overall TCO number per alternative and more or less ignore attribute information that is not included in the "bottom-line" TCO number, then a lower weight for the non-included attribute would result.

Decision makers tend to adjust their strategies to the requirements of the decision task (Payne et al. 1993). In the TCO setting discussed here, we suggest that the decision strategy will depend on the persuasiveness of the provided TCO information. The first decision strategy considers more of the available information and is more difficult compared to the second, because it is compensatory and requires a tradeoff between TCO information and other attributes. The second decision strategy is a mix of compensatory and non-compensatory elements. However, the compensatory element is in the TCO number and it requires no effort on the part of the decision maker. From the perspective of a decision maker who adjusts the heuristic to the decision task, the second heuristic is essentially non-compensatory.[6] In the setting discussed here, using only or primarily the TCO number (the second decision strategy) becomes more attractive as the amount of information apparently summarized by the TCO number becomes larger, as it suggests that the TCO number is more comprehensive. Hence, we expect that the second decision strategy is more likely to be adopted when the number of attributes for which information is provided is larger and the TCO number incorporates more information. The number of attributes for which information is provided is labeled Complexity in this study.

The arguments presented above can be summarized in the following hypotheses regarding an interactive effect of complexity and TCO information:

H1: Providing the decision maker with TCO information of alternatives, increases the weight of an attribute that is not included in the TCO calculation, for low decision complexity.

H2: For high decision complexity, providing the decision maker with TCO information of alternatives reduces the weight of an attribute that is not included in the TCO calculation.

Experience is also a factor we expect to influence the results. For multi-attribute sourcing decisions in a business setting, decision makers with less business experience may respond differently compared to decision makers with more experience. It is, however, difficult to formulate a directional prediction, as will be discussed below. Experience implies not only expertise in executing a particular task, but also mere familiarity with the task (Alba and Hutchinson 1987). While more expertise may enable a decision maker to use a more advanced decision strategy (compared to a decision maker with less experience), more familiarity may at the same time lead decision makers to routinely apply a decision strategy that they are used to, and to be less mindful about whether a particular decision strategy is appropriate for the specific task (Cohen et al. 1972).

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[6] Note that we use "non-compensatory" more generically to indicate a judgment process that does not consider all relevant information, or introduces information sequentially, based on salience, and only to the extent that information already introduced does not allow a decision. In this sense, ignoring uptime and using only the attribute information included in the TCO number is a non-compensatory strategy. We are not referring to specific rules such as conjunctive or a lexicographic rule as they are described in the literature.

Previous research in management accounting, auditing and consumer research has, indeed, found benefits of experience in judgment and decision-making tasks (Dearman and Shields 2001). More experienced decision makers are better able to use complex information (large amounts, diverse attributes, incomplete, etc.) under difficult circumstances (time pressure, accountability, etc.) compared to less experienced decision makers (Bonner and Lewis 1990; Frederick 1991; Dorsey et al. 1999; Herz and Schultz 1999; Libby 1995; Spilker 1995; Shelton 1999; Vera-Muñoz, Kinney et al. 2001).

Yet, there is also empirical evidence for detrimental effects of experience, resulting from a lack of fit between the knowledge structures recalled from memory and the given problem situation (Bédard and Chi 1992; Nelson et al. 1995). For example, Vera-Muñoz (1998) found that for resource allocation decisions, decision makers with high accounting knowledge were more likely to ignore opportunity costs than decision makers with low accounting knowledge, because such knowledge may lead people to construct a problem representation based on their knowledge of GAAP-based rules that do not generally incorporate opportunity costs.

In our study, Experience does not relate to specific, technical accounting knowledge (as in many other accounting studies investigating experience, including those cited above), but pertains to "professional experience" that leads to understanding of operations, technology, and of the usage of cost information in organizations. It is gained not so much through instructions and experience in a specific domain, but more through work experience in organizations, reading and education in general, and all kinds of individual life experiences (Bonner and Lewis 1990). In one of few studies investigating a similar kind of experience Bonner and Lewis (1990) found that general experience explained less than 10% of the variance in performance scores in an experimental audit task.

We do not formulate a directional hypothesis for the effect of professional experience. Below we consider arguments for both directional possibilities. On the one hand, someone with more professional experience may also more often have seen in organizations that accounting numbers do not "tell the whole story." Some considerations are more subtle. They may rely on experience, gut-feel, instinct or some other subjective source. They may be ambiguous (but important, somehow), or they can be explained to-the-point in words, but not in terms of monetary, or any, quantification. The richness of some of these considerations may be getting lost in the process of quantification and translation into a monetary unit of measurement (Galbraith 1973; Chapman 1997). People with more professional experience may appreciate more that such other considerations are sometimes very relevant for decision-making, and they may therefore be more inclined to pay attention to arguments outside the economic calculation. They may be more open to the notion that important considerations sometimes need to enter the decision-making process through other means than accounting numbers. More experienced subjects are likely to better understand the limitations of accounting numbers than students. With such an effect of professional experience, more experienced participants would be more likely to still pay attention to an attribute that is not included in the TCO number, and, as a consequence, results for more experienced participants would provide more support for H1 and less support for H2.

On the other hand, we expect that someone with more professional experience has more often encountered work situations in organizations in which the seemingly "objective" facts get all the attention. For example, more experienced auditors are better able to select information that is more likely to provide explanations for audit findings, and they are less influenced by irrelevant information, compared to less experienced decision makers (Libby and Frederick 1990; Waller Shelton 1999). We expect discussions to center on numbers, particularly on financial numbers; and more subtle, nuanced considerations are taken less seriously and not discussed in great detail. More experienced participants are more likely to understand the persuasiveness of the TCO information for decision-making in organizations, and to read the TCO information as a signal of the importance of cost, especially when the TCO calculation incorporates more individual information items (high complexity condition). Usage of TCO may be even more reasonable considering that TCO is not a standard, automatically-produced calculation. It is presumably produced because top management wants it to be used for decisions—and it presumably includes what top management thinks it is important to include. More experienced individuals are likely to be more aware of this organizational context than students. Therefore, more experienced participants would be more likely to pay much attention to the "bottom-line" TCO number and less to an attribute not included in the TCO number. As a consequence, results for more experienced participants would provide more support for H2 and less support for H1.

The discussion above points to an interactive effect of complexity, TCO information, and experience. Although the effect of experience is an open question, for clarity we summarize the discussion in two opposing hypotheses:

H3a (H3b): For low complexity: Providing the decision maker with TCO information of alternatives, increases the weight of an attribute that is not included in the TCO calculation, and this effect is stronger (weaker) for more experienced decision makers.

For high complexity: Providing the decision maker with TCO information of alternatives reduces the weight of an attribute that is not included in the TCO calculation, but this effect is weaker (stronger) for more experienced decision makers

2.3 Research method

In the experiments, participants were asked to make a purchasing decision. Participants received information about two brands of a machine. They were asked to compare both brands and to decide which brand they would purchase. Incentives did not play a role in this study and no information was provided about reward structures related to this purchasing task. For both brands, they received information on lifetime, uptime, purchase price, and electricity usage. The dependent variable is the choice for Brand B, a dichotomous variable (*Choice B*). We conducted two experiments with a total number of 1,028 participants. In the first experiment, we included conditions for low and high complexity; in the second experiment, we collected additional data for the low-decision complexity conditions.

The experiment used a 2 × 2 × 2 between-participants design while adding experience as a measured variable. The first manipulated factor was the availability of total cost information (*TCO info*), which is a dummy variable: see Figure 2.1a for the information provided without total cost data. Figure 2.1b shows the information including total cost data, which centers on the total cost per hour of each option, based on the lifetime, purchase price and energy consumption. The total cost number did not include costs associated with the expected uptime of each brand, so “uptime” is the attribute that is not included in the costing system.[7]

The second factor was the uptime percentage of Brand B (*Uptime B*). For half of the participants in each experiment the uptime percentage of option B was set at 99.5%. For the other half, this was set at 96.0%. The interaction of the two independent variables *TCO info* and *Uptime B* allows testing the first two hypotheses. Note that the preference for Brand B is expected to decrease as the uptime of Brand B decreases. If the preference for Brand B decreases more strongly in the TCO condition compared to the condition without TCO, then uptime (the attribute not included in the costing system) has a higher weight in the TCO condition compared to the non-TCO condition. Logistic regressions will be used with the following specification:

$$\textit{Choice B} = \beta 0 + \beta 1\ \textit{TCO info} + \beta 2\ \textit{Uptime}\ \text{B} + \beta 3\ (\textit{TCO info} \times \textit{Uptime B}).$$

[7] We tested whether participants correctly understood this information, in particular that no cost consequences of downtime were included in the TCO number. A sample of practitioners and students was asked, after completing the task, to provide a short written explanation of how two components of the TCO number were calculated; 86% of the answers treated uptime correctly in the calculation. An additional 4% of the calculations were not correct but it still demonstrated that the participant understood that uptime is not fully considered in the provided TCO information.

If the coefficient for the interaction of *TCO info* and *Uptime B* is statistically significant and positive, then the effect of Uptime B on the dependent variable Choice B will be stronger if TCO information is available compared to when there is no TCO information available. A negative coefficient indicates a lower weight.

The third factor was the level of complexity of the information provided (*Complexity*). The low-complexity condition was as described above, while in the high-complexity condition the number of attributes per option was increased by splitting the purchase price into four components. Instead of providing one purchase price of € 1,280 for brand A, the prices of four separate components were given (€ 760, € 170, € 250, € 100) without giving the total purchase price, and this translated into four numbers in the TCO condition. The purchase price for brand B was separated in a similar way. See Figures 2.1c and 2.1d for the information provided in conditions of high complexity, without and with *TCO info*.

Participants were either students or practitioners, and this difference will be used as a measured independent variable (*Experience*). Student participants (N = 444) were undergraduate business students, who had had at least introductory courses in accounting and finance. They completed the task anonymously, at the end of a session in the lab during which they performed several experimental tasks, or after a session in which they worked on questions for an examination. They were not paid for participation. Practitioners (N = 373) were contacted at professional trade fairs for industrial production and agricultural equipment, and also during a meeting of production and maintenance engineers. They had an interest in technology and engineering, and they were users of cost accounting information in organizations. The median year of birth of all practitioner participants was 1961, and their median budget responsibility (of those who provided this information) was € 1,000,000. The participants completed the task anonymously, in the presence of the researcher, and in the same room in which the participant had been contacted. The practitioner participants were not paid for participation, nor did they receive any other extrinsic reward; they participated for the sake of advancing a young researcher's project, who personally approached them.[8]

After we ran the experiment described above (for low and high complexity), we conducted a second experiment for the low-complexity conditions. A total

[8] Visitors of these trade fairs were asked if they were willing to answer a short question for a research project, which would only take a few minutes. A participant received a pen and one sheet of paper clamped on a clipboard with the experimental task on one side, and background questions about the participant on the other side. The participant completed the task and answered the background questions in the presence of the researcher, and this took place at a quiet spot in the same room in which the participant had been contacted. If requested, the researcher explained the research project after completing the task. Each person participated only once and was randomly assigned to an experimental condition. From our observations, we have the distinct impression that participants attended seriously to the task.

number of 141 students and 70 practitioners participated in this second experiment. Students and practitioners had the same background and characteristics as participants in the first experiment.[9] They participated under similar conditions as participants in the first experiment. In Table 2.1 the number of participants (N = 1,028) in each condition is specified.

Table 2.1. Number of participants choosing brand B (between parentheses) and total number of participants, for each condition

Low complexity

TCO info		No TCO		TCO	
Experience		Students	Practitioners	Students	Practitioners
Uptime B	96.0%	57 (6)[1] 39 (7)	41 (6) 20 (3)	55 (15) 35 (11)	48 (16) 16 (7)
	99.5%	64 (30) 34 (14)	47 (21) 16 (12)	54 (49) 33 (30)	47 (33) 18 (12)
	Total	194	124	177	129

[1] Top figures indicate # participants in the first experiment (and # participants choosing brand B), and bottom figures indicate # participants in the second experiment (and # participants choosing brand B).

High complexity

TCO info		No TCO		TCO	
Experience		Students	Practitioners	Students	Practitioners
Uptime B	96.0%	61 (13)	48 (5)	54 (15)	46 (20)
	99.5%	53 (31)	46 (24)	46 (44)	50 (32)
	Total	114	94	100	96

The information was provided on paper.[10] Each participant made only one decision. Participants received an introduction (which was identical in all conditions, see figure 2) and the information specific to their experimental condition. The introduction and the task were tested first in a pilot with 21 students and 5 practitioners for qualitative feedback on the task, and then in an

[9] The median year of birth of the practitioners in the second experiment was 1962, and their median budget responsibility was € 3,191,617. A t-test indicated no differences between the mean year of birth and mean budget responsibility for the practitioners in the first and second experiment.

[10] With some international participants we used an English version of the experimental task. To check the translation, the task was translated from Dutch to English and then translated back to Dutch independently by two people who had not been involved in the first translation. The translation was similar to the original formulation.

experiment with 321 students to test different levels of uptime in the experimental task (99.5, 99.0, 98.0, and 96.0%).[11]

Figure 2.2 Text introducing the experimental task

You are the manager of a production department. One machine has to be renewed. You can choose between two brands, both meet all specifications.

In the table below information is provided about: the purchasing price of a new machine, the lifetime of a new machine, energy consumption per hour, and the uptime percentage of the machine. The 'uptime (%)' is the percentage of the time the machine is available for production. 100% – 'uptime (%)' = 'downtime (%)'. Downtime is caused by machine failure, maintenance, etc. that cause rescheduling of production, not meeting delivery times, etc.

Table with information about the alternatives.

Indicate which brand you will buy:_____

2.4 Results

To investigate H1, we analyze the results for the low-complexity condition with all participants. We expect that the impact of uptime on the preference for brand B is stronger with TCO info compared to without TCO info. This effect is statistically tested using logistic regression. The coefficients for the interaction term of *Uptime B* and *TCO info* are positive (as predicted), but not significant (p = .312 and p = .462); see column (1) in Table 2.2.

However, if we analyze the results for students and practitioners separately, we find differences between the two groups. Figure 2.3a suggests that for students the weight increases as a result of providing TCO information, while for practitioners the weight is the same with or without TCO in the first experiment, and providing TCO may reduce the weight in the second experiment. Indeed, the coefficient for the interaction of *Uptime B* and *TCO info* is positive for students and (marginally) significant (p = .096 and p = .031)[12] and this coefficient is not significant for practitioners in the first experiment (p = .999) and marginally significant, but negative, in the second experiment (p = .088) (see column 1a and

[11] During the main experiment it was also tested whether another ordering of attributes, with uptime as the last attribute, influenced the outcomes. We included a condition with this alternative ordering (with students, low complexity, 119 participants). Results (not tabulated) showed that none of the interaction terms that included "order" had significant coefficients.

[12] A joined analysis of the results for the first and second experiment (N = 371) indicated that the coefficient for the interaction Uptime B by TCO info is significant (p = .007) for low complexity.

1b in Table 2.2).[13] In all, these results show support for H1 for students, but not for practitioners. Finding stronger support for H1 for student participants than for practitioner participants is consistent with H3b.

[13] The pilot experiment gave similar results. This involved only students and low complexity. The coefficient of the interaction term *TCO info* × *Uptime B* was positive and statistically significant at p = .056.

Table 2.2 Logistic regression results of experiments with students and practitioners

	(1) Low complexity		(2) High complexity	(1a) Low complexity, Students		(1b) Low complexity, Practitioners		(2a) High complexity, Students	(2b) High complexity, Practitioners
	N = 413[1]	N = 211[2]	N = 404[3]	N = 230	N = 141	N = 183	N = 70	N = 214	N = 190
Constant	-51.531[4]	-47.375	-52.189	-57.406	-33.423	-44.278	-79.446	-46.541	-63.558
	(.000)	(.000)	(.000)	(.000)	(.028)	(.003)	(.001)	(.000)	(.000)
Uptime B	51.626	47.694	52.675	57.569	33.233	44.286	80.949	47.120	63.965
	(.000)	(.000)	(.000)	(.000)	(.032)	(.003)	(.001)	(.000)	(.000)
TCO info	-12.534	-12.109	-2.027	-33.080	-51.912	1.054	53.289	-65.405	40.318
	(.363)	(.504)	(.876)	(.114)	(.036)	(.957)	(.086)	(.008)	(.039)
Uptime B ´ TCO info	14.230	13.637	3.155	35.666	54.846	.017	-53.964	68.496	-40.030
	(.312)	(.462)	(.812)	(.096)	(.031)	(.999)	(.088)	(.007)	(.044)

[1] The variable Experience was not included for testing the hypothesis. In a specification with also Experience as an independent dummy variable in the logistic regression, the coefficient of the interaction term Uptime B × TCO info applies to either only students or practitioners (depending on the coding). We did estimate a specification including Experience: the three-way interaction term was not statistically significant (p = .221) and neither the Chi-square difference between both specifications (χ^2d = 7.965, df = 4, p = .093).

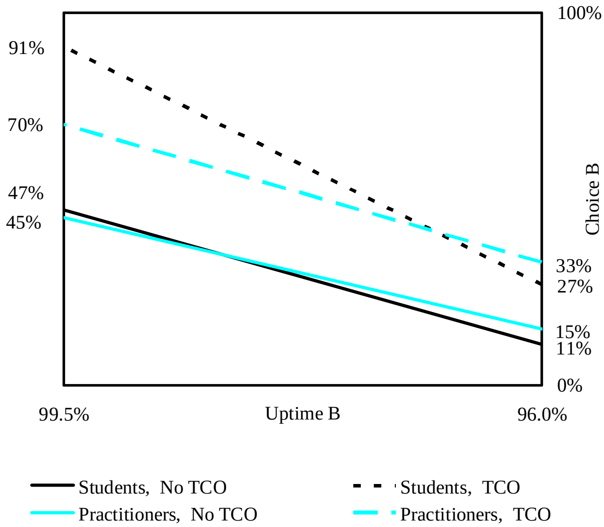
[2] See note 1. The three-way interaction term was statistically significant (p = .007) and the Chi-square difference between both specifications was significant (χ^2d = 10.484, df = 4, p = .033).

[3] See note 1. The three-way interaction term was statistically significant (p = .001) and the Chi-square difference between both specifications was significant (χ^2d = 21.954, df = 4, p = .000).

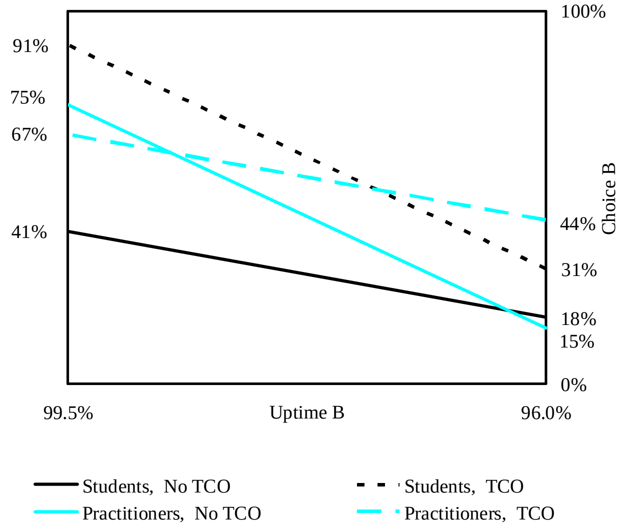
[4] Logistic regressions, values of coefficients (and p-values for two-tailed Wald test).

Figure 2.3 Students versus practitioners

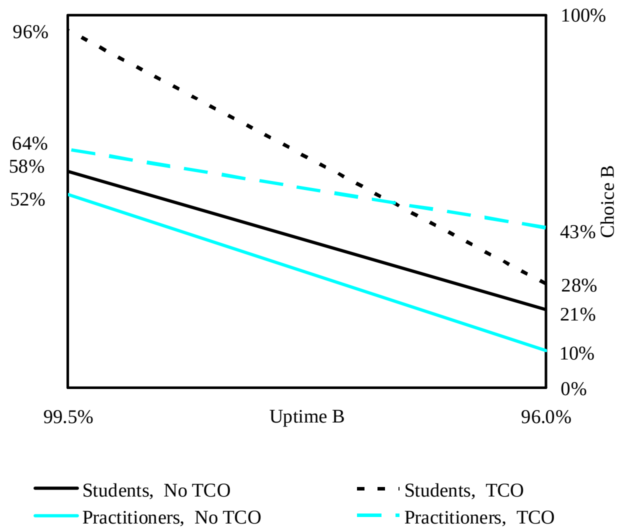
2.3a Low Complexity (N = 413) (First experiment)



2.3b Low complexity (N = 211) (Second experiment)



2.3b High complexity (N = 404) (First experiment)



To investigate H2, the results for high complexity are analyzed. The coefficient for the interaction term of ***Uptime B*** and ***TCO info*** is positive (as predicted), but not significant (p = .812) (see column 2 in Table 2.2). The separate results for students and practitioners in Figure 2.3b and the signs of the coefficients for the two-way interaction terms of Uptime and TCO info in columns 2a and 2b of Table 2.2 show that, for students providing TCO info increases the weight of uptime (p = .007) (contrary to H2), while for practitioners providing TCO info reduces the weight of TCO info (p = .044) (consistent with H2). The fact that for H2, we find stronger support for practitioners than for students is also consistent with H3b.

To summarize the results: H1 was supported for student-participants and not for practitioner-participants. H2 was supported for practitioners, but was rejected for students. Students always gave greater weight to uptime as a result of being provided with TCO info, which is what we expected for low complexity (H1), but not for high complexity (H2). The way in which these findings for H1 and H2 differed between students and practitioners, provided support for H3b, and not for the opposing hypothesis H3a.[14]

2.4.1 Further analysis of practitioner results

The differential results for students and practitioners suggest that that experience may be an important factor in understanding how human decision-makers take cost information into account when making a difficult multi-attribute decision. This will be explored further in this and the next section.

We analyzed results of the first experiment within the group of practitioners to explore whether different levels of experience among practitioners are associated with different weights of cost information in their decision-making.[15] In other words, are practitioners with less experience more similar to students, and practitioners with more experience more different from students? For this analysis we used two demographic characteristics collected from the practitioners: year of birth (***YofB***) and budget responsibility (***Budget***), which was formulated as follows: "How large is the budget for which you are responsible? ___ (€)" For year of birth, 372 participants provided an answer (out of 373), and for budget responsibility 249 participants answered. The data were split in two groups at the median (***YofB*** = 1961 and ***Budget*** = € 1,000,000, respectively). Responses for

[14] We also conducted alternative analyses to correct for multi-collinearity, which did not lead to any different conclusions. Because the categorical variables (Experience, TCO info) were either 0 or 1, we transformed the uptime percentages to uptime hours (e.g., Uptime = 99%, Lifetime = 2,800 hours, Uptime hours = 2,800 × 99% = 2,772 hours), and centered uptime hours as suggested by Cronbach (1987) and Jaccard et al. (1990). Tolerances for the independent variables did not indicate a serious risk on multi-collinearity (always above .20), and results did not change.

[15] Because of the small number of practitioner-participants in the second experiment, only the practitioner results of the first experiment are used here.

YofB and ***Budget*** at the median were allocated such that the differences in the number of observations per subgroup were minimized.[16] Furthermore, there was only one observation in the entire Budget range between € 500,000 and € 1,000,000 and observations from € 1,000,000 onwards were more continuous, which provided another reason to include the responses for € 1,000,000 with the higher budgets.

Results for low complexity (H1), using the ***YofB*** variable, are in Figure 2.4a, which suggests that providing decision makers with TCO information increases the weight for the less experienced but not for the more experienced participants. Table 2.3, column 1, shows that the coefficient of the three-way interaction term (***Uptime B ´ TCO info ´ YofB***) is marginally significant (p = .079), and results for both groups separately are not statistically significant (p = .179; p = .257) (column 1a and 1b). Results using the ***Budget*** variable are comparable; see columns 1, 1a, and 1b in Table 2.4.[17]

[16] Including observations for YofB = 1961 in columns 1b and 2b of table 3, would make the observations more uneven: 86 and 97 for columns 1a and 1b (difference of 11) and 87 and 102 for columns 2a and 2b (difference of 15), giving a total difference of 26 compared to 9 + 3 = 12 in the current table. Including observations for Budget = € 1,000,000 in columns 1a and 2a of Table 2.4, would also make the observations more uneven: 72 and 48 for columns 1a and 1b (difference of 24) and 68 and 61 for columns 2a and 2b (difference of 7), giving a total difference of 31 compared to 4 + 19 = 23 in the current table.

[17] These conclusions remain unchanged when the allocation of observations at the median is changed.

Table 2.3 Further analyses of practitioners results, based on year of birth

	(1) Complexity low, N = 183	(2) Complexity high, N = 189	(1a) Complexity low, YofB ≥ 1961 N = 96	(1b) Complexity low, YofB ≤ 1960 N = 87	(2a) Complexity high, YofB ≥ 1961 N = 96	(2b) Complexity high, YofB ≤ 1960 N = 93
Constant	-38.097	-51.078	-38.097	-49.199	-51.078	-86.551
	(.067)	(.009)	(.067)	(.024)	(.009)	(.006)
Uptime B	38.080	51.430	38.080	49.222	51.430	86.986
	(.071)	(.010)	(.071)	(.027)	(.010)	(.006)
TCO info	-38.239	-11.564	-38.239	32.578	-11.564	97.983
	(.193)	(.671)	(.193)	(.242)	(.671)	(.005)
YofB	-11.102	-35.474				
	(.713)	(.335)				
Uptime B ´ TCO info	40.383	12.677	40.383	-32.141	12.677	-98.571
	(.179)	(.647)	(.179)	(.257)	(.647)	(.006)
Uptime B ´ YofB	11.142	35.556				
	(.716)	(.340)				
TCO info ´ YofB	70.817	109.546				
	(.080)	(.014)				
Uptime B ´ TCO info ´ YofB	-72.524	-111.248				
	(.079)	(.014)				

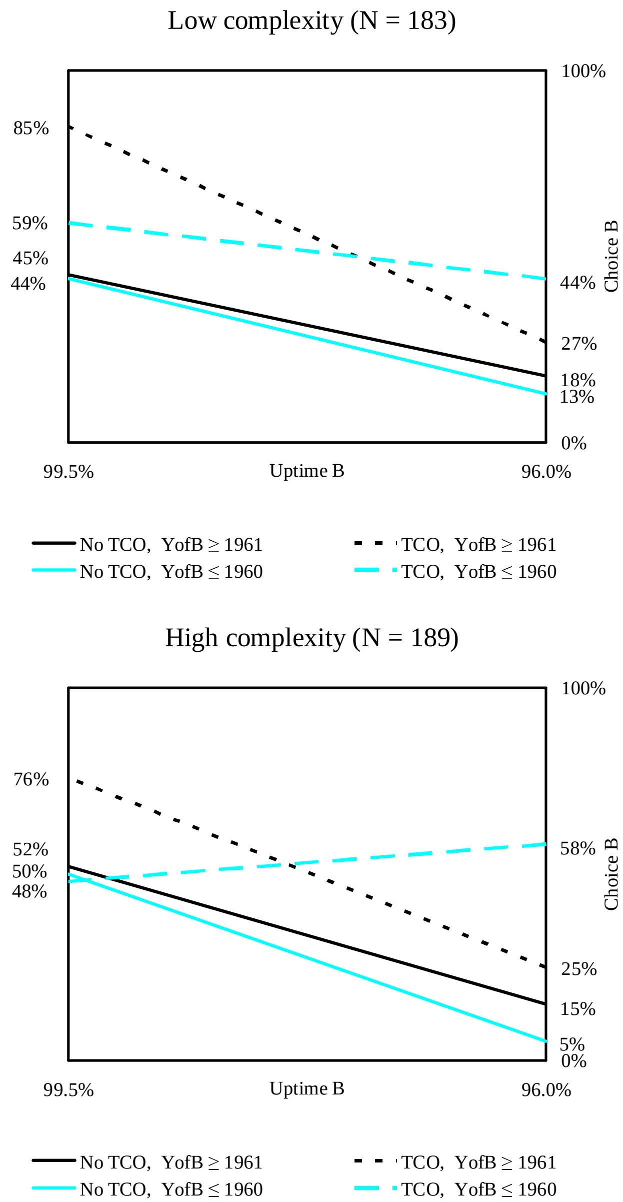
Logistic regressions: values of coefficients and p-values (for two-tailed Wald test) are tabulated. The total number practitioners was 373, and 372 answered the question about their year of birth. The median response was 1961.

Table 2.4 Further analysis of Practitioner results, based on budget responsibility

	(1) Complexity low, N = 120	(2) Complexity high, N = 129	(1a) Complexity low, Budget ≤ € 800,000 N = 62	(1b) Complexity low, Budget ≥ € 1,000,000 N = 58	(2a) Complexity high, Budget ≤ € 800,000 N = 55	(2b) Complexity high, Budget ≥ € 1,000,000 N = 74
Constant	-65.459	-27.569	-65.459	-58.213	-27.569	-64.502
	(.041)	(.244)	(.041)	(.033)	(.244)	(.012)
Uptime B	65.788	27.574	65.788	58.689	27.574	64.960
	(.042)	(.253)	(.042)	(.034)	(.253)	(.012)
TCO info	23.565	-48.500	23.565	-42.091	-48.500	82.334
	(.549)	(.178)	(.549)	(.216)	(.178)	(.010)
Budget	7.246	-36.932				
	(.863)	(.289)				
Uptime B ´ TCO info	-22.499	47.799	-22.499	41.895	47.799	-82.714
	(.573)	(.174)	(.573)	(.228)	(.174)	(.011)
Uptime B ´ Budget	-7.099	37.386				
	(.868)	(.292)				
TCO info ´ Budget	18.526	130.835				
	(.722)	(.006)				
Uptime B ´ TCO info ´ Budget	-19.397	-132.513				
	(.714)	(.007)				

Logistic regressions: values of coefficients and p-values (for two-tailed Wald test) are tabulated. The total number of practitioners was 373, of which 249 answered the question about their budget responsibility. The median response was € 1,000,000, and there were no responses for Budget between € 800,000 and € 1,000,000.

Figure 2.4 Less experienced practitioners versus more experienced practitioners, based on year-of-birth



As formulated in H2, we expect that for high decision complexity, providing the decision maker with TCO information of alternatives reduces the weight of an attribute that is not included in the TCO calculation. Results for high complexity, first using the *YofB* variable, are in Figure 2.4b and Table 2.3. For less experienced participants, there appears to be no effect of providing TCO info on the weight of uptime (parallel lines) (no support for H2), while for more experienced participants the weight of uptime decreases when TCO info is provided (support for H2). The coefficient of the three-way interaction term is statistically significant (column 2, p = .014). Results for the two groups separately indeed show that the coefficient of the two-way interaction term (*Uptime B ´ TCO info*) is not significant for less experienced participants (p = .647) (column 2a), but it is statistically significant for more experienced participants (column 2b, p = .006).[18] Results for the Budget variable are similar; see columns 2, 2a, and 2b in Table 2.4.[19]

These results based on *YofB* and Budget provide complementary support, because both ways of dividing practitioner participants produced quite differently composed subgroups of less and more experienced participants: 111 individuals (of the 249 for which both *YofB* and Budget data were available) were allocated to another sub-segment of less vs. more experienced practitioner participants based on Budget compared to *YofB*. Still, as reported above, results for both analyses mirror each other.

The results are summarized in Table 2.5. The further analysis of results within the group of practitioners provided no additional insights for H1. There was no support for this hypothesis for any of the subgroups identified within the practitioners that participated. However, some interesting findings related to H2 were revealed. Results for the more experienced practitioners provided strong support for H2 (as we found for practitioners overall), while results for less experienced practitioners were not statistically significant. This suggests that experience is a key factor in understanding the use of cost information in complex multi-attribute decisions: H2 was supported for the most experienced subgroup of practitioners, results were not significant for the less experienced practitioners, and H2 needed to be rejected for students. This pattern of stronger support for H2 and weaker support for H1 as participants are more experienced is consistent with H3b, and not with the opposing hypothesis H3a.

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[18] These conclusions remain unchanged when the allocation of observations at the median is changed.

[19] These conclusions are not significant when the allocation of observations at the median is changed.

Table 2.5 Summary of findings

	All participants	Students	Practitioners	Less experienced practitioners YofB ≥ 1961	More experienced practitioners YofB ≤ 1960	Less experienced practitioners Budget ≤ € 800,000	More experienced practitioners Budget ≥ € 1,000,000
H1	No support	Support	No support	No support	No support	No support	No support
H2	No support	Rejected	Strong support	No support	Strong support	No support	Strong support
H3	This pattern of weaker support for H1 and stronger support for H2 as participants are more experienced is consistent with H3b, and not with the opposing hypothesis H3a.						

2.5 Further discussion of practitioners versus students results

The results suggest that *Experience* is an important moderating variable for understanding how decision makers use accounting information that monetizes and aggregates nonfinancial attributes. In fact, this may be more important in our results than the level of complexity. Figures 2.3 and the results in Table 2 indicate that participant behavior in the low-complexity settings did not differ markedly from their behavior in the high-complexity settings. For students, the coefficient of the interaction term of *Uptime B* and *TCO info* was always positive and (marginally) significant ($p = .096$, $p = .031$, $p = .007$, respectively). For practitioners, the coefficient of the interaction term of *Uptime B* and *TCO info* was either close to zero or negative and (marginally) significant ($p = .999$, $p = .088$, $p = .044$, respectively).

Note also that when TCO information was provided, students chose B almost exclusively (91%, 91%, 96%), while practitioners' preference for B was smaller (70%, 67%, 64%). These results are surprising, because the provision of TCO information explicates that alternative B dominates alternative A in those conditions: uptime of B is better (99.5% versus 99.0%) and total cost per hour is lower (€ 0.65 versus € 0.70). We suggest that this may be understood as further support for the motivation underlying H3b: TCO may be a signal that is particularly salient to practitioner participants that attributes included in the TCO number are more important than attributes not included in that number. This would be consistent with the observation that on the left-hand side of figures 3a and 3b practitioners did not always chose Brand B, although it dominates Brand A, in the following way: The attribute of lifetime was accounted for in the calculation of the total cost per hour, and we found that participants understood this calculation correctly.[20] However, it may be that practitioners still considered the difference in lifetime, if they saw the difference as an indication of the importance of this attribute (because it was included in the TCO number). Hence, the lifetime attribute may still carry a weight in the practitioner's decision-making. Uptime is not included, and this might be taken as a signal that it is less important. Then alternative B would not dominate A, because it was better on two attributes (uptime and total cost per hour), but not on lifetime. This may explain why practitioners on the left-hand sides of Figures 2.3a and 2.3b when presented with TCO information did not overwhelmingly chose B, as students did.

We presented the experimental task to a group of 18 practitioners during a meeting of a professional association of engineers working in production and maintenance management. The participants completed the experimental task and afterwards the researchers asked them to reflect on the task and on comparable decisions in their own organizations. The ensuing discussion was recorded and later transcribed. The exploratory impression emerging from this discussion is that the availability of TCO information shifts attention from uptime to costs. When discussing the task without TCO information, participants commented predominantly on uptime as the dominant criterion. (One participant worked in an environment where energy costs were a main cost, so he gave special attention to electricity usage.) However, when discussing the task with the provision of TCO information, the participants articulated the overriding importance of costs and factors that could be translated into costs. They also described that other so-called "nonfinancial" considerations may be considered earlier, as constraints that impact which set of alternatives is subsequently compared in terms of costs. Student participants do not have this practitioners' knowledge and may have attached relatively less weight to the TCO information and the lifetime attribute, compared to the experienced participants. Results show a consistent pattern within

[20] Life time (in hours) was the denominator in the purchase price per hour calculation, and this was intended to incorporate the cost differences due to different lifetimes. In principle, differences in life time could also have other economic consequences. For example, an asset that lasts one year and an asset that lasts five years pose significantly different risks and thus impose different costs on owners that are not included in a TCO calculation like this. Of course, the difference in lifetime between the two assets in the experiment was small (2,800 vs. 2,900 hours) and should not make much practical difference. Furthermore, the pilot-test provided no indications that participants would suspect other economic consequences of this small difference, and neither did practitioners at the meeting of production and maintenance engineers (referred to on pages 14 and 21) make remarks about the (possible) consequence of the small differences in life time. So we did not conduct further tests of whether participants might have thought that these different lifetimes would also have other consequences. We did test whether participants understood correctly how the TCO calculation incorporated the difference in life time. Students (N = 43) and practitioners (N = 24) were asked to explain the calculation of the purchase price per hour, as provided in the experimental task. Results indicated that 94% of the participants showed they correctly understood that life time was in the denominator of the calculation of the purchase price per hour.

the practitioners' results: less experienced practitioners are more similar to students than more experienced practitioners are.

These results are especially interesting if we observe the findings by Snijders et al. (2003) and Tazelaar and Snijders (2004). They studied purchasing managers' ability to judge the likelihood of problems in purchasing transactions. One of the tasks in purchasing is to assess how much attention should be given to particular purchasing transactions. After all, purchasing transactions should not be generalized; some transactions may ask for more attention (e.g., better-detailed contracts, more screening), compared to other transactions. Purchasers should be able to judge the likelihood of problems resulting from purchasing transactions. Being unable to judge the likelihood of occurring problems may result in high costs.

The researchers used data from a large database with real purchasing transactions. Therefore, they knew if and what problems occurred for each of the purchasing transactions in the experiments. The researchers constructed vignettes (i.e., experiments) using the database. The independent variables were fourteen cues (i.e., independent variables) describing information relevant to evaluate the occurrence of possible problems after the transaction (i.e., information about the product, the supplier, the buyer, and ex ante purchasing management information). These cues were presented to participants who had to evaluate these cues and assess the likelihood of a problematic transaction (on a 100-point scale) and tick were appropriate the problems they expected most likely to occur (i.e., late delivery, over price/budget, incorrect specifications upon delivery, inadequate documentation).

The researchers were especially interested in the impact of experience on purchasers' ability to evaluate the likelihood of problems. To do this they compared the answers of the participants to a prediction made by a simple regression formula. The general question was whether more experience would result in a better ability to judge the likelihood of problematic purchasing transactions. Comparable studies in clinical and statistical research (although in a different field) found superior effects of simple formulas over humans; experts are hardly ever better (and actually often worse) able to predict the likelihood of occurrences, compared to a simple statistical formula. Snijders et al. (2003) and Tazelaar and Snijders (2004) constructed a simple regression formula by using (a number of) the independent variables used in the vignettes. In line with the previous research findings, a simple regression formula outperformed purchase managers; the formula was better able to predict the likelihood of the occurrence of purchasing transaction problems, compared to the human participants.

In contrast to our results, they found no effects of experience, experience did not seem to drive their results; more experienced managers did not outperform less experienced managers, and managers did not outperform students.[21] However, for a sub-group of experienced purchasing managers, they even found some evidence for detrimental effects of more experience. However, comparing our results to the results found by Snijders et al. (2003) and Snijders and Tazelaar (2004) is complicated; their studies differed in several respects from our study. First, we transformed attributes with different dimension to one monetary dimension; they did not. This difference may considerably influence the decision-making process and the weight decision makers attach to specific attributes. After all, financial information is persuasive in an organizational context and likely to receive much attention (Kadous et al. 2005). Hence, monetary quantifying attributes, as we did in our study, is likely to lead to different results. Second, we were not able to assess the correctness of the outcome; they were. Third, we asked participants to evaluate one purchasing decision; they asked participants to answer questions for a series of purchasing transactions. Fourth, we asked decision makers to choose between sourcing alternatives; they asked participants to evaluate one purchasing transaction.

2.6 Conclusions

Alternative purchasing options can be described by several attributes. Some are financial in nature; other attributes describe quality or functionality. Deciding which option to choose involves multi-attribute decision-making, and this is cognitively challenging for human decision-makers. They adjust their decision strategies to the complexity of the particular decision they have to make. More complex decisions require decision strategies that reduce the complexity to a level that human decision makers can handle. TCO information may be used for this purpose.

We looked at decisions where participants, in an experimental setting, had to choose between two alternative purchase options (“Brand A” or “Brand B”) that were both characterized by four attributes. In one half of all conditions, TCO information showed the total cost per hour on basis of three of the four attributes. We investigated the weight of the attribute that was not included as a result of providing the decision makers with TCO information. When given TCO information, would participants primarily look at the TCO numbers and pay less attention to the not-included attribute (“ignore” strategy), or would they rather tradeoff the TCO information against the non-included attribute and, hence, give more weight to that attribute (“tradeoff” strategy)? The “tradeoff” strategy is more difficult than the “ignore” strategy. Therefore when complexity is low we expected that the “tradeoff” strategy would be used and the weight of the not-

[21] Also in an experimental study on trust and willingness to cooperate in purchasing relations (Snijders et al. 2000), no differences were reported between students and purchasing managers.

included attribute would increase (H1). When complexity is high, however, the decision strategy needs to be adjusted and we expected participants to use the less complex “ignore” strategy, leading to a lower weight of the not-included attribute as a result of providing the decision maker with TCO information (H2).

For low complexity (H1), the hypothesis was not supported by the results for all participants. However, separate analyses showed support within the student group and no support for practitioners. Within in the group of practitioners, neither the results for the less experienced, nor for the more experienced subgroup were significant. For high complexity, results supported H2 for practitioners as a whole, and particularly for the most experienced subgroup of practitioners; results were not significant for the less experienced practitioners; and H2 was rejected for students.

The consistency in this pattern is remarkable. Taken together, the results strongly suggest that experience is an important determinant of the use of TCO information in complex multi-attribute decisions. They also suggest that experienced decision makers, when provided with TCO information, become more likely to give a lower weight to attributes that are not compounded in the TCO calculation. The bottom line is that, as summarized in H3b, experience may lead decision makers to focus more on TCO as the overall decision criterion and to be less sensitive to the incompleteness of such information.

The results of this study may have managerial implications for the introduction and use of TCO information, and other costing information that better captures the indirect costs of cost objects, but at the same time leaves out some important characteristics of these objects. Improved costing information that captures financial impact and aggregates financially quantifiable attributes may be helpful for the decision maker, but care should be given to unintended affects—that those elements that are not included in the new costing information get less attention as a result of providing the information. This suggests that when introducing such information, it is important that the limitations should be explained clearly to managers. It is probably also important to give a prominent position in costing reports to the excluded attributes. It might also be helpful to organize discussions about the new tradeoffs that are involved and to hold managers accountable for addressing the tradeoffs between financial and nonfinancial considerations.

Several limitations of this study should be mentioned. A limitation is that no quantitative data (e.g., how many seconds it took to make the decision) or qualitative data (e.g., impressions of the load imposed by the task) regarding the decision process where gathered. Another limitation is that the settings in which participants were tested, were not exactly the same for practitioners (at the trade fairs) than for students (in a lab setting). Both were the result of design choices aimed at increasing the number of experienced participants. We were able to involve 443 experienced participants. To achieve this, the task was given on a sheet of paper, so we could convincingly say that it would only take a few minutes (while standing with a notebook computer may raise suspicion about the size of the task). Furthermore, the task was conducted in the same room as where the participant was first approached (rather than going to a separate room, which would take much more time at the large exhibition center). Also, we did not require participants to think aloud or explain their decision. Although this might have given more insights into the decision strategies that participants followed, with such a more time-consuming design we feel it would not have been possible to have the same high number of participants.

An obvious avenue for future research would be to test cognitive process explanations for the effects we obtained. This would require a research plan in which thought processes are either traced or manipulated, and choices are recorded for the same participants. Only such a design would allow investigating whether and how these thought processes mediate the relationships between the experimental conditions and the participants' choices. A direct examination of the decision making process would be very interesting, and would require a different and much longer experimental task and better control of random environmental noise, probably only obtainable in a lab study with students (or other non-expert) participants.

Furthermore, future research could address other variables that affect decision processes using TCO information, or other ways in which TCO information is not "perfect". And finally, while in this study individual decision-making has been investigated; future research could also investigate the use of imperfect costing information in decisions that are taken in a social context. For example, the weight of attributes not included in TCO information may also depend on the need to justify purchasing decisions to senior management or to obtain support from other functional areas (e.g, Tetlock 1983).

3 Reflective Thinking

In this chapter, we investigate the impact of reflective thinking on the weight decision makers attach to inaccurate total cost of ownership (TCO) information. A "perfectly" accurate monetary quantification of all relevant information into TCO numbers is unrealistic. We conceptualize three different kinds of inaccuracy in TCO numbers, and investigate how reflective thinking and experience influence the weight decision makers attach to the inaccurate included cost numbers.

A total number of 358 participants took part in the experiments. We found support for the hypothesis that reflective thinking increases the weight decision makers attach to the cost number that is included as a minimum in the TCO numbers. The hypothesis that reflective thinking reduces the weight decision makers attach to the as a maximum included cost number was not supported. We found no support for the hypothesis that decision makers attach more weight to the excluded attribute if they reflect on the presented TCO numbers. Students and practitioners differed, however, significantly in the weight they attached to attribute excluded from the TCO numbers. We found no support for the hypothesis that professional experience moderates the effect of reflection. Together these results suggest that TCO numbers should be provided with care and possible inaccuracies should be clarified.

3.1 Introduction

This chapter focuses on comparing alternative supplier offerings when making sourcing decisions, and it investigates how such comparisons can be supported by accounting information. Many different considerations come into play when comparing alternative supplier offerings, and various kinds of data may be available: qualitative information (such as lists of reference customers provided by different suppliers), quantitative non-financial information (such as lead times), and financial information (such as purchase price and discounts). There is no shortage of data available in organizations, but we know that human decision makers cannot consider everything, especially when different kinds of information are involved (Bettman et al. 1998; Bonner 1994). And so there is the temptation to reduce to monetary figures to simplify the task (Kadous et al. 2005). However, that may come at a cost of disregarding factors that may be important, but cannot be financially quantified. In this study, we investigate the challenge for people to consider both types of information in a sourcing decision.

"Total cost of ownership" (TCO) is a term used in accounting for the monetary quantification of all costs associated with acquiring and using a particular purchasing alternative, such as transaction costs related to purchasing activities (e.g., ordering, freight, quality control), costs resulting from poor quality (e.g., rejection, rework, and warranties), or costs related to performance (e.g., inventory, transportation costs) (Carr and Ittner 1992; Ellram 1995b). Degraeve et al. (2005) demonstrate the applicability of TCO in a case study of a manufacturer of electronic products. They compare alternative suppliers of standard electrical components such as resistors, transformers, and printed circuit boards. And based on the quantitative results in this case, they recommend that for reducing TCO, purchasers should evaluate the number of suppliers, the order policy, the quality of the products purchased, and make strict agreement on the delivery times of products.

Monetary quantification is the key element of TCO. Attributes that are initially not expressed in a financial metric are "translated" into financial numbers, and financial data are aggregated into a summary measure (such as the cost per hour, cost per unit, or net present value). As in activity-based costing, cost drivers can be at various levels, such as unit level (e.g., purchasing price, quality control cost when each item must be inspected), batch level (e.g., cost of creating a purchasing order, inspecting an order received), supplier sustaining level (e.g., cost of identification and certification of a supplier), and product or part sustaining level (e.g., cost of maintaining technical product information). Monetary quantification and aggregation is persuasive and likely to have a significant impact on the decision-making processes. A financial metric draws attention, suggests accuracy, is easy to communicate, and makes comparisons of alternatives easy. In one of the few empirical studies explicitly focusing on the persuasiveness of monetary quantification, Kadous et al. (2005) found that it suggests a greater competence of the manager who prepared it and a higher subjective plausibility of a favorable outcome.

However, monetary quantification of non-financial attributes can be problematic, at least for some attributes. Accounting information often does not reflect all operational effects of these attributes (Galbraith 1973; Israelsen 1994; Chambers 1996; Chapman 1997; Lillis 2002) and is in that sense inaccurate. The problems around accurately calculating cost numbers can also be found in the public sector. For example, Skærbæk and Thisted (2004) describe similar problems governmental agencies are facing when allocating and calculating costs. Nonetheless, little is known about decision-making processes that involve the combination of accounting information and other decision-relevant information.[22]

[22] Previous empirical studies in accounting have demonstrated that characteristics of accounting information, decision context, and decision makers have effects on decision-making processes. For example, it was found that complexity and amount of information provided may impact decision-

How much importance will decision makers attach to available and relevant information that is, however, not, or inaccurately, reflected in the financial quantification? This question is relevant for many complex decisions in which accounting information is a key input, but where it cannot encompass every important consideration, such as in capital budgeting decisions, or cost-benefit analyses in public administration.

We conduct two experiments to investigate the impact of reflective thinking and experience on the weight decision makers attach to the attribute that is not or inaccurately included in TCO numbers. The differences between both experiments are shown in Table 3.1. We expect that reflective thinking will stimulate decision makers to process the presented cost information more carefully. As a result, we expect that this will affect the weight decision makers attach to the inaccurate included TCO numbers. The second experiment was conducted with both students and practitioners to investigate the influence of experience on the weight decision makers attach to the attribute excluded from TCO.

Table 3.1 Experiment 1 versus 2

	Experiment 1	Experiment 2
Participants:	Students	Students and Practitioners
Sourcing information:	3 alternatives, described by 6 attributes each	2 alternatives, described by 4 attributes each
Conceptualization of inaccuracy:	Minimum or maximum TCO	One attribute excluded from TCO
Manipulation of reflection:	Participants are motivated to think thoroughly before choosing	Participants have to justify their decision strategy after choosing

We contribute to research in several ways. Firstly, we conceptualize three ways in which monetary information can ignore decision-relevant information.

making strategies (Shields 1980), decision quality (Isselin 1988), and information selection and judgment accuracy (Shields 1983). Groups may process information better compared to individuals (Stocks and Harrell 1995). Financial information tends to carry more weight compared to non-financial information (Reck 2001; Schiff and Hoffman 1996). Recent studies showed that unique measures may receive less weight compared to common measures when comparing the performance of organizational units (Lipe and Salterio 2000). This effect may also depend on the presentation of performance measures in categories (Lipe and Salterio 2002), subjectivity of the performance measurement system (Ittner et al. 2003), accountability (Libby et al. 2004), and on links between measures and the unit's strategy (Banker et al. 2004). Other studies have investigated how accounting knowledge (Dearman and Shields 2001) and accounting systems (Briers et al. 1997; Cardinaels et al. 2004; Gupta and King 1997) may impact the use of accounting information, in particular how decision makers consider the inaccuracy of cost information. In sum, the accounting literature has shown that judgment and decision-making processes are central to understanding the impact of accounting information on the outcomes of decision-making processes. However, such processes are not well understood when it comes to multi-attribute decisions and the role of imperfect monetary quantification of information that is initially non-financial.

Secondly, we empirically investigate how reflective thinking affects the weight of the attribute that is inaccurately quantified. Thirdly, we investigate how this effect is moderated by experience of the decision maker.

The remainder of this chapter is structured as follows. In the next section, we discuss various ways in which TCO numbers may be inaccurate. Section 3 is about the effect of reflection on the weight of an attribute that is inaccurately quantified as part of provided TCO numbers (first experiment), and section 4 is about the effect of experience and reflection on the decision weight of an attribute that is excluded from the provided TCO numbers (second experiment). In both sections, hypotheses are developed and the experimental design and results are presented. Finally, concluding remarks are in section 5.

3.2 Inaccuracy of TCO information

We investigate three forms of inaccuracy of TCO information, which we will discuss in this section: a non-financial attribute might be (1) included as minimum costs, (2) included as maximum costs, or (3) excluded from the cost numbers.

Firstly, the financial translation can be downwardly biased: the financial implications are only partly included in the financial number. More ambiguous implications, for which it is hard to include costs objectively, are not included. For example, downtime of production equipment may lead to costs for repair and extra labor costs, and these costs may be accurately quantifiable. Downtime may also lead to production orders being to late and, as a consequence, disappointed customers. Such costs may be much more difficult to estimate. This example has also been used in the experimental tasks, see Figure 3.1. Uptime is one of six attributes provided for three alternative brands of a machine. Except for the uptime attribute, costs per hour numbers can be calculated straightforward. The costs of downtime are only partially included, and the estimated cost of downtime is a minimum cost estimation. This type of inaccuracy is investigated in the first experiment.

Secondly, the financial translation can be upwardly biased; the maximum costs that could be incurred by the firm may be estimated and included in the monetary quantification. In the example, all remotely possible costs associated with uptime can be included, together with the costs for repair and extra labor, in the monetary quantification of the attribute downtime. The financial translation of this attribute is upwardly biased, and the TCO number provided is a maximum cost estimation. This type of inaccuracy is also investigated in the first experiment.

Figure 3.1 Experimental task in the first experiment (Condition: Uptime C = 99%; no-reflection; downtime cost included as a minimum)

You are the manager in a company. One machine has to be renewed. You can choose between three brands, all three meet all specifications.

In the table below information is provided about:

- The lifetime of a new machine;
- The uptime percentage of the machine;
- The time an employee needs to check the machine;
- The purchasing price of the four component new machine;
- Energy consumption per hour;

The 'uptime (%)' is the percentage of the time the machine is available for production. 100% – 'uptime (%)' = 'downtime (%)'. Downtime is caused by machine failure, maintenance, etc. that cause rescheduling of production, not meeting delivery times, etc. Some downtime cost, like failure cost, maintenance cost, etc. can be calculated objectively. Objectively calculable costs are included in the table below. Other downtime cost, like cost of not reaching times of delivery or additional transports are highly uncertain and therefore not included in the table below.

Labor cost per operator (€/hour)	€ 30,00
Electricity price (€/Kwh)	€ 0,13
Chemicals (€/liter)	€ 10,00

		Brand A	Cost per hour	Brand B	Cost per hour	Brand C	Cost per hour
Life time (hours)		2.900		2.700		2.800	
Uptime (%)		99,0%	€ 1,01*	96,0%	€ 6,25*	99,0%	€ 1,41*
Inspection time (minutes/hour)		9,0	€ 4,50	11,0	€ 5,50	10,0	€ 5,00
Purchasing price (€):	Component A	€ 2.800	€ 0,97	€ 2.300	€ 0,85	€ 2.100	€ 0,75
	Component B	€ 1.700	€ 0,59	€ 1.400	€ 0,52	€ 1.300	€ 0,46
	Component C	€ 2.000	€ 0,69	€ 1.600	€ 0,59	€ 1.600	€ 0,57
	Component D	€ 1.300	€ 0,45	€ 1.100	€ 0,41	€ 1.000	€ 0,36
Energy (kwh/hour)		7,0	€ 0,91	6,0	€ 0,78	5,0	€ 0,65
Chemicals (liter/hour)		0,09	€ 0,90	0,09	€ 0,90	0,08	€ 0,80
Total cost per hour			€ 10,01		€ 15,80		€ 10,01

* Minimum downtime cost estimation

Indicate which brand you will buy: _____

Thirdly, the financial translation can be incomplete: attributes that are difficult to estimate may be completely left out of the calculation of TCO numbers. In experiment 2, costs for downtime are not included in the presented TCO numbers. Therefore, a decision maker has to trade-off the (non-financial) uptime attribute against TCO numbers. Figure 3.2 shows an example of the experimental task used in experiment 2.

Figure 3.2 Experimental task in the second experiment (Condition: Uptime B = 96%; no-reflection)

You are the manager of a production department. One machine has to be renewed. You can choose between two brands, both meet all specifications.

In the table below information is provided about: the purchasing price of a new machine, the lifetime of a new machine, energy consumption per hour, and the uptime percentage of the machine. The 'uptime (%)' is the percentage of the time the machine is available for production. 100% – 'uptime (%)' = 'downtime (%)'. Downtime is caused by machine failure, maintenance, etc. that cause rescheduling of production, not meeting delivery times, etc. Both machines only differ on the four attributes mentioned below; the machines are equal on all other attributes.

Energy cost (Kwh)	€ 0.13

	Brand A	Cost per hour	Brand B	Cost per hour
Life time (hours)	2,900		2,800	
Uptime (%)	99.0%		96.0%	
Purchasing price (€)	€ 1,280	€ 0.44	€ 1,020	€ 0.36
Energy per hour (Kwh)	2.0	€ 0.26	2.2	€ 0.29
Total cost per hour		€ 0.70		€ 0.65

Indicate which brand you will buy: _____

3.3 Reflective thinking

This section contains the motivation of hypotheses, experimental design and results of the first experiment. Based on these results, the second set of hypotheses and findings will be presented in the next section.

3.3.1 Hypotheses development

Human decision makers often adopt a strategy of least effort. They often want to finish decision-making as soon as possible and are not willing or not able to adopt a demanding cognitive strategy such as specified in normative models (Dewey 1933; Simon 1979; Tetlock 1985). Reflective thinking may enhance the quality of decisions (Langer 1978). Reflection may help decision makers to judge the meaning, relevance, and quality of the available information, and such judgments may help decision makers to get more insight in the data, and bring together facts that seem to be incoherent and disconnected (Dewey 1933). Reflective thinking is often considered to be beneficial by increasing self-knowledge, getting a better understanding of the information, and making better decisions (Raiffa 1968; Keeney 1977; Langer 1989).[23]

We hypothesize that reflection will increase the awareness of the inaccuracy of the TCO numbers provided. Participants who are motivated to reflect will be more conscious of the complexity of the multi-attribute purchasing problem and think and weight the information more carefully. We expect that they will take the inaccurately quantified attribute into consideration and adjust the weight for the inaccuracy. The implication is that providing TCO numbers as minimum or maximum costs might result in opposite effects of reflection. Reflective decision makers may attach more weight to inaccurate TCO numbers if these numbers are estimated as minimum costs, while they may attach less weight to inaccurate TCO numbers if these numbers are estimated as maximum costs. Minimum TCO numbers are likely to be underestimations, so the relative weight of the inaccurately translated attribute will increase if a decision maker considers that the costs can actually be higher. The opposite will be the case if costs are estimated as maximum TCO numbers; these numbers are likely to be overestimations, and so the relative weight of the attribute may decrease when the decision maker takes this estimation error into account. The arguments given above lead to the following hypotheses:

H4: Minimum TCO information: Reflection will increase the weight of the attribute that is inaccurate included in the TCO numbers.

H5: Maximum TCO information: Reflection will decrease the weight of the attribute that is inaccurate included in the TCO numbers.

3.3.2 Research method

Participants were undergraduate students who were familiar with the basic concepts of cost accounting. They were provided with three alternative purchasing options from which they had to select one. These options concerned alternative brands for production equipment. Information was presented on the same attributes for each brand. Some information was financial (i.e., expressed in Euros) and other information was quantitative non-financial. The dependent

[23] The process through which reflection can improve decision-making may involve steps such as problem recognition, thinking through the problem and generating possible causes and solutions, building hypotheses and testing these, and evaluation and revision of possibilities (Baron 1981). Empirical studies have demonstrated that reflective thinking may improve the quality of decision-making, which has been measured in various ways, for example by less discrepancy between answers and actions (Pryor et al. 1977), greater predicted correctness of answers (Koriat et al. 1980), and higher correspondence between attitudes and behavior (Snyder and Kendzierski 1982).

variable was the choice for a particular alternative (*Choice C*). The experiment was run as a 2 × 2 between-subjects design, with two separate sessions for minimum and maximum cost numbers.

The uptime percentage of Brand C (*Uptime C*) was an independent variable at two levels (99% and 96%).

The second independent variable was reflection on the information provided (*Reflection*), which was manipulated at two levels (no-reflection, reflection). Participants in the no-reflection conditions were only asked to choose one of three alternatives. Participants who were encouraged to reflect were asked to answer the following two questions before choosing one alternative:

"Please, explain below how you make a choice for one of the three brands and which trade-offs you make.

"Please, explain below to what extent you are able, on the basis of the information provided above, to make a choice without further analysis."

TCO information was provided as an estimation of either the minimum costs or the maximum costs. In the minimum-cost condition, participants learned that TCO numbers for downtime were difficult to estimate, and they were instructed that costs for downtime could be higher:

"Some downtime cost, like failure cost, maintenance cost, etc. can be calculated objectively. Objectively calculable costs are included in the table below. Other downtime costs, for example costs of not reaching delivery times or additional transports, are highly uncertain and are therefore not included in the table below."

Figure 3.1 shows the text introducing the experimental task in the first experiment and the table that follows after this text (for the condition Uptime C = 99% and no-reflection). In the maximum-costs condition, participants were instructed that costs for downtime could be lower than estimated. The experimental task was the same, except for the note placed below the table, which was formulated as "Maximum downtime costs estimation". Furthermore, the sentence on the estimation of downtime cost was different. Instead of the last sentence shown in the introductory text in Figure 3.1, it was stated:

"Other downtime costs, for example costs of not reaching delivery times or additional transports, are highly uncertain. The number in the table below is an estimation of the maximum downtime costs that might occur, however these might be lower."

The interaction of the two independent variables *Uptime C* and *Reflection* allows testing of H1 and H2, based on a logistic regression[24] with the following specification:

[24] With 3 possible choices, multinomial regression is applicable. However, only 3 out of 148 participants actually choose Brand B, hence we excluded these data points. This is suggested by SPSS to avoid unexpected singularities in the output after running a multinomial logistic

$$Choice\ C = \beta1 + \beta2\ Uptime\ C + \beta3\ Reflection + \beta4\ (Uptime\ C \times Reflection)$$

If coefficient β4 is significant and positive, then the effect of *Uptime C* on the dependent variable will be stronger if participants have to reflect compared to when participants do not have to reflect. A negative coefficient indicates the opposite, a lower weight. Note that the preference for *Brand C* is expected to decrease as the uptime of *Brand C* decreases. If the preference for *Brand C* decreases more strongly in the reflection condition compared to the no-reflection condition, which is indicated by the interaction term *Uptime C* × *Reflection*, the weight of the attribute uptime is higher with than without reflection. In this study, "weight" is the weight across all decision makers; it is not the weight of an individual decision maker. The weight indicates the influence of the independent variables on the choice for *Brand C* (i.e., the dependent variable).

3.3.3 Results and discussion

Table 3.2 shows the number of participants and their choices in the various conditions of the first experiment.

Table 3.2 Total number of respondents and the choices per condition in experiment 1

Estimation		Minimum TCO		Maximum TCO	
Reflection		No-reflection	Reflection	No-reflection	Reflection
Uptime C	96%	15 (4)[1]	14 (1)	35 (7)[2]	35 (4)[3]
	99%	14 (8)	14 (12)	37 (27)	38 (24)
Total		29	28	72	73

[1] Between parentheses: number of respondents choosing Brand C, from A, B or C.
[2] Two participants chose Brand B in this condition (not included in the numbers in the table).
[3] One participant chose Brand B in this condition (not included in the numbers in the table).

Results related to H1 are in Figure 3.3a and in Table 3.3. We expected that, if the TCO information for uptime was provided as an estimation of minimum costs, the impact of uptime on the preference for Brand C would be larger if participants are encouraged to reflect, compared to when they only have to choose. Figure 3.3a shows that, consistent with this hypothesis, the effect of

regression when some categories have no observations. Data with two categories can be analyzed with binary logistic regression, and formulas for the ratios in the multinomial regression and binary logistic regression methods are equal (Borooah 2001).

Uptime C on Choice C was moderated by Reflection. The coefficient for the interaction term was significant (p = .043).[25]

Table 3.3 Logistic regression results first experiment (H4 and H5)

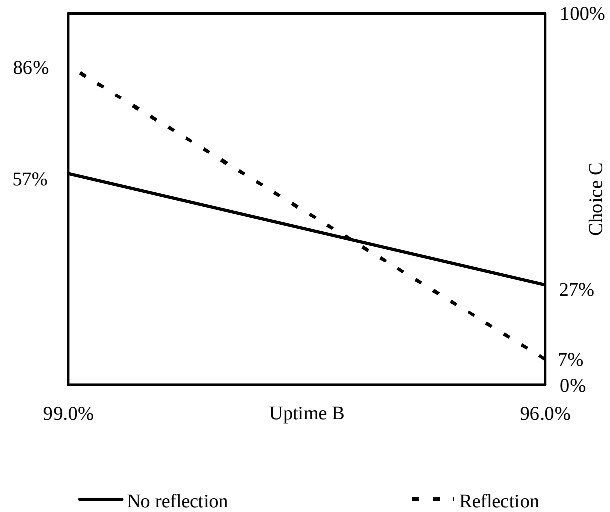
Choice C is the dependent variable	Minimum TCO N = 57[1]	Maximum TCO N = 145
Constant	-.373[2] (.349)	-.155 (.578)
Uptime C	.015 (.102)	.028 (.000)
Reflection	-.051 (.946)	-.554 (.184)
Uptime C ´ Reflection	.036 (.043)	.002 (.806)

[1] It is recommended to have samples of at least 100 (Long 1997). It might be risky to use maximum likelihood with samples smaller than 100; smaller p-values are required in small samples. Nonetheless, these guidelines are "not hard and fast" (Long 1997, p.53).
[2] Values of coefficients (and p-values for two-tailed Wald test).

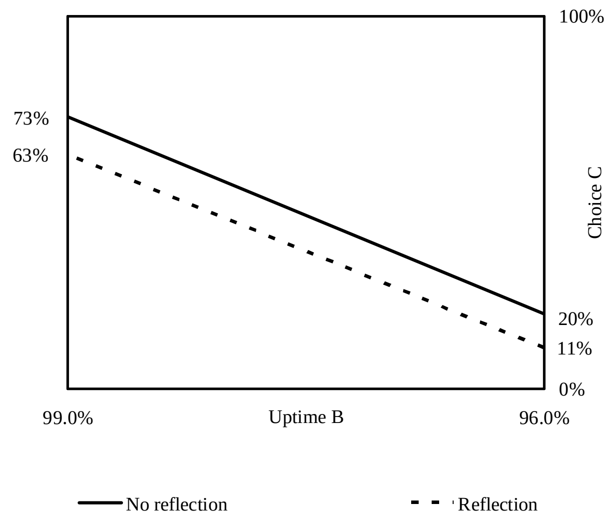
[25] We conducted analyses to check for multi-collinearity. Because the categorical variables in the first and second experiment (Experience, Reflection) were either 0 or 1, and Uptime was close to one (96%, 99%, or 99.5%), interaction terms would be 0, 1, or close to 1, leading to a risk of multi-collinearity. We transformed the uptime percentages to uptime hours (e.g., Uptime = 99%, Lifetime = 2,800 hours, Uptime hours = 2,800 × 99% = 2,772 hours), and centered uptime hours as suggested by Cronbach (1987). Thereafter, tolerances for the independent variables did not indicate a serious risk on multi-collinearity (always above .10 and mostly above .20).

Figure 3.3 Interaction of Reflection by Uptime C (First experiment)

3.3a Minimum TCO, percentage of participants choosing Brand C (N = 57)



3.3b Maximum TCO, percentage of participants choosing Brand C (N = 145)



Results for H4 are in Figure 3.3b and Table 3.3. This hypothesis is not supported. We expected that, if the TCO information on uptime was provided as an estimation of maximum costs, the impact of uptime on the preference for Brand C would be smaller if participants are encouraged to reflect compared to when they only have to choose. Figure 3.3b suggests that the weight was the same whether or not they were encouraged to reflect. The coefficient for the interaction term between Reflection and Uptime C was not significant ($p = .806$).

The difference between results under the minimum versus maximum conditions is relevant to discuss further. It could be that the provision of TCO as a minimum estimation has more impact than a maximum estimation, and that might explain that the effect of reflection is stronger for the minimum condition compared to the maximum condition. Representing costs as a minimum or maximum implies that decision makers have to make a decision under uncertainty; "real" costs might deviate from the TCO numbers provided in the tables. Prospect theory (Kahneman and Tversky 1979) describes how human decision makers attach more weight to negative consequence (losses) than to the equivalent positive consequences (gains). Reflective decision makers considering a minimum cost may realize that costs could also be higher, which will be experienced as a relative loss, and receive a high weight in the decision. On the other hand, a maximum cost representation indicates that "it can only get better", which will be experienced as a relative gain. Therefore, decision makers could have attached relatively more weight to a cost attribute represented as a minimum compared to costs represented as a minimum.

Additionally, the difference between results under the minimum versus maximum conditions may be understood on the basis of the implied ranges under both conditions. Formulating costs as a minimum implies a larger range of possible outcomes compared to formulating costs as a maximum. Decision makers tend to give a higher weight to larger ranges (Fischer 1995). For example, the downtime cost of Brand C in Figure 3.1 is € 1.41. When this is an estimation of the minimum cost, the range is, in principle unlimited: € 1.41 to infinity. When this is an estimation of the maximum cost, the range is € 1.41 (at most € 1.41 and at least € 0). Decision makers are therefore likely to attach more weight to the downtime cost in case these costs are represented as a minimum compared to when these costs are represented as a maximum.

This first experiment suggests that reflection matters for the way in which TCO numbers are used to support purchasing decisions, and also the type of inaccuracy of such TCO numbers may have an impact. However, the findings are based on experiments pertaining to business decisions taken by students. Therefore, a logical next step is to involve more experienced research participants. This also raises the question of how reflective thinking may be achieved in real-life situations, and in the next experiment we will create such business like real-life conditions to invoke more careful and reflective decision-making.

3.4 The moderating effect of experience

In this section, we study reflective thinking in relation to TCO numbers from which some attributes are totally excluded (the third type of inaccuracy described above). We will investigate the impact of reflective thinking and experience on the weight attached to the excluded attribute. Experience in this study refers to general business experience, or professional experience, and not to specific experience with and knowledge of accounting or purchasing tasks. We assume that professionally experienced people have a better understanding of operations, technology and the usage of cost information in organizations; the kind of knowledge related to general business knowledge (Bonner and Lewis 1990). For example, knowledge obtained during college, working in business, reading and other kinds of individual life experiences.

3.4.1 Hypotheses development

In the previous experiment, Reflection was manipulated by simply asking participants to explicate how they arrived at their choice (beforehand), and this was expected to induce sufficient reflective thinking to improve their understanding of the information provided. However, in real business settings decision makers may need “stronger” incentives to encourage reflective thinking, such as the expectation that they will have to justify their decisions. Because in the second experiment more experienced participants are involved, we manipulated Reflection by creating a setting of decision justification (Curley et al. 1986; Tetlock 1992). Reflective thinking is important in business; organizational buyers have to be able to provide analysis and give a more formal justification than consumers (Sherlock 1991). Being able to give sound justifications is also important for managers; managerial success is close related to being able to convince others (Tetlock 1985). Decision makers may want to avoid “loosing face” when they feel they have to justify their decisions, and this may change their decision processes (Carnevale 1985). This may be even more so in threatening situations; if the decision maker’s explanation is monitored by others and mistakes may result in sanctions (Fox and Staw 1979). Therefore, decision justification may motivate decision makers to adopt a strategy that will result in profound analysis and evaluations (Tetlock 1983). For example, Doney and Armstrong (1996) found that purchasers who will have to motivate their decision-making process analyze information more extensively than purchasers who only have to motivate their choice for a certain alternative. Decision makers who are encouraged to take a closer look at the cost information and reflect on their decision-making might attach more weight to the information not included in the TCO numbers; they may realize that the attribute excluded from the TCO numbers may raise the total costs of an alternative, and should be traded-off against the TCO numbers.

However, reflective thinking in a social setting might also result in the opposite effect. A decision maker might shift to a strategy that will result in a decision that will satisfy the person to whom the decision has to be justified (Tetlock 1983). To adopt this strategy a decision maker should know (or can readily infer) the beliefs and preferences of the evaluator. For example, the importance of cost information in business might result in focusing mainly on the cost numbers and a tendency to ignore cost not included in the cost numbers. In addition, the difficulty to explain a multi-attribute trade-off between different attributes might result in a decision strategy that is easily to explain. Obviously, decision makers will realize that TCO numbers are not automatically produced. TCO information is presumably produced (when top) management wants it to be used for decisions–and it presumably includes what top management thinks it is important to include. As a result, decision makers may ignore attributes for which no TCO numbers are calculated; decision makers may assume that these attributes are not important in their manager's eyes.

Therefore, we posit that reflection influences the weight attached to the attribute not included in the TCO numbers. However, because of the contradictory findings we predict no directional effect. Thus, we hypothesize:

H6: Incomplete TCO information: Reflection will influence the weight of the attribute that is not included in the TCO numbers.

Experience may moderate the effect of Reflection, but first we will discuss a main effect of experience. Expert decision makers should be more mindful of the inaccuracies in the provided data. Experience may result in expertise, defined as a general ability to solve domain specific problems (Alba and Hutchinson 1987). For example, more experienced decision makers appear better able to distinguish relevant from irrelevant information (Shelton 1999). Experience may help a decision maker to distinguish what information is relevant and what information can be excluded from the decision-making process (i.e., whether or not the attribute that is not included in the cost numbers should be taken into account). Broad domain knowledge (e.g., knowledge of basic accounting principles that accounting professionals have who are working in specialized accounting areas), may help them to recognize problems and to further investigate relevant information, even if they are not directly familiar to a specific topic (Vera-Muñoz et al. 2001). Experience is especially helpful if tasks become more complex; and general training (such as education in business administration) and experience helps decision makers too outperform less experienced decision makers (Chang et al. 1997). Experience may help decision makers to assess the completeness of the provided cost information. More experienced decision makers should better understand that some attributes are not included in these cost numbers, and they may better realize that it is important to make a deliberate trade off between the

TCO numbers and the non-included attributes. As a result, experienced decision makers could be expected to attach more weight to the attribute not included in the TCO numbers, compared to less experienced decision makers.

However, experience may also have the opposite effect. It may be associated with habit, routine, automaticity, and superficial thinking. Several studies found unfavorable effects of experience. Experienced decision makers may find it difficult to adopt another strategy, and they may unconsciously adopt the same decision strategy over and over again unless something stops them from doing this (Alba and Hutchinson 1987). For example, Marchant et al. (1991) found dysfunctional effects of high-accounting knowledge as a result of inflexibility to change decision strategies. Also, a task that deviates from the task structure experts are used to might make it difficult for experts to excel (Nelson et al. 1995). In another study (Vera-Muñoz 1998) it was found that information that is highly relevant according to economic theory was ignored by more experienced decision makers, because they were used to analyze information by decision rules that attached less importance to this particular type of information. These studies indicate that expert knowledge might result in inflexible decision strategies. These studies make us expect that decision makers mainly focus on the TCO numbers and show a tendency to ignore information not included in TCO numbers. After all, financial information is important and caries a lot of weight in decisions (Schiff and Hoffman 1996; Reck 2001).

No directional effect is predicted; these contradictory empirical findings do not indicate whether experienced decision makers attach more or less weight to information not included in TCO numbers. Therefore, we formally hypothesize:

H7: Incomplete TCO information: Experience will influence the weight of the attribute that is not included in the TCO numbers.

Experience may moderate the effect of Reflection. The idea behind H7 is that more experienced decision makers have a more “outspoken” decision strategy. This leads them to either pay less attention to attributes not included in the TCO info, or to pay more attention to these (hence, we made no directional prediction for H7). However, compared to students, we expect practitioners to change their decision strategy (and the weight they give to uptime) less as a result of reflective thinking. Suppose the main effect of experience is such that these decision makers give more weight to the attribute not included in TCO, because decision makers with business experience may have learned that not all relevant information is accurately included in cost numbers, and they are reluctant to ignore information that is not included in cost numbers. For these decision makers, we would expect the effect of reflective thinking to be smaller than for students. Suppose the main effect of experience is such that decision makers with business experience give less weight to the attribute not included in TCO, because they realize that top management wants purchasers to use TCO numbers, and these numbers are then also likely to include what management thinks is important. If reflective thinking of these decision makers is stimulated, they are less likely to change their decision strategy and give another weight to excluded attributes, compared to students. To summarize, we formally posit the following hypothesis:

> *H8: Incomplete TCO information: Experience will negatively moderate the impact of reflection on the weight of the attribute that is not included in TCO numbers.*

3.4.2 Research method

As in the first experiment, participants received information on several purchasing alternatives (two in this case) from which they had to select one. Inaccuracy of cost information in this experiment meant that for the attribute uptime no cost estimation was included in the TCO information (see Figure 3.2), instead of the minimum cost and maximum cost manipulations in the first experiment 1.

The dependent variable was again the choice for a particular alternative, for brand B in this case (*Choice B*) because participants were given two alternatives instead of three. A 2 × 2 between-subjects design was used, and *Experience* was added as a measured variable (students versus practitioners). The first independent variable was the uptime percentage of brand B (*Uptime B*), set at two levels (99.5% and 96.0%).

The level of reflection (*Reflection*) was the second independent variable, and it was manipulated at two levels (no-reflection versus reflection). Participants in the no-reflection condition participated anonymously and were only asked to choose one alternative. These participants received a one-sided printed sheet on which the experimental task was printed (the other side was blank). Participants in the reflection condition received a double-sided printed sheet. Participants had to fill-out their name, e-mail address, and phone number on the front page (the page that was blank in the no-reflection condition). Students could read on the front page that we needed those data to organize a meeting where we would discuss their choices. Practitioners could read on the front page that we needed their contact information to call them for additional questions concerning their choice. Practitioners in the reflection condition were also asked to think aloud while conducting the experimental task.[26]

[26] We recorded what they said only for the purpose to increase the motivation to think thoroughly as a result of the feeling that detailed questions might have to be answered afterwards. The sound

Experience was included as a third independent variable, measured at two levels. Some participants (N = 94) were undergraduate students similar to the first experiment, and another group of participants (N = 60) consisted of practitioners who were visitors and exhibitors at a large international maritime trade fair in Rotterdam. The median years of working experience was 18.5 years, and practitioners were on average 42 years old. Each participant participated only once in the experiment (see also Table 3.4 below).

The hypotheses H6, H7 and H8 are tested using logistic regression with the following specification:

$$\begin{aligned} \textit{Choice B} = {} & \beta0 + \beta1\ \textit{Uptime}\ \mathrm{B} + \beta2\ \textit{Reflection} + \beta3\ \textit{Experience} + \\ & \beta4\ (\textit{Uptime B} \times \textit{Reflection}) + \beta5\ (\textit{Uptime B} \times \textit{Experience}) + \\ & \beta6\ (\textit{Reflection} \times \textit{Experience}) + \\ & \beta8\ (\textit{Uptime B} \times \textit{Reflection} \times \textit{Experience}) \end{aligned}$$

The coefficient β4 of the interaction term of *Uptime B* × *Reflection* is estimated for testing H3. Note that the preference for Brand B is expected to decrease as the uptime of Brand B decreases. A significant coefficient β4 indicates that decision makers attach a different weight to Uptime B if they are encouraged to reflect, compared to decision makers who are not encouraged to reflect. The coefficient β5 of the interaction term of *Uptime B* × *Experience* is estimated for testing H4. A significant coefficient β5 indicates that professionally experienced decision makers attach a different weight to Uptime B, compared to students. Finally, the coefficient of the interaction term *Uptime B* × *Reflection* × *Experience*, β8, is estimated for testing H5. Keeping Reflection constant, a significant value β8 would indicate that *Reflection* has a significant influence on the interaction of *Uptime B* × *Experience*. That is, the weight students and practitioners attach to the attribute not included in the TCO numbers is different as a result of reflective thinking.

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quality of the recordings did not enable further analysis of the content of participants' considerations.

3.4.3 Results and discussion

Table 3.4 shows the number of participants and their choices in the various conditions of the second experiment.

Table 3.4 Total number of respondents and the choices per condition in experiment 2

Reflection		No-reflection		Reflection[1]	
Experience		Students	Practitioners	Students	Practitioners
Uptime B	96.0%	35 (11)[2]	16 (7)	11 (4)	12 (4)
	99.5%	33 (30)	18 (12)	15 (14)	14 (10)
Total		68	34	26	26

[1] Participants who did not provide contact information or made no choice (18 students, and 2 practitioners) are excluded.
[2] Between parentheses: number of respondents choosing Brand B.

Results for H6, H7 and H8 are in Table 3.5. In column 1, the coefficient of *Uptime B* × *Reflection* is not significant (p = .950), hence, we find no support for our hypothesis H6. In column 2, the coefficient for the two-way interaction term *Uptime B* × *Experience* was significant (p = .020), hence, these results support hypothesis H7. As Figure 3.4 shows, students put a higher weight on the attribute uptime, which was not included in the TCO number in this experiment, compared to practitioners. In column 3, the coefficient for the interaction term *Uptime B* × *Reflection* × *Experience* was not significant (p = .759), hence, we find no support for hypothesis H8.

Table 3.5 Logistic regression results second experiment (H6, H7 and H8)

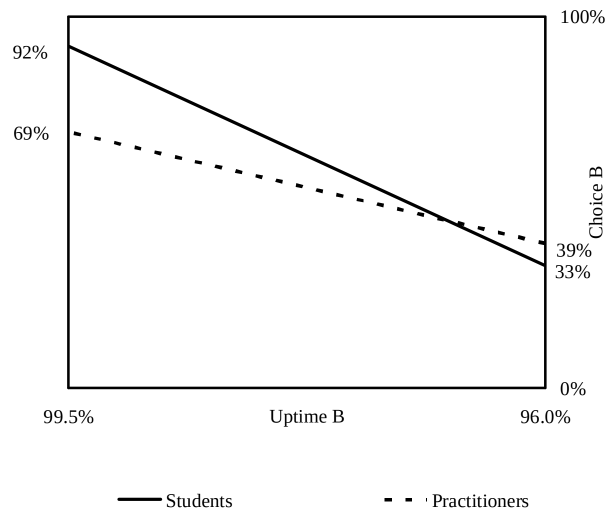
Choice B is the dependent variable	Incomplete TCO N = 154		
	H6[1]	H7[2]	H8
Constant	.5093 (.032)	.897 (.004)	.239 (.500)
Uptime B	.022 (.000)	.032 (.000)	.010 (.183)
Experience		-.696 (.091)	.582 (.250)
Reflection	.004 (.992)		-.096 (.862)
Uptime B × *Experience*		-.019 (.020)	.022 (.033)
Uptime B × *Reflection*	.001 (.950)		.007 (.549)
Experience × *Reflection*			.377 (.676)
Uptime B × *Experience* × *Reflection*			-.006 (.759)

[1] A specification including Experience as an independent variable was also estimated (as for H8). Because the Chi-square difference was not significant (χ^2d =7.817, df = 4, p = .099), we estimated the coefficient for Uptime B × Reflection using the empirical specification provided in the first column in the table above (cf. Pampel 2000).

[2] A specification including Reflection as an independent variable was also estimated (as for H8). Because the Chi-square difference was not significant (χ^2d =.572, df = 4, p = .966), we estimated the coefficient for Uptime B × Experience using the empirical specification provided in the second column in the table above.

[3] Values of coefficients (and p-values for two-tailed Wald test).

Figure 3.4 Percentage of practitioners choosing Brand B (N = 154)



The lack of support for the effect of reflective thinking in this experiment is surprising. We assumed that reflective thinking would change the weight of the attribute that was not included in the TCO numbers (H6). One possible explanation could be that the experimental task might have been too simple. The inaccuracy might have been too obvious to ignore, regardless of the manipulation of reflection. Maybe participants made the same trade off in all conditions between total costs and the attribute that was not included in this TCO information. A higher task complexity, for example through more attributes per alternative, might have been required to see an effect of reflection. For a more difficult task, decision makers who are not pushed to think more carefully might ignore the inaccuracy in the TCO numbers and attach less weight to TCO numbers, compared to decision makers who do not reflect.

Another explanation could be that selection bias in the experimental design may have countered the effect of reflective thinking. Participants were asked to provide their contact details, as explained above. Their responses were excluded if they refused to provide such information. As can be seen from Table 4, the number of participants in the reflection conditions is smaller than in the no-reflection conditions.[27] As a result of self-selection, it could be that the resulting

[27] A total number of 175 students were asked to participate in this experiment. They were randomly assigned to one of the conditions, but the willingness to participate and provide contact details was lower in the reflection conditions. This yielded 68 participants in the no-reflection conditions and 26 participants in the reflection conditions. For practitioners, the differences in the numbers of practitioners in these conditions were smaller than for students (34 and 26

participants in the reflection conditions were more confident or were otherwise not particularly concerned about how their decisions would be judged. In other words, for those participants we may have failed to actually create reflective thinking and anxiety for losing face. However, this limitation is not exclusive to our study, although few studies of reflective thinking discuss it in great detail. For example, in reflective thinking studies conducted by Antonioni (1994) and Schwartz et al. (2004) the number of participants who were stimulated to reflect was lower compared to the number of participants who were not stimulated to reflect. As in our study, participants could drop out of the experiment at any time, and they did more so if they were motivated to reflect because of being accountable for their decisions. Antonioni (1994) asked subordinates in an insurance company to evaluate their managers. Participants admitted that they preferred anonymous appraisals because reprisal might be costly. Participants in the study by Schwartz et al. (2004) were family physicians who selected a patient treatment. Reflection was stimulated by asking the physicians for a written justification on their decision, which also disclosed the research participant's name. In both studies, it is possible that self-selection factors were stronger in the reflection condition than in the no-reflection condition.

3.5 Concluding remarks

In this study, we investigated decisions that are informed by reports on the total cost of ownership (TCO) of sourcing alternatives. TCO aims to provide a monetary quantification of points of difference of such alternatives, and this enables comparisons between non-commensurate differences in alternatives. However, a "perfectly" accurate monetary quantification of all attributes is unrealistic. We considered three ways in which an attribute may be inaccurately included in the TCO information: as a minimum cost, a maximum cost, or not at all. We investigated the weight of such an attribute in sourcing decisions, and how this depends on the type of inaccuracy, reflective thinking and experience.

Sourcing decisions like the ones we described in this chapter are cognitively challenging. The alternatives can be described by several attributes; some are financial, while other attributes are non-financial and describe, for example, quality. Humans will adapt their decision-strategy to the specific situation, and try to minimize cognitive effort (Payne et al. 1993). Relying on TCO information is

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participants). Practitioners participated sequentially (students simultaneously). The researcher kept searching for a practitioner who was willing to answer a randomly selected condition before changing to a new randomly selected condition. It was much more time consuming to find a practitioner who was willing to participate in the reflection condition, compared to finding a practitioner who was willing to participate in the no-reflection condition, because some practitioners who were willing to participate refused to continue the experiment after learning that they had to provide contact details and possible had to answer questions afterwards.

tempting, because monetary quantification facilitates tradeoffs among attributes that are non-comparable, as the measurement units of these attributes were initially much more difficult to compare. However, the monetary quantification may often not be capable to fully capture the operational considerations, and "decisions can no longer be taken and actions can no longer be chosen at a distance via the abstract language of numbers. Operational considerations must to some extent be involved in the decision process, not coded, but in their original form." (Chapman 1997, page 202) We investigated how reflective thinking and experience may affect how carefully decision makers consider the inaccuracy of the TCO info, and, hence, how much weight they gave to the inaccurately quantified attribute.

Participants in our experiments had to choose between alternative offerings for replacing a production machine, each characterized by several attributes.[28] One attribute (downtime of the machine) was problematic in terms of providing a monetary quantification. In some conditions in the first experiment, the cost associated with downtime was included in the TCO numbers as minimum cost estimation. As hypothesized, it was found that the weight attached to the inaccurate included TCO numbers increased as a result of reflective thinking. In other conditions, the maximum cost associated with downtime was estimated and included the TCO numbers. We found no support for the hypothesis that the weight attached to this attribute was reduced as a result of reflective thinking. In the second experiment, downtime was completely excluded from the TCO calculation. We found no support for the hypothesis that reflection would affect the weight of this attribute or a possible interaction between experience and reflection. We found strong support for the hypothesis that professional experience would affect that weight of this attribute. The importance of experience is particularly attention-grabbing if we observe two studies by Snijders et al. (2003) and Tazelaar and Snijders (2004). They studied the ability of purchasing managers to judge the likelihood of problems in purchasing transactions. Contrary to our findings, they found no effect of experience (see paragraph 2.5 for an extensive discussion).

The results of this study may have managerial implications for the introduction and use of TCO information, and other costing information that aims to better capture the indirect costs of cost objects, but at the same time leaves out some

[28] Theoretically, the difference in life time could have consequences we did not take into account. For example, an asset with a long life time could have other economic consequences compared to an asset with a short life time. The risk might be totally different for those two assets. However, in our experimental setting were differences in hours of life time small, and did therefore not make much practical difference. A pilot test did not indicate that participants thought about other economical consequences as a result of this small difference in life time. Neither did a group of maintenance engineers, with whom we discussed a similar setting, mention the possible economical consequences as an unrealistic shortcut to calculate cost per hour.

important characteristics of these objects. Improved costing information that captures financial impact and aggregates financially quantifiable attributes may be helpful for the decision maker, but care should be given to unintended affects—that those elements that are not included in the new costing information get less attention as a result of providing the information. The results suggest that when introducing cost information, it is important that the limitations should be explained very clearly to managers, so that they will take a closer look at the accuracy of the cost information. This seems to be especially important in case TCO numbers are likely to be underestimated; without additional information, decision makers may tend to ignore the inaccuracies in these cost numbers. It is probably also important to give a prominent position in costing reports to the excluded attributes. This might attract attention and result in judgment and decision-making where decision makers take these results into account.

Several limitations have to be mentioned. Conducting experiments on computers is preferable to running experiments by paper. A computer would have provided the opportunity to measure process variables such as decision time. Although we are aware of this limitation, we choose to conduct experiments on paper for several practical reasons. We wanted to include practitioners in our experiments. Although it is not too difficult to run experiments with students in a laboratory, it is much harder too find a group of practitioners. For that reason, we did not ask practitioners to come to our laboratory, but decided to go to locations where we would find many practitioners from many different companies. We used paper because we were not able to use computers on the trade fair. As we wanted to minimize the impact of different methods, we choose to conduct the experiments with students and practitioners on paper. Despite the fact that we had the intention to run all experiments with both students and practitioners, the difficulty to find enough practitioners, (i.e., get access to trade fairs) made us decide to conduct only the second experiment with practitioners.

Future research could help to get a better understanding of the impact of TCO information on in judgment and decision-making. The impact of a social context on judgment and decision-making is an interesting topic for a new study. In this study individual in judgment and decision-making has been investigated. However, humans do not live in an isolated world, they live and work in setting where they interact with each others (Katz and Kahn 1978); future research could therefore research the use of inaccurate costing information in relation to reflective thinking in a social context. Additionally we could model the imperfectness of TCO numbers, which is central in this study, differently. While we modeled inaccurateness as minimum and maximum TCO numbers, we might also give explicit ranges for TCO numbers (i.e., costs are between € 2.00 and € 3.00). Investigating the impact of ranges on in judgment and decision-making is relevant while human decision makers do deviate from normative theory by attaching not enough or too much weight to a range (Fischer 1995).

4 Mental Load

The aim of this chapter is to research the weight decision makers attach to information that is not (or inaccurately) included in total cost of ownership (TCO) numbers. We do this for different levels of mental load. That is, we research how the level of mental load changes the weight of the attribute that is not (or inaccurately) included in the TCO numbers. We conducted two experiments with 711 students in total. In the first experiment, we examined whether decision makers, who experienced a high mental load, would attach less weight to the attribute that was not included in the TCO numbers. In the second experiment, we researched whether decision makers weigh costs presented as a range differently compared to costs presented as an estimated in a point. We investigated this for low and high levels of mental load. The results did not support our hypotheses.

4.1 Introduction

We investigated the impact of mental load on the weight decision makers attach to cost numbers that are inaccurately included in sourcing information. Decision makers only have a limited amount of cognitive capacity available to process information (Simon 1979). Therefore, most humans face difficulties in processing more than one (effortful) task at the same time. It is quite unlikely that people can fully concentrate on one task; for example, colleagues asking questions will interrupt decision-making (Banks and Murphy 1985). We simulated mental load in an experiment by asking participants to do two tasks simultaneously; the purpose of increasing mental load is to hinder the decision makers' ability to concentrate fully on a sourcing task.

Sourcing decisions are difficult, decision makers have to evaluate a number of alternatives for several attributes (see also the previous chapters). TCO information can reduce the complexity of these decisions by transforming all information into easily comparable cost numbers. However, financially quantified attributes are often inaccurate. Decision makers should consider the inaccuracy in TCO numbers, but may be less able to do so when experiencing a high mental load. In a first experiment, we conceptualized inaccuracy by excluding an attribute from the calculation of the TCO numbers (see also Chapters 2 and 3). We investigated how much weight decision makers attached to the attribute excluded from the TCO numbers, when experiencing different levels of mental load. In a second experiment, we conceptualized inaccurate cost information by presenting particular cost numbers as a range. In this experiment, we investigated the weight decision makers attached to the limits of a cost range when experiencing different levels of mental load. A total number of 711 students participated in the experiments.

Managers' cognitive abilities to process information, the impact of management accounting information, and the interactive effect of managers' cognitive abilities and management accounting information are important topics of research, but so far these topics have not received much attention so far (Lipe and Salterio 2000). We contributed to research by investigating the interacting impact of mental load and TCO numbers on the weight decision makers attach to information excluded from these numbers. A second contribution is the conceptualization of different methods to representing inaccuracy in cost numbers. For example, attributes cost is difficult to calculate can be excluded from the cost numbers (Chapter 2 and 3), or can be included as a minimum or as a maximum cost number (Chapter 3). In this chapter we conceptualized inaccuracy in cost numbers in a fourth method; we investigated the impact of representing inaccuracy as a range (e.g., costs range between € 4 and € 6). A range gives a more vivid representation of the inaccuracy in cost numbers. However, it is unclear whether presenting cost numbers as ranges influenced decision makers in the weight they attached to the excluded cost numbers.

The structure of the remainder of this chapter is as follows. In section 2 we will discuss the first experiment, and in section 3 the second experiment. Within these sections, we develop hypotheses, explain the research design, and present and discuss results. Finally, we will conclude and discuss our overall results and findings in section 4.

4.2 Experiment 1

In experiment 1 we discuss the impact of mental load on the weight decision makers attach to an attribute that is excluded from the TCO numbers. For a discussion about TCO we refer to Chapter 1 and the introductory paragraphs in Chapter 2 and 3.

4.2.1 Development of hypotheses

A setting where people can fully concentrate on one task, without being interrupted, is rare in daily situations; for example, e-mail, phone calls or colleagues asking questions distract and interrupt decision makers in their ability to process information systematically (Banks and Murphy 1985, Bodenhausen 1990). Decision makers have to divide their attention over several tasks that all consume cognitive effort (Gilbert and Hixon 1991). In this chapter, we manipulate the ability to process information by increasing mental load. Hence, participants in our experiments are not able use all their cognitive resources to concentrate on one specific task (i.e., making a sourcing decision). Below, we start by discussing the impact of mental load on a decision maker's cognitive ability to process information. Thereafter, we discuss the impact of mental load on the weight a decision maker attaches to an attribute excluded from the TCO numbers.

Humans' cognitive abilities to process information are limited (Payne 1982, Russo and Dosher 1983, Baddeley 1999); controlled and effortful processes will be the first to decline; these processes are heavily capacity demanding (Bargh 1984). Attentively evaluating multi-attribute purchasing alternatives is effortful; purchasers have to analyze information carefully, weight the importance of attributes, decide about trade-offs between attributes and alternatives, sum costs for several attributes, etc. High cognitive load reduces the cognitive capacity available to process information of a second task. Therefore, decision makers who experience a high mental load may experience more difficulty to evaluating sourcing alternatives attentively, compared to decision makers who experience lower levels of mental load.

Decision makers who experience a high cognitive load are more likely to use heuristics when engaged in cognitively challenging tasks (Payne et al. 1993; Roch et al. 2000).[29] Humans often adopt a strategy of minimal cognitive effort and are even described as "cognitive misers" (Fiske and Taylor 1984, p. 12); decision makers prefer to finalize decision-making as soon as possible and are reluctant, or unable to use demanding strategies such as specified in normative models (Dewey 1933; Simon 1979; Tetlock 1985). Decision makers may have a strong tendency to minimize cognitive effort rather than making better decisions; decision makers tend to adopt a strategy of minimizing the joint costs of error and effort (Russo and Dosher 1983). Decision makers are even willing to select a less optimal alternative to save cognitive effort, or to reduce possible negative affects of more cognitive effort (Carbarino and Edell 1997). Decision makers may purposely use a strategy of which they know that it may not result in the normative best solution. For example, a decision maker who faced too many alternatives explained that eliminating alternatives as soon as possible is a useful strategy to limit the amount of information available (Payne 1976). However, it is important to remind oneself that using heuristics when experiencing a high cognitive load may result in different decisions compared to situations where decision makers can use all their cognitive resources to process a task systematically; a manager should always consider the impact of cognitive load on decision-making (Roch et al. 2000).[30]

[29] A similar effect has been described by Bodenhausen (1990) and Pendry and Macrae (1994). They found that high mental load makes decision makers more likely to rely on stereotypes.

[30] However, high cognitive load may also positively affect judgment and decision-making. Decision makers under low cognitive pressure can fully concentrate on all information available, and may thereby start to 'overprocess' information and get 'seduced' by using and applying superfluous and nondiagnostic information (Gilbert and Krull 1988). For example, people who learned that certain information was false still used this information while evaluating performance

Summarized, the cognitive load of a task limits the cognitive ability to do a second task simultaneously. Decision makers may not have enough cognitive resources available to evaluate purchasing alternatives extensively when experiencing a high mental load. We assume that decision makers adapt their decision behavior to their mental load; that is, we assume that decision makers are more likely to use heuristics when cognitive load increases. Within the following paragraphs, we will formulate two hypotheses; firstly, for decision makers who experience a low mental load during a purchasing decision, and secondly, for decision makers who experience a high mental load during a purchasing decision.

Under low levels of mental load, decision makers can fully concentrate on making a deliberate sourcing decision. Each sourcing alternative can be described by several attributes (e.g., lifetime, uptime, electricity consumption). To make a cautious decision, a decision maker should carefully evaluate the sourcing information available. Nonetheless, decision makers may find it difficult to make a deliberate multi-attribute sourcing decision. In general, human decision makers find it difficult to make a multi-attribute decision, and the complexity of such a task increases as there are more alternatives available to choose from, the number of attributes describing each alternative is greater, decision makers experience time pressure, etc. (Payne et al. 1993). The complexity of a sourcing decision can be reduced by aggregating several attributes (with different dimensions) into TCO numbers. Recoding information is an extremely powerful tool for increasing the amount of information humans can deal with (Miller 1956). Aggregation of several attributes into TCO numbers allows decision makers to focus on the impact of an alternative as a whole, rather than on the individual attributes within the alternative. With TCO numbers, a decision maker only has to compare the TCO numbers of the alternatives and select the alternative for which total cost is lowest. However, not all information can be included accurately in TCO numbers (see also previous chapters). Therefore, a decision maker should make a trade-off between the TCO numbers and the information not included in these numbers. The question is, do decision makers attach a higher or lower weight to an attribute not included in the TCO numbers if TCO numbers are presented, compared to the weight they would attach to this attribute when TCO numbers are not available?

We expect that decision makers will attach more weight to the attribute excluded from the TCO numbers available, than they would attach to the attribute

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of another person (Wegner et al. 1985). High cognitive load may make decision makers relatively immune to processing too much and superfluous information (Gilbert and Krull 1988). Nonetheless, we do not research the impact of superfluous or irrelevant information on the weight decision makers attach to the attribute that was not included in the cost numbers; in this study, decision makers do not receive superfluous or irrelevant information (e.g., the colour of the components). Therefore, we do not expect positive effects of a high cognitive load in our study.

when TCO numbers are not available.[31] With TCO numbers available, the excluded attribute becomes more salient, compared to conditions where TCO numbers are not available. In conditions without TCO numbers, the attribute becomes one of many attributes with all kinds of different dimensions; decision makers may not be able to see the wood for the trees. With TCO numbers available only two attributes are left: the TCO numbers and the excluded attribute. Besides, with TCO numbers available, making a trade-off between the attributes describing each alternative is easier, compared to the situation without TCO numbers. It is unlikely that decision makers will ignore attributes; they have no reason to assume certain attributes are less important. To conclude, we expect decision makers to attach more weight to the attribute not included in the TCO numbers, where TCO numbers are available, compared to the weight they would attach to this attribute when no TCO numbers are available: (1) the attribute excluded from the TCO numbers is more prominent if TCO numbers are available, and (2) the excluded attribute is easier to include in decision-making if TCO numbers are available.

H9: Providing the decision maker with TCO information of alternatives, increases the weight of an attribute that is not included in the TCO calculation, for low mental load.

High mental load may change the weight decision makers attach to the information not included in TCO numbers. Under high cognitive load, decision makers may not have enough cognitive capacity to make a well-considered trade-off (i.e., use a demanding compensatory decision strategy like predicted in H9) between the TCO numbers and the attribute not included in these numbers. To make a deliberate trade-off, decision makers need to understand which attributes are (not) aggregated in the TCO numbers. If the TCO number is an aggregation of a greater number of financially quantified attributes that include most costs, then the attributes that are not included are likely to receive relatively less weight. Contrary, if the aggregated attributes (in the TCO number) comprise only a minority of the attributes and costs, then the excluded attributes will receive more weight relatively. However, a higher mental load decreases the decision maker's cognitive capacity to analyze the attributes that are aggregated in the TCO number. In that case, we expect that decision makers will find it more difficult to find a trade-off between (and attach appropriate weighs to) the TCO number and the attribute not included in these numbers. We expect that decision makers will

[31] This is comparable to Hypothesis 1 in Chapter 2. Hypothesis 1 in Chapter 2 and Hypothesis 1 in this chapter are formulated for conditions where one attribute is not included in the TCO numbers, decision makers experience low levels of mental load, and the complexity of the provided information is low.

then show a tendency to attach more weight to the TCO numbers and less weight to the attribute that is not included in these numbers. After all, financially quantified information is tempting to use, and it suggests a high competence of the person who produced the financial numbers (Kadous 2006). We hypothesize that under high mental load decision makers will attach less weight to an attribute not included in the available TCO numbers:

H10: Providing the decision maker with TCO information of alternatives, reduces the weight of an attribute that is not included in the TCO calculation, for high mental load.

If TCO numbers are available, the weight a decision maker attaches to an attribute not included in the TCO numbers is likely to decrease with higher levels of mental load. As formulated above in H10, a decision maker has less cognitive capacity available to process the information available when experiencing a high mental load. In addition, because of the temptation to use the financially quantified information available, we expect that decision makers will show a tendency to ignore the non-financial information; we expect that decision makers will attach less weight to the information not included in the TCO numbers when experiencing a high mental load:

H11: If TCO information is available: the weight a decision maker attaches to an attribute that is not included in the TCO calculation decreases for higher levels of mental load.

In this paragraph, we will present a numerical example to illustrate the theoretical discussion above. Figure 4.1a and 4.1b show a simplified example of a purchasing decision where decision makers have to choose between two alternatives (the same information will be used in the experiments). For each sourcing alternative, we provide decision makers with four attributes: lifetime, uptime, purchase price, and energy consumption. Calculation of the TCO numbers (in terms of total cost per hour) is straightforward for purchase price and energy consumption, but the cost implications of downtime are much harder to determine. Therefore, such an attribute may be excluded from the TCO numbers (see Figure 4.1b). Without TCO numbers (Figure 4.1a) a decision maker has to make a trade-off between four attributes, but when TCO numbers are used (Figure 4.1b) only two attributes are left (the total cost number and Uptime). Compared to the situation without TCO numbers, the excluded attribute is more salient in the situation with TCO numbers. It is unlikely that decision makers will ignore attributes, because they have no reason to assume certain attributes to be less important. With TCO numbers available, making a trade-off between relevant attributes is also easier; only two attributes (TCO numbers and Uptime) have to be compared, while in the situation without TCO numbers four attributes have to be evaluated. Therefore, we predict that the weight a decision maker tends to attach to an attribute excluded from the available TCO numbers will be higher than to an attribute in a situation without TCO numbers.

Figure 4.1 Sourcing information

4.1a no TCO info available

	Brand A	Brand B
Life time (hours)	2,900	2,800
Uptime (%)	99.0%	96.0%
Purchasing price (€)	€ 1,280	€ 1,020
Energy per hour (Kwh)	2.0	2.2

4.1b TCO info available

Energy cost (Kwh) € 0.13

	Brand A	Cost per hour	Brand B	Cost per hour
Life time (hours)	2,900		2,800	
Uptime (%)	99.0%		96.0%	
Purchasing price (€)	€ 1,280	€ 0.44	€ 1,020	€ 0.36
Energy per hour (Kwh)	2.0	€ 0.26	2.2	€ 0.29
Total cost per hour		€ 0.70		€ 0.65

4.2.2 Research method

We used experimental research to test the hypotheses. Participants were asked to choose between two alternative brands of machine which had to be replaced. Figure 4.2 details the text introducing participants to the setting and the information about the alternatives. For each alternative, they received information on lifetime, uptime, purchase price, and electricity usage (see Figure 4.1). The dependent variable is the choice of Brand B, a dummy variable (*Choice B*).

The experiments used a 2 × 2 × 2 between-subjects design. The first factor that was manipulated was the availability of total cost information (*TCO info*), which is a dummy variable: see Figure 4.1a for the information provided without total cost data; Figure 4.1b shows the information including total cost data, which centres on the total cost per hour for each option, based on the purchase price and energy consumption. The total cost number did not include costs associated with the expected uptime of each brand. Thus, “uptime” is the attribute excluded from the TCO numbers.

The second factor was the uptime percentage for Brand B (*Uptime B*), specified at two different levels (99.5% and 96.0%).

Mental load was the third manipulated factor. Many different manipulations are available to create cognitive load. For example, asking decision makers to remember numbers or letters, count pictures appearing on a computer screen or listen to distracting noises while simultaneously performing a second task, or by increasing the differences between the alternatives to be evaluated (e.g., Wijting and Smith 1969, Hutchinson and Alba 1991, Moneith and Voils 1998, Camos and Barrouillet 2004). We manipulated mental load by asking participants in the group with conditions of high mental load conditions to remember a seven-digit number.[32] Remembering information requires rehearsal, and because rehearsal requires cognitive resources less cognitive capacity is available for another task (Gilbert et al. 1988). Participants in the high mental load group had to remember a seven-digit number presented to them before reading the text introducing the TCO numbers. Participants had to reproduce this number later in the experiment. Participants in the group with a low mental load did not have to remember a number, they were only asked to make a sourcing decision; so, they did not have to perform two tasks simultaneously (making a purchasing decision and remembering a number).

The participants (N = 338) were undergraduate students at a West European university. The students were familiar with the basic concepts of cost accounting. The participants performed the task anonymously, in a lab session during which they performed several experimental tasks. We did not pay students for participating in the experiments. Table 4.1 shows the number of participants in each condition.

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[32] We ran two sessions to collect data for this experiment. In both sessions mental load was manipulated by asking participants to remember a seven-digit number. However, in the first session the mental load number was a randomly generated number, while in the second session the mental load number was the same for all participants. As the results from both sessions did not differ (p = .375), we combined the data of both sessions and analysed the results together.

Table 4.1 Number of respondents and choices for Brand B per condition (N = 287)

Mental load		Low		High[1]	
TCO info		No TCO	TCO	No TCO	TCO
Uptime B	96.0%	41 (3)[2]	44 (7)	29 (0)	43 (10)
	99.5%	41 (24)	41 (33)	21 (7)	27 (19)
Total		82	85	50	70

[1] 51 subjects were excluded from this table and from further analysis, they responded incorrectly by filling out the wrong number in the high mental load condition.
[2] Between parentheses: number of respondents choosing Brand B

Figure 4.2 Text introducing the task in experiment 1

"You are the manager of a production department. One machine has to be renewed. You can choose between two brands, both meet all specifications.

In the table below information is provided about: the purchasing price of a new machine, the lifetime of a new machine, energy consumption per hour, and the uptime percentage of the machine. The 'uptime (%)' is the percentage of the time the machine is available for production. 100% – 'uptime (%)' = 'downtime (%)'. Downtime is caused by machine failure, maintenance, etc. that cause rescheduling of production, not meeting delivery times, etc.

(Table with information about the alternatives)

Indicate which brand you will buy: _____"

The interaction of the two independent variables *Uptime B* and *TCO info* allows for the testing of H9 and H10, based on a logistic regression with the following specification:

$$\textit{Choice B} = \beta 1 + \beta 2\ \textit{Uptime B} + \beta 3\ \textit{TCO info} + \beta 4\ (\textit{Uptime B} \times \textit{TCO info})$$

Note that the preference for Brand B is expected to decrease as the uptime of Brand B decreases. For H9, if coefficient β4 is significant and positive, then the effect of Uptime B on the dependent variable will be stronger if participants are provided with TCO numbers, compared to the situation where TCO numbers are not provided. For H10, if coefficient β4 is significant and negative, then the effect of Uptime B on the dependent variable will be weaker if participants are provided with TCO numbers compared to the situation where TCO numbers are not provided.

The interaction of the two independent variables *Uptime B* and *Mental load* allows for the testing of H11, based on a logistic regression with the following specification:

Choice B = β5 + β6 *Uptime B* + β7 *Mental load* + β8 (*Uptime B* × *Mental load*)

Again, the preference for Brand B is expected to decrease as the uptime of Brand B decreases. If coefficient β8 is significant and positive, then the effect of mental load on the dependent variable will be stronger if participants are provided with TCO numbers, compared to the situation where TCO numbers are not provided.

4.2.3 Results

Results of the testing of H9 and H10 are presented in Figure 4.3 and Table 4.2. For low mental load (H9), the coefficient for the interaction effect of *Uptime B* × *TCO info* is not significant (p = .823). For high mental load (H10), the coefficient for the interaction effect *Uptime B* × *TCO info* is not significant either (p = .369).[33] Neither is *Uptime B* × *Mental load* for H11 not significant (p = .198). Consequently, we find no support for the hypotheses H9, H10 or H11.

[33] Results in Table 4.1 show that for one condition (High mental load, Uptime 96%, No TCO) no participant chose Brand B. This is problematic for logistic regression analysis, since this leads to a division by zero in the equation of the odds ratio p / (1 – p). This results in inefficient estimation of the parameters in the model, but it is not known to result in biased parameters or in inaccurate (as opposed to inefficient) inferences (Menard 1995 page 69). There are no standard solutions for this problem. Hosmer and Lemeshow (1989) and Menard (1995) suggested the following approaches for handling a zero cell: accepting the high standard errors and the uncertainty about the values of the logistic regression coefficient, recoding the categorical independent variable in a meaningful way (either by collapsing categories or by eliminating the problem category) to eliminate the problem of zero cell count, and adding a constant to each cell of the contingency table to eliminate zero cells. In this study, we applied this last solution and added .5 to each cell in the contingency table (see also, Hosmer and Lemeshow 1989, Agresti 1990).

Figure 4.3 Results from experiment 1(N = 287)

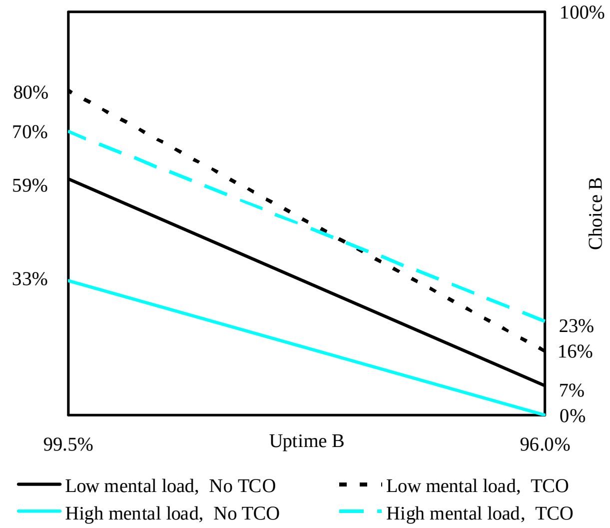


Table 4.2 Logistic regression results for testing H9, H10 and H11

Choice B is the dependent variable[1]	H9	H10	H11
Constant	-1.123[2] (.001)	-2.710 (.002)	-.313 (.279)
Uptime B	.029 (.000)	.035 (.022)	.031 (.000)
TCO info	.971 (.029)	2.346 (.010)	
Mental load			.022 (.956)
Uptime B × *TCO info*	.002 (.823)	-.015 (.369)	
Uptime B × *Mental load*			-.010 (.198)
N	167	120	155

[1] Three-way interaction (after adding Mental load as a third independent variable), Uptime B × TCO info × Mental load, results in p = .375.
[2] Values of coefficients (and p-values for two-tailed Wald test).

4.2.4 Discussion of results

In this section, we discuss the results that of experiment 1. A general discussion can be found at the end of this chapter.

Providing TCO numbers does not seem to change the weight decision makers attach to information not included in TCO numbers; decision makers seem to attach the same weight to an attribute whether excluded from the TCO numbers or in a situation without TCO numbers. The insignificant regression results for *Uptime B* × *TCO info* (see Table 4.2) indicate that the provision of TCO information does not change the weight decision makers attach to an attribute excluded from the TCO information. We have no information available to provide additional insight in the adopted decision strategies. Nonetheless, one possible explanation might be that decision makers tend to ignore attributes we provided TCO information for; they might have adopted a decision strategy where they compared both sourcing alternatives on uptime and not on other attributes. This might have been the result of stressing the importance of uptime too much in the text introducing the sourcing alternatives (Figure 4.2). In a new experiment, we could stress the importance of including all attributes in decision-making. Then, decision makers may be more tempted to make a trade-off between the attributes.

The importance of comparing TCO numbers with the attribute for which costs are difficult to calculate may be stressed by presenting an (inaccurate) estimation of the downtime costs. Decision makers will clearly see that downtime costs are not accurately included into the TCO numbers and that the transformation of the Uptime attribute in costs may significantly influence total costs. Decision makers may then become more aware of the importance of costs and make a trade-off between the accurate TCO numbers and the attribute for which costs are inaccurately estimated. Below, we will discuss an experiment where some attributes presented as a range.

4.3 Experiment 2

Information that is hard to quantify does not necessarily need to be excluded from TCO numbers (like in experiment 1). Even if it is not possible to quantify costs exactly, it may still be possible to estimate cost numbers. Experts may estimate cost numbers for attributes that are difficult to quantify financially. For example, experts may estimate the minimum or maximum cost of a certain attribute (like in Chapter 3). However, presenting the estimation as a single cost number (e.g., € 7) may be inappropriate; it may inappropriately suggest high accuracy of the cost number. In these cases, it may be better to make the uncertainty in cost numbers more obvious by indicating that the estimated number may vary between a lower and upper limit (e.g., € 2.00 – € 12.00). In this study, we research whether decision makers weigh the lower and upper limit of a cost range equally, or if they attach more weight to one of the range's limits.

4.3.1 Hypotheses development

If the costs of an attribute are specified within a range, the attribute is likely to receive more weight in the decision-making process than to when costs for this attribute are estimated as a single point. Creyer and Ross (1988) found the relative weight of an attribute to increase if the range of this attribute increases, (i.e., decision makers attach more weight to attributes with a greater range). That is, decision makers attach more weight to an attribute for which the cost range is € 2 – € 10 than if this is € 4 – € 6. Creyer and Ross (1988) also found support for the hypothesis that decision makers perceive an attribute to be more important as it has a greater range.[34] Therefore, we predict that costs of an attribute specified within a range will receive more weight, compared to costs presented as a single point.

The effect of ranges can also be motivated based on Prospect theory. Kahneman and Tversky (1979) state that losses loom larger than equivalent gains. For decision makers who calculate expected costs, they may feel they "earn" € 5 when costs turn out to be € 2 instead of the expected € 7, and "loose" € 5 if costs turn out to be € 12. Decision makers will likely attach more weight to a loss of € 5 than to a gain of € 5, as humans attach more weight to losses compared to equivalent gains. Hence, a decision maker may tend to estimate costs to be higher than € 7 to reduce the negative feeling in the case real costs turning out higher than expected.. For example, a decision maker who assumes that costs will be € 10 reduces the possible negative feeling of loosing to € 2 (if the price turns out to be € 12) and increases the possible feeling of earning to € 8 (if the price turns out to be € 2). However, this implies that an alternative gets less attractive, compared to an alternative with fixed costs. Therefore, specifying costs as a range reduces the attractiveness of alternatives, and decision makers are assumed to choose an alternative for which costs are formulated within a range less frequently.[35]

[34] Kahn and Sarin (1988) found a similar effect for ambiguity in probabilities (e.g., a probability between .3 and .7); decision makers take other decisions if there is ambiguity compared to situations without ambiguity, even if the expected risk is the same in both situations.

[35] The relative difference with other alternatives also influences the attractiveness of an alternative. A range does influence the relative attractiveness of alternatives. For example, a weight of 60 grams is judged as light when it is compared to a range of weights from 50 – 100 grams, a typical contrast effect (Janiszewski and Lichtenstein 1999). Moreover, adding an anchor to the endpoints of a range of values will result in judgments in the direction of the anchor (Sherif et al. 1958). While placing an anchor further away from the endpoints will result in constriction of the range (Sherif et al. 1958). Therefore, the upper limit of a range will get more attention if an anchor is close to this upper limit. And visa versa, the lower limit will get more attention if the anchor is close to the lower limit of the range. In our experiment, a range is given for the costs of the Downtime and Scrap attributes of Brand A (see figure 4.4b). Decision makers who compare these

The effect can be even stronger if decision makers focus on the upper limits of the cost range. Human decision makers are generally motivated to spend as little cognitive effort as possible on solving a problem (Payne et al. 1993). As decision makers have to take more steps to evaluate alternatives, the task becomes more complex (Bonner 1994). Range information is more difficult to process than costs in single point. Decision makers have to evaluate the range information, decide how to weight the upper and lower limits and subsequently calculate the expected cost of the range. As decision makers prefer to limit their cognitive effort they will try to limit the mental effort necessary to evaluate the costs. Therefore, we predict that decision makers prefer to focus on the limits of the range and do not calculate the expected cost.

This paragraph will illustrate the theoretical discussion above with a numerical example. Figure 4.4 shows an example of the information we used in the experiments. In this example, costs per hour for downtime and scrap were hard to quantify and therefore estimated by experts. Costs for downtime and scrap were either given as single points (Figure 4.4a) or as ranges (Figure 4.4b). Note that no information about the probability distribution is provided. Hence, there are no obvious reasons to assume a skewed distribution with an expected value other than the middle point of the range. According to the "principle of insufficient reason" (Baron 2000), decision makers can make all kinds of assumptions, but if a decision maker has no reasons to assume that one event is more likely than another, then a decision maker should consider the events to be equally likely. Accordingly, expected costs for downtime and scrap in Figure 4.4b are equal to the numbers in the point estimation. For example, the range of cost for downtime of Brand A, € 2.00 – € 12.00, has an expected value of € 7.00. Hence, based on expected values, the decisions for Brand A or B should be identical whether cost information on downtime and scrap is provided as a range or as a point. Note that total expected costs for Brand A are € 34 (€ 22 + € 7 downtime + € 5 scrap) while for brand B these are € 35 (€ 26 + € 6 downtime + € 3 scrap). Nonetheless, as we described above decision makers may attach more weight to the upper limit of the range.

attributes for Brand A and Brand B see that costs for Brand B are closer to the lower limit of the cost range than to the upper limit. Therefore, costs for Brand B may be perceived as relatively low compared to costs for Brand A. Hence, the cost range in our experiment reduces the attractiveness of Brand A and increases the attractiveness of Brand B. We admit that this effect is the result of our design choice, and would be different for another design.

Figure 4.4 Information provided for decision-making the experimental task

4.4a TCO table and estimated costs for Brand A as points

Labour cost per operator (€/uur)	€ 30.00
Electricity price (€/kwh)	€ 0.15
Chemicals (€/liter)	€ 6.00

	Brand A	Cost/hour	Brand B	Cost/hour
Lifetime (hours)	2,900		3,000	
Component A (€)	€ 8,900	€ 3.07	€ 11,000	€ 3.67
Component B (€)	€ 8,700	€ 3.00	€ 11,500	€ 3.83
Component C (€)	€ 8,800	€ 3.03	€ 11,400	€ 3.80
Component D (€)	€ 8,700	€ 3.00	€ 11,100	€ 3.70
Inspection time (min/hour)	6.0	€ 3.00	7.0	€ 3.50
Energy (kwh/hour)	22.0	€ 3.30	26.0	€ 3.90
Chemicals (liter/hour)	0.6	€ 3.60	0.6	€ 3.60
Cost/hour		€ 22.00		€ 26.00
Downtime (%)	3%	€ 7.00	1%	€ 6.00
Scrap (‰)	2‰	€ 5.00	1‰	€ 3.00

4.4b: TCO table and estimated costs for Brand A as ranges

Labour cost per operator (€/uur)	€ 30.00
Electricity price (€/kwh)	€ 0.15
Chemicals (€/liter)	€ 6.00

	Brand A	Cost/hour	Brand B	Cost/hour
Lifetime (hours)	2,900		3,000	
Component A (€)	€ 8,900	€ 3.07	€ 11,000	€ 3.67
Component B (€)	€ 8,700	€ 3.00	€ 11,500	€ 3.83
Component C (€)	€ 8,800	€ 3.03	€ 11,400	€ 3.80
Component D (€)	€ 8,700	€ 3.00	€ 11,100	€ 3.70
Inspection time (min/hour)	6.0	€ 3.00	7.0	€ 3.50
Energy (kwh/hour)	22.0	€ 3.30	26.0	€ 3.90
Chemicals (liter/hour)	0.6	€ 3.60	0.6	€ 3.60
Cost/hour		€ 22.00		€ 26.00
Downtime (%)	3%	€ 2.00 - € 12.00	1%	€ 6.00
Scrap (‰)	2‰	€ 2.00 - € 8.00	1‰	€ 3.00

To summarize, we predict that attributes for which costs are specified in a range receive more attention compared to attributes for which costs are specified in a point. Formulated in a hypothesis:

H12: Decision makers attach more weight to the cost number at the upper limit of a range, and less to the cost number at the lower limit of this range, compared to decision makers for whom cost are presented in a point.

We also expect a moderating effect of mental load on the weight decision makers attach to the limits of the range. Mental load may strengthen the effect of H12; mental load increases the weight a decision maker attaches to the cost number at the range's upper limit. High mental load reduces decision makers' cognitive capacities; fewer cognitive resources are available to evaluate the sourcing alternatives and to decide which alternative is best. Decision makers who do not have enough cognitive capacity left because of a high mental load may focus mainly on the range's limits, even more so than decision makers who experience low mental load. We assume that there is a tendency to focus on the upper limit (as predicted by prospect theory), and that this is the result of higher levels of mental load. We predict an interacting effect of mental load and the processing of range information:

H13a: Decision makers attach more weight to the cost number at the upper limit of a range than to the cost number at the lower limit of this range, and this effect is strengthened by higher levels of mental load.

On the other hand, high mental load may lead decision makers to pay less attention to attributes that are too difficult to process. Range information is more difficult to process than cost information as points. If the cognitive abilities of decision makers are stretched to a maximum by increasing the mental load, decision makers may not be able to include the information that is difficult to process in the decision-making process. As said before, decision makers should carefully evaluate which information is attributes are aggregated in the TCO numbers and which attributes are not. Only after analyzing which attributes are (not) included in the TCO numbers will a decision maker be able to weight the attributes properly. As a result, decision makers may show a tendency to ignore information and mainly focus on the information they can process easily; that is, the objectively calculated cost numbers. Such a strategy reduces the cognitive effort necessary to process the sourcing information. Therefore, opposite to H13a:

H13b: Decision makers attach more weight to the cost number at the upper limit of a range than to the cost number at the lower limit of this range; this effect is, however, weakened by higher levels of mental load.

4.3.2 Research method

We ran this experiment twice; once on a computer in a laboratory and once in a class-room without computers. Therefore, we had to use different methods to manipulate mental load (see below). Participants had to choose between two alternatives to replace a machine in their production facility. Participants received cost per hour information for all attributes of both alternatives (see Figure 4.4 for an example). In the introductory information participants learned that experts had estimated the cost of two of the attributes for which cost per hour was difficult to calculate for (i.e., scrap and downtime). These attributes were presented separately underneath the TCO table (see Figure 4.3). We did not include these estimated numbers in the total cost numbers to stress that the cost numbers for these attributes were somewhat different. The dependent variable in both experiments was the choice of one of the alternatives (*Choice A*).

We used a 2 × 2 between subjects design. *Range* was the first independent variable we manipulated on two levels (Point, Range). In the point condition downtime cost per hour and scrap cost per hour for Brand A were estimated to a point (See Figure 4.4a). In the range condition these costs were presented as a range (See Figure 4.4b).

Mental load was the second independent variable we manipulated on two levels (low, high). Mental load was manipulated differently for the class-room experiment to the computer facilitated laboratory experiment. In the class-room experiment, we manipulated mental load by asking participants to sum numbers in their head. Counting is a demanding task, consuming cognitive resources of the working memory (Camos and Barrouillet 2004). Participants were first asked to read the instructions for the experiments, and thereafter the introduction to the TCO table (see Figure 4.5). Mental load was created after the participants finished reading this information. Therefore, mental load did not influence the ability to interpret the instructions on the introduction to the TCO table. Participants had three minutes to evaluate the information in the TCO table and make a sourcing decision (no other questions were asked during this experiment).

In the computer laboratory, mental load was created by asking participants to remember a six-digit number. We introduced the mental load after participants finished reading the instructions and introduction to the experiment (see Figure 4.5). Therefore, the mental load did not influence participants' ability to interpret the instructions or the introduction to the TCO table. Consequently, participants in both groups, with a low as well as a high mental load, were able to interpret the instructions and information to the same extent. In the low mental load conditions participants were asked to memorize 123456, a number that does not require much working memory to remember. The participants in the high mental load conditions were asked to remember 342615; a number that was much more difficult to remember.[36] Participants had seven seconds to memorize the six-digit number. Thereafter, the participants had to answer four questions under mental load. First, the participants had to choose which alternative they would purchase. Secondly, they had to indicate their estimation of the cost per hour for scrap and downtime. Finally, the participants had to write down their decision strategy. After these four questions, the participants had to enter the mental load number they were supposed to remember.

Figure 4.5 Text introducing the task in the experiment

You are the manager of a production department. One machine has to be renewed. You can choose between two brands, both meet all specifications.

In the table below information is provided about:

- o Lifetime of a new machine
- o Purchasing price of a new machine
- o Time an employee needs to operate the machine
- o Energy consumption per hour
- o Amount of chemicals needed
- o Uptime percentage of the machine
- o Scrap permillage

Downtime (%) is the time the machine is not available for production. 100% – uptime (%) = downtime (%). Downtime is caused by machine failure, maintenance, changing tools, etc. As a result of downtime, production schedules have to be renewed, delivery times cannot be reached, overtime has to be done, etc.

The product is checked after production. Scrap (‰) gives the permillage of rejected products. Scrap is caused by deviances in the material, wrong adjusted machines, dust particles disturbing the production process, etc. In case low quality products are delivered, in spite of quality checks, customers can ask for compensation or move to a competitor.

Both cost/hour for downtime and scrap are hard to determine. Consulted experts estimated these cost/hour numbers.

The main effect of *Estimation* allows testing of H12. Hypothesis H12 predicts that decision makers will attach more weight to the upper limit of a range. This means that participants assume that costs are higher for an alternative for which costs are estimated to be in a range (i.e., Brand A in our experiment), compared to when these costs are estimated in a point. Therefore, an alternative

[36] A pilot study indicated that 99.1% (N= 106) remembered 123456 correctly in the low mental load condition, while only 71.7% (N = 127) remembered 342615 correctly in the high mental load condition.

(i.e., Brand A) gets less attractive if costs are estimated in a range, compared to when these costs are estimated in a point. As a result, the relative number of participants choosing Brand A should decrease if costs for Brand A are estimated to be in a range, compared to when these costs are estimated to be a point. We use a logistic regression equation with the following specification to test H12:

H12: $\textit{Choice A} = \beta 1 + \beta 2\ \textit{Estimation}$

For H12, we can say that if coefficient β2 is significant and negative, then the effect of ***Estimation*** on the dependent variable is larger, and indicates that less decision makers will choose brand A if costs are presented as a range instead of as a single point.

The interaction of the two independent variables ***Estimation*** and ***Mental load*** allows for testing of H13. Logistic regression with the following specification is used to test this hypothesis:

H13: $\textit{Choice A} = \beta 3 + \beta 4\ \textit{Estimation} + \beta 4\ \textit{Mental load} + \beta 6\ (\textit{Estimation} \times \textit{Mental load})$

For H13, we can say that if the preference for Brand A decreases more strongly in the high mental load condition compared to in the low mental load condition, which is indicated by coefficient β6 of the interaction term ***Estimation* × *Mental load***, the weight of the attribute ***Estimation*** is higher for high than for low levels of mental load. This indicates that participants attach more weight to the upper limit of the range under higher levels of mental load (H13a). A significant and positive coefficient β6 indicates the opposite (H13b).

Participants were undergraduate students from two West European universities; all students (202 students in the class-room experiment, and 171 students in the laboratory experiment) were familiar with the basic concepts of cost accounting. Participants were randomly assigned to one of the experimental conditions, and each participant participated only once. Table 4.3 shows the number of participants in the various conditions. All participants were included in the regression analysis to test H12 (see Table 4.3a). To test H13, only participants who filled out the correct mental load number were included in the regression analysis (see Table 4.3b).

Table 4.3 Total number of respondents and choices per condition for testing hypothesis H12 and H13

4.3a hypothesis H12

		Class-room	Laboratory
Estimation	Point	100 (55)[1]	99 (40)
	Range	102 (54)	72 (28)
Total		202	171

[1] Between parentheses: number of respondents choosing Brand A.

4.3b Hypothesis H13

		Class-room (N = 143)		Laboratory (N = 158)	
Mental load[1]		Low	High	Low	High
Estimation	Point	47 (25)[2]	25 (15)	41 (18)	26 (8)
	Range	50 (27)	21 (10)	58 (22)	33 (16)
Total		97	46	99	59

[1] 59 participants in the class-room experiment and 13 in the laboratory experiment are excluded from the table above and further analysis of H13, they responded incorrectly by reproducing the wrong number in the high mental load condition.
[2] Between parentheses: number of respondents choosing Brand A.

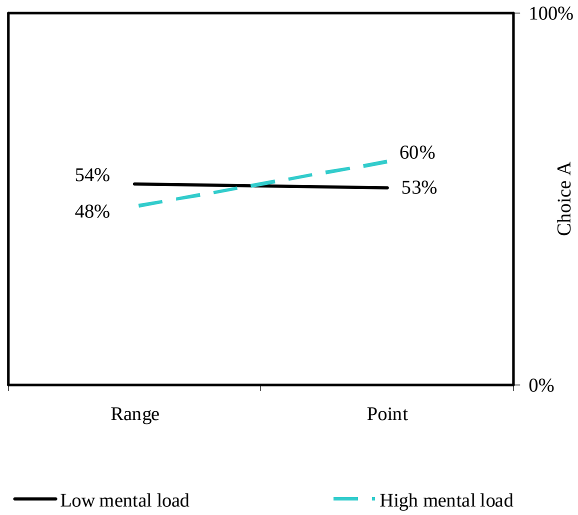
4.3.3 Results

Results for H12 are presented in Figure 4.6 and Table 4.4. The coefficient indicating the effect of *Estimation* was not significant (Class-room experiment, $p = .769$; Laboratory experiment, $p = .808$). Hence, we found no support for hypothesis H12.

Results for H13 are also presented in Figure 4.6 and Table 4.4. The coefficient for the two-way interaction term *Estimation* × *Mental load* was not significant (Class-room experiment, $p = .538$; Laboratory experiment, $p = .147$). Therefore, no support was found for hypothesis H13 either.

Figure 4.6 Experimental results

4.6a Class-room experiment (N = 143)



4.6b Laboratory experiment (N =158)

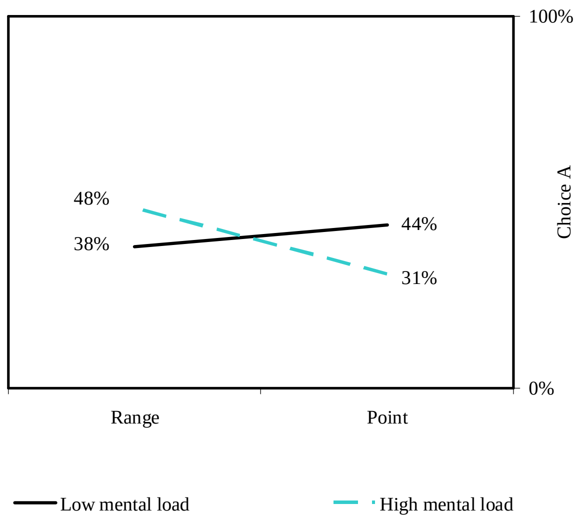


Table 4.4 Logistic regression results for testing H12 and H13

Choice A is the dependent variable	Class-room		Laboratory	
	H12[1]	H13	H12[2]	H13
Constant	.201 (.318)	.083 (.773)	-.370 (.125)	-.245 (.436)
Estimation	-.083 (.769)	.077 (.849)	-.077 (.808)	-.247 (.551)
Mental load		.427 (.403)		-.566 (.285)
Estimation ´ Mental load		-.683 (.349)		-.998 (.147)
N	202	143	171	158

Values of coefficients (and p-values for two-tailed Wald test)

[1] A specification including Mental load as an independent variable was also estimated (we included all participating students). Because the Chi-square difference was not significant (χ^2d =.362, df = 2, p = .834), we estimated the coefficient for Estimation using the empirical specification provided in the table above.
[2] A specification including Mental load as an independent variable was also estimated (we included all participating students). Because the Chi-square difference was not significant (χ^2d =.441, df = 2, p = .802), we estimated the coefficient for Estimation using the empirical specification provided in the table above.

4.3.4 Discussion of the results

We conducted a further analysis to investigate the results of the laboratory experiment. Decision makers gave a written explanation of their decision strategy. Because high mental load reduces the cognitive capacity, high mental load is assumed to result in a less complex decision strategy for the sourcing decision. We used three proxies for decision strategy complexity: (1) the number of words used to describe the decision strategy (*Words*), (2) the number of attributes mentioned in the description of the decision strategy (*Attributes*), and (3) a categorical variable (*Mentioned*) to split the participants into those who did mentioned scrap and/or downtime, and those who did not. We assumed that decision makers under a high mental load would use fewer words and attributes to describe their decision strategy and might not mention the inaccurately included attributes in their description.

Including the variable *Words* as a third independent variable in the logistic regression equation for H13[37] did not result in significant regression coefficients; neither the coefficient for *Estimation* × *Mental load* × *Words* (p = .187) nor the

[37] The logistic regression equation if *Words* is added as a third independent variable: *Choice A* = β1 + β2 *Estimation*+ β3 *Mental load*+ β4 *Words* + β5 (*Estimation* × *Mental load*) + β6 (*Estimation* × *Words*) + β7 (*Mental load* × *Words*) + β8 (*Estimation* × *Mental load* × *Words*).

coefficient for *Estimation* × *Mental load* (p = .916) was significant. Including the variable *Attributes* as a third independent variable in the logistic regression equation for H13[38] did not result in significant regression coefficients; neither the coefficient for *Estimation* × *Mental load* × *Attributes* (p = .259) nor for *Estimation* × *Mental load* (p = .085) was significant.

The third proxy *Mentioned* was used to split the participants into two groups: (1) participants who mentioned downtime and/or scrap in the description of their decision strategy and (2) participants who did not mention these attributes. Subsequently we used H13 to test for the significance of *Estimation* × *Mental load* for both groups. Figure 4.7a shows the results for participants who used the Downtime and/or Scrap attributes to describe their decision strategy. For low mental load, the weight participants attached to the inaccurately included attributes decreased if costs were presented as a range, compared to when these were given as a single point. For high mental load, participants responded in the opposite way to the participants in the low mental load condition; participants attached more weight to the upper limit of the range compared if costs were presented as a range. However, the coefficient for the interaction *Estimation* × *Mental load* for participants who mentioned scrap and/or downtime was not significant (N = 108; p = .139). Decision makers who did not refer to these attributes in their decision strategy responded similar (Figure 4.7b). The coefficient for the interaction *Estimation* × *Mental load* was not significant (N = 50; p = .766). Although these results were not significant, Figure 8a suggests that decision makers who adopted a more demanding strategy were influenced by high mental load, while decision makers who did not adopt a demanding strategy did not experience mental load in their decision-making.

[38] The logistic regression equation if *Attributes* is added as a third independent variable: *Choice A* = β1 + β2 *Estimation*+ β3 *Mental load*+ β4 *Attributes* + β5 (*Estimation* × *Mental load*) + β6 (*Estimation* × *Attributes*) + β7 (Mental *load* × *Attributes*) + β8 (*Estimation* × *Mental load* × *Attributes*).

Figure 4.7 Analysis of strategies written down

Figure 4.7a Scrap and/or downtime mentioned (N = 108)

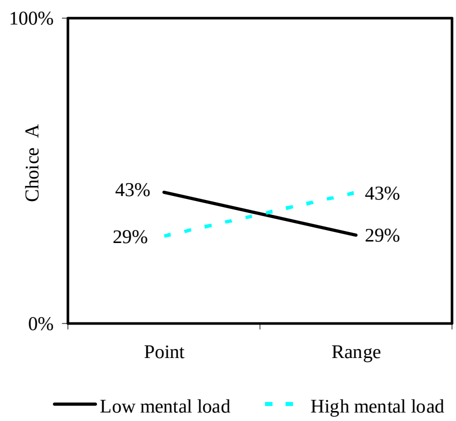
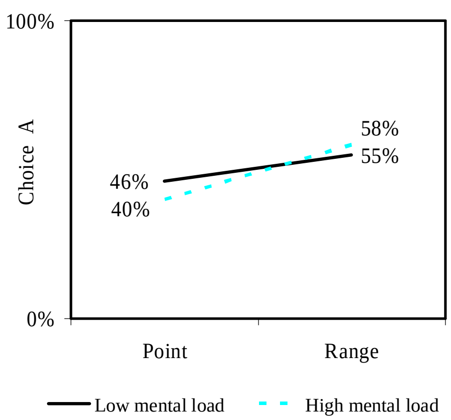


Figure 4.7b Scrap and/or downtime was not mentioned (N = 50)



Decision makers were asked to give their own estimation of the expected downtime and scrap cost per hour. Participants' mean estimation of downtime cost per hour for the single point was € 1,852 (N = 70), and € 81 (N = 98)[39] for the range. A t-test indicated that these mean estimations of downtime cost per hour were significantly different (p = .001). Participants' mean estimation of scrap cost per hour in the single state condition was € 2,381 (N = 70), and € 163 (N = 99) for the range condition. A t-test indicated that these mean estimations of scrap cost per hour were significantly different (p = .003).[40] Although estimations of costs per hour are high, participants' estimations of costs per hour for the range condition were small compared to the estimations of cost per hour in the single point condition. Participants were randomly assigned to a group which assured that the findings were not the result of differences in group characteristics. These results indicated that decision makers made a more conservative estimation of costs when costs per hour were presented as a range compared to when these costs were presented as a single point. These results also indicated that participants thought that the costs at the upper limit were more realistic compared to costs at the lower limit of the range. Therefore, as predicted in H12, these results do indirectly provide support for the hypothesis that decision makers show a tendency to attach more weight to the upper limit of a cost range compared to the lower limit.

To summarize, the results did not indicate that decision makers adopt another strategy when they had to make a decision under high mental load. Therefore, similar to the first experiment, decision makers seemed to be able to handle several tasks simultaneously. Mental load did not significantly influence decision-making. Besides this, decision makers seemed to be able to handle uncertainty in cost numbers. Their decisions were not influenced if cost information was given in a range; participants did not seem to make better decisions if costs were presented as a range compared to presenting them as a point. A clearer representation of uncertainty did not change the weight decision makers attached to cost information. It did not seem necessary to make uncertainty more explicit in the TCO numbers.

[39] Not all participants gave an estimation of the cost per hour of downtime and scrap; three participants did not give an estimation of the downtime cost per hour, and two participants did not give an estimation of the scrap cost per hour.

[40] In a similar t-test we divided participants by the mental load condition (low, high mental load). For downtime cost per hour, participants' mean estimation of downtime cost per hour in the low mental load condition was € 1,126 (N = 96) and in the high mental load condition € 1,036 (N = 72). A t-test did not indicate that these means were significantly different. For scrap cost per hour, participants' mean estimation of scrap cost per hour in the low mental load condition was € 853 (N = 97) and in the high mental load condition € 762 (N = 72). A t-test did not indicate that these means were significantly different.

4.4 Concluding remarks

We conducted experiments to investigate the impact of mental load on the weight decision makers attach to attributes in a sourcing decision. We found no support for our hypotheses; that is, we could not conclude that high mental load significantly influenced the weight decision makers attached to attributes for which costs were difficult to include in TCO numbers accurately. We found no support for the hypothesis H9 concerning low mental load; where TCO information was available, decision makers did not attach more weight to the attribute that was not included in the TCO numbers. Neither did we find support for the premise that decision makers under high mental load would attach less weight to this attribute where TCO numbers were available. In addition, we found no support for hypothesis H12 or H13. We found no support for the hypothesis that a range made an alternative less attractive or that the weight decision makers attached to the upper limit of a range changed as a result of mental load.

We found no support for the hypotheses H9, H10 or H11 in experiment 1. Although high mental load should have made it more difficult to trade-off TCO numbers against the attribute excluded from the TCO numbers, we found no support for this premise. One reason may have been that the task was too simple. Even under high mental load, participants' cognitive resources may have been large enough to make the necessary trade-offs. In a new experiment, a more demanding mental load task (e.g., asking participants in the high mental load condition to remember a ten-digit number) may decrease cognitive capacity available. Then, decision makers in the high mental load conditions may not able to make the same trade-off anymore as participants in low mental load conditions. Increasing the complexity of the purchasing task is another possibility to make the sourcing decision cognitively more challenging (see also Bonner (1994) for a discussion about task complexity). For example, increasing the number of sourcing alternatives makes it more complicated to make a trade-off between TCO numbers and the information excluded from these numbers. Under high mental load, decision makers may show a higher tendency to ignore information not included in TCO numbers. Thus, by increasing mental load or the task complexity support may be found for our hypotheses.

We found no support for our hypotheses (H12 and H13) about the impact of ranges on judgment and decision-making. However, results of the laboratory experiment indicated that decision makers attach more weight to the upper limit of a range than to the lower limit. Therefore, decision makers should carefully interpret attributes for which cost is presented as a range, especially under high mental load. A more realistic representation of the uncertainty surrounding the costs of certain attributes may be misleading and result in an overestimation of costs.

Although our results were not significant, we do learn from these experiments. Mental load did not significantly change the weight decision makers attached to the attributes that were inaccurately or not included in TCO numbers. Given our levels of mental load, cost information did not seem to be more persuasive under high mental load than under low mental load. Decision makers seemed to be able to do two cognitive challenging tasks simultaneously. However, the level of mental load may have been too low, or the combination of both tasks may have not been challenging enough. Furthermore, mental load of a (purchasing) task in real life is much higher, compared to the level of mental load in our experiments. Therefore, our findings may have been the result of relatively low levels of mental load. New experiments may further investigate up to which level of mental load decision makers are able to handle multi-attribute purchasing decisions.

Another theoretical interesting implication is related to the presentation of cost numbers. Some of the cost numbers were hard to calculate accurately and were presented as estimations made by experts. We asked participants to give their estimation of cost per hour for these attributes. The experts' estimation of cost per hour was either presented as a single point, or as a range (the expected cost per hour of the range equaled the single point cost per hour). Participants' estimations of the costs of an attribute were much higher if the cost was presented as a single point, than if costs were presented in a range. This indicates that it is important to think about the format in which cost is presented; a different format may result in totally different cost estimations, and influence the outcome of (sourcing) decisions dramatically. New experiments may further investigate the impact of the cost number format on cost estimation.

Several limitations should be mentioned. Firstly, we would have preferred to conduct all experiments on computers. For practical reasons (i.e., no availability of a laboratory with computer facilities), we had to run one experiment in a classroom with hardcopies. Therefore, the execution of this experiment was less structured than the experiment using computers. Nonetheless, it was a well-designed experiment where we could use the same conditions throughout and manipulate participants effectively, which is preferable to not running an experiment because of a lack of computer facilities.

Secondly, we were not able to investigate the impact of experience. Do experienced decision makers respond similarly to students, or does their experience in business help them to handle the mental load better? After running the class-room experiment with students on paper we had hoped to be able to repeat this later under similar circumstances with practitioners (alas, time restrictions made this not possible). For practical reasons it would be too difficult to ask practitioners to come to a computer equipped laboratory.

Future research may unravel the questions asked in this chapter. Firstly, an experiment may investigate how under different levels of mental load experienced decision makers would weigh the information that is not (or inaccurately) included in TCO information. Experienced decision makers may attach different weights to financially quantified information; practitioners' knowledge about the difficulties of quantifying information into cost, and about the weight attached to financial information received in business may make them weigh inaccurate information differently compared to the students in our experiments (see also Chapter 2 and 3).

The persuasiveness of quantified information (that is initially non-quantitative) depends on the expertise of the person who quantified the numbers (Yalch and Elmore-Yalch 1984). For example, information given by an expert is trust worthy and decision makers tend accept it without questioning it. One of our participants wrote[41], "Since I don't know anything about technology, I assume the specialists made a good estimation." Therefore, results may have been different if less experienced managers had provided the estimations for the cost per hour information. New experiments may investigate whether the source of information influences the weight decision makers attach to the inaccurate cost information.

[41] Although we did not ask for comments some participants made a few remarks on their answer sheet.

5 General Conclusions

This final chapter will give a summary of the main findings and contributions to literature. We will also highlight managerial implications, and discuss limitations and make suggestions for future research. Specific issues related to each study can be found in the preceding chapters.

5.1 Theoretical key contributions

Before highlighting the key contributions, we will briefly summarize the motivation behind this research project. Purchasing is an important cost factor in today's business (Ellram and Siferd 1998, Degraeve and Roodhooft 2001). Decision makers should look beyond the initial purchasing costs. After all, the initial purchasing costs are often only a fraction of the total costs that result from a sourcing decision. Decision makers may calculate TCO numbers to gain insight in the total costs associated with purchasing a product. However, accurately calculating TCO numbers is complicated and it is likely that these numbers are inaccurate. Inaccuracy may result from the problems of quantifying non-financial information (e.g., service) into cost numbers, difficulty finding the information necessary to calculate cost numbers, because this information is not available at the relevant level (e.g., logistic cost information may be available at business unit level, but not at the individual product level), et cetera. Although TCO numbers may support decision-making by reducing decision complexity and easing comparison between alternatives, it may also result in unintended side-effects: decision makers may be tempted to ignore information that is not or inaccurately included in the presented TCO number. After all, the use of financial information is tempting (e.g., Schiff 1996, Kadous et al. 2006) and it is generally assumed that decision makers minimize the cognitive effort necessary and adapt their decision behavior to the specific circumstances (Payne et al. 1993). We researched the interactive effect of providing inaccurate cost numbers and variables like decision complexity, reflective thinking and mental load on the weight decision makers attach to the attribute that is not (or inaccurately) included in the TCO number. We researched questions that form part of the fundamental issues in accounting: the cost and benefits of aggregating information and of financial versus non-financial information.

The experimental results were mixed; we found support for several hypotheses, but not for all. We contributed to research with the following findings:

- *Low decision complexity results in more weight for an attribute not included in the TCO numbers*. Our results from testing hypothesis H1 (Chapter 2) showed that when TCO numbers were provided and decision complexity was low, students attached more weight to an attribute not included in the TCO number.
- *High decision complexity results in less weight for an attribute not included in the TCO numbers*. Our results from testing hypothesis H2 (Chapter 2) showed that practitioners attached significantly less weight to an attribute not included in the TCO number, when TCO numbers were provided and decision complexity was high.
- *Reflective thinking results in more weight for the attribute inaccurately included in the TCO numbers*. Decision makers who reflected up on an attribute that was included as a minimum in TCO numbers attached significantly more weight to this attribute, compared to decision makers who did not (see H4 in Chapter 3).
- *More experienced decision makers attach more weight to the TCO numbers, compared to less experienced decision makers.* Experience was an important moderating variable that explained the weight decision makers attached to information that was not included in TCO information (see H2 in Chapter 2, and H7 in Chapter 3). These results showed that we have to be careful not to generalize results.

These findings support our ideas behind the experiments in this thesis; information not included in cost numbers is lost if cost information is provided and: (1) decision makers do not reflect on the cost information that is included as a minimum in the cost information, (2) experienced decision makers are confronted with high information complexity, and (3) decision makers have more professional experience.

Besides these findings, we contributed to research by conceptualizing different methods to represent inaccuracy in cost numbers, something we did not find in research so far. We made the inaccuracy in cost numbers visible by: (1) excluding one attribute from the presented TCO numbers, (2) including an attribute as a minimum or (3) as a maximum, and (4) by presenting cost attributes as a range. Table 5.1 shows the results and methods of conceptualizing inaccuracy in each of the chapters.

Although we cannot formulate conclusions as it comes down to the quality of the decision, we do think that the quality of a decision is higher if a decision maker carefully evaluates the attributes available, and makes a thoughtful trade-off between the attributes available. Based on our results, we think that decision makers take better decisions if the amount of information they have to evaluate is limited and if they reflect on the information available. As our results show that more experienced decision makers tend to ignore information that is not included in the TCO number, we recommend that they discuss their decision with less experienced decision makers (who attached more weight to the attributes not (or inaccurately) included in the TCO number).

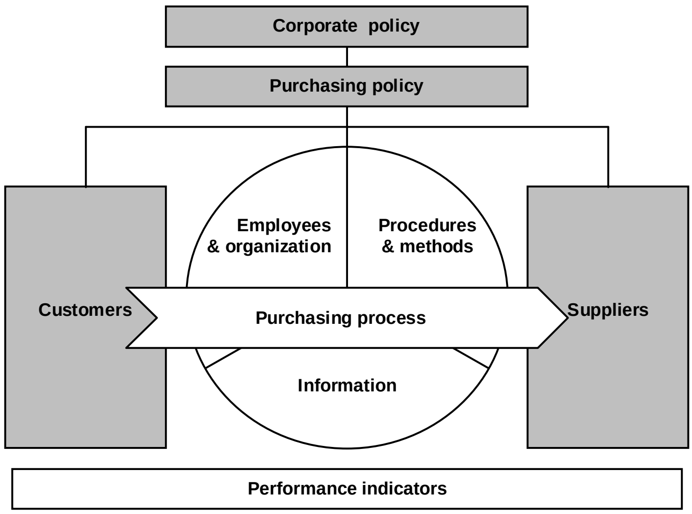
Table 5.1 Hypotheses and results

Conceptualization of inaccuracy in TCO numbers	Complexity experiments (N = 1,028), Chapter 2			Reflective thinking experiments (N = 358), Chapter 3	Mental load experiment (N = 711), Chapter 4	
	First experiment		Second experiment			
	(Low complexity)	(High complexity)	(Low complexity)		(Low mental load)	(High mental load)
Excluded	Students: *(No TCO* vs. *TCO)* Hypothesis 1: + Result: not significant	**Students:** ***(No TCO* vs. *TCO)*** **Hypothesis 2: –** **Result: +, p = .007.**	**Students:** ***(No TCO* vs. *TCO)*** **Hypothesis 1: +** **Result: +, p = .031**	*(No reflection* vs. *Reflection)* Hypothesis 6: + or – Result: not significant	Students: *(No TCO* vs. *TCO)* Hypothesis 9: + Result: not significant	Students: *(No TCO* vs. *TCO)* Hypothesis 10: – Result: not significant
	Practitioners: *(No TCO* vs. *TCO)* Hypothesis 1: + Result: not significant	**Practitioners:** ***(No TCO* vs. *TCO)*** **Hypothesis 2: –** **Result: –, p = .044**	Practitioners: *(No TCO* vs. *TCO)* Hypothesis 1: + Result: not significant	***(Students* vs. *Practitioners)*** **Hypothesis 7: + or –** **Result: –, p = .020**	Students, TCO info available: *(Low mental load* vs. *High mental load)* Hypothesis 11: – Result: not significant	
	(Students vs. *Practitioners;* *No TCO* vs. *TCO)* Hypothesis 3: + or – Result: not significant	***(Students* vs.** ***Practitioners;*** ***No TCO* vs. *TCO)*** **Hypothesis 3: + or –** **Result: –, p = .001**	***(Students* vs.** ***Practitioners;*** ***No TCO* vs. *TCO)*** **Hypothesis 3: + or –** **Result: –, p = .007**	*(Students* vs. *Practitioners;* *No reflection* vs. *Reflection)* Hypothesis 8: – Result: not significant		
Minimum				**Students:** ***(No reflection* vs.** ***Reflection)*** **Hypothesis 4: +** **Result: +, p = .043**		
Maximum				Students: *(No reflection* vs. *Reflection)* Hypothesis 5: – Result: not significant		
Range					Students: *(Point* vs. *Range)* Hypothesis 12: + Result: not significant	
					Students: *(Point* vs. *Range;* *Low mental load* vs. *High mental load)* Hypothesis 13: + or – Result: not significant	

5.2 Managerial implications

Our experimental results have managerial implications for the introduction and use of TCO information, and of other costing information that aims to capture the indirect costs of objects, though in doing so might leave out some important characteristics of these objects. We will discuss our recommendations to management by referring back to elements interacting with the purchasing process (see Figure 5.1, similar to Figure 1.2).

Figure 5.1 The purchasing organization, elements of the purchasing function



Based on the results, we recommend managers to:

- *Purchasing policy*
  - *Explain the intention of provided TCO numbers.* Our results show that decision makers with different levels of professional experience attach different weights to an attribute not included in the TCO numbers. Experienced decision makers attached less weight to an attribute excluded from the TCO numbers, while students attached more weight to the same attribute. The results indicate that decision makers (more so for more experienced decision makers) may interpret the provision of TCO numbers, as an indication of an attribute's importance. Senior management should explain what their intention is when providing TCO numbers. The pur-

chasing policy should make clear to decision makers how to apply TCO information in decision-making.

- *Procedures and methods:*
  - *Stimulate decision makers to reflect on the provided TCO numbers.* Our results show that reflective thinking may be important to include in decision making, as it may help make decision makers aware of information that is inaccurately included in TCO numbers. Reflective thinking results in decision makers evaluating the available information deliberately and making a balanced trade-off between the information included in the TCO numbers and the information not included in these numbers. This might prevent decision makers attaching inappropriate weights to available cost numbers.
  - *Explain which information is included in the TCO numbers.* Limitations of cost calculations should be made clear to the people who use the cost numbers. Decision makers should know which information is (not) included in the cost numbers and why. Only then can decision makers evaluate the presented information properly and make a deliberate trade-off between the cost numbers and the information excluded from these cost numbers.
- *Organization and personnel:*
  - *Teach decision makers how to handle inaccurate cost numbers:* Decision makers should understand the limitations of cost accounting and be able to make a thoughtful tradeoff between TCO numbers and the information not included in these numbers. After all, decision makers who ignore information not included in cost numbers may ignore information that may be important to take into account. Our results indicate that more experience is associated with attaching more weight to cost numbers, compared to information not included in these numbers. Therefore, special attention may be given to more experienced decision makers.
- *Information systems:*
  - *Information systems may be improved to increase tracing of costs numbers.* A more advanced method to trace information and calculate cost numbers may improve the accuracy of the TCO numbers calculated. Management may invest in more advanced computer systems to collect and store relevant (cost) information. In case the accuracy of cost information can be improved, decision makers need to worry less about making complicated multi-attribute decisions between TCO numbers and the information not included in these numbers. However, it will remain complicated to calculate accurate costs numbers.
- *Performance indicators:*
  - *Be careful by using TCO information as performance indicators:* Although using TCO numbers to reduce the purchasing costs is preferred to

using the initial purchasing price, care should be given to possible unintended side-effect of using TCO numbers. The results indicate that purchasers may ignore information not included in the TCO numbers. Therefore, we recommend being careful when using TCO numbers as performance indicators; management should always carefully evaluate possible side-effects of using specific performance indicators.

To summarize, to deal with the inaccuracy in cost numbers management should take several of the elements influencing the purchasing process into account. Although better and more advanced management accounting techniques can improve the accuracy of cost information, cost numbers will always be inaccurate. Therefore, making decision makers aware of inaccuracy in cost numbers may be the most important recommendation to management.

5.3 Limitations and suggestions for future research

Research is never finished, and never perfect. To understand the implication of research, limitations should be explained. Next, we will discuss some of the studies' limitations and suggest directions for future research.

Several of the experiments we ran did not result in significant results. In daily life and business, decision making is much more difficult than the decision-making in our experiments. Decision makers may only be able to handle sourcing information under "simple" conditions such as in our experiments. The findings which gave a non significant findings, may stress the importance of providing sourcing information in a simple format. However, more research is necessary to test this proposition.

Experimental research is ideal to study causal relationships. Nonetheless, Birnberg et al. (1990) recommend using multiple research methods to study management accounting phenomena; no research method is superior in all criteria. A future study may, for example, use case study research to investigate the trade-offs being made during different stages of the sourcing activities at different departments in a company. Another possibility would be to use survey research to investigate further which information is important in a sourcing process according to different stakeholders.

Conducting experiments on computers is preferable to running experiments on paper. A computer provides the opportunity to measure process variables such as decision time. Sometimes practical choices had to be made to increase the number of participants. Computer equipped laboratories were not available at our student test locations. Neither were we able to use computers during the practitioners' experiments at the trade fairs. Practitioners were willing to participate, but only if it did not take up too much of their time. Showing them an experimental scenario printed on one sheet only made it clear that they would be able to finish the experiment quickly. This is why, we also conducted experiments on paper.

An interesting avenue for further research would be to investigate the impact on managerial decision-making of the use of TCO numbers in performance appraisal. For example, what weight do decision makers attach to (inaccurate) TCO numbers if these numbers are used to assess their performance? Instead of using the initial purchasing price, TCO numbers may be used to assess the ability of purchasers to lower costs (see also Wouters et al. 2005, Anderson et al. 2006).

Participants in our experiments were asked to choose between sourcing alternatives; a decision that reflects an actual sourcing decision best. We have no information on why participants preferred one alternative to another. This information may be interesting to help understand why decision makers (with different levels of experience) attach a certain weight to specific attributes. More knowledge about the reasons behind participants' decision-making behavior may help to understand the impact of inaccurate cost information on decision-making.

Participants in our experiments had technical and financial knowledge. The weight decision makers attach to attributes may however depend on their background and profession (see also Wouters et al. 2005). For example, financially educated managers may be more aware of possible inaccuracies in cost numbers, but not able to interpret the technical information that is not included in the TCO number. As a result, they may tend to ignore information not included in the TCO number. A new study could further investigate the impact of the background of decision makers on the weight they attach to inaccurate cost information.

We studied individual decision-making. However, it is unlikely individual decision-making will occur in business. Most often, several decision makers with different functions will have to convince each other and justify their decisions to different colleagues in the hierarchy. On the one hand, this may result in more awareness of inaccuracy in TCO numbers. On the other hand, different decision makers may focus on different attributes and not be able to come to a decision. Then, the presented cost numbers may become interesting as they represent deliberate trade-offs that include the considerations of all decision makers. Therefore, investigating the impact of group decision-making on the weight decision makers attach to inaccurate cost numbers may be another interesting avenue for research.

5.4 Relations to other research fields

The studies in this thesis describe a typical management accounting topic, the inaccuracy of cost numbers. The problem of accurately calculating numbers can also be found in other research fields. For example, financial institutes and insurance companies are extremely interested in the possible liquidity risks of their clients. Mathematical models to calculate these risk numbers are very challenging to understand. It may be questionable if decision makers who use these mathematical models in daily practice understand these models. If they do not, then it is doubtful whether they will be able to make a careful trade-off between the calculated liquidity risk and information not included in this risk number. In all cases, decision makers should consciously evaluate the information they use for their decision-making and attach an appropriate weight to each attribute.

Marketing is another field that may learn from our findings. Evaluating how much the return from an investment exceeds the cost of capital can help managers in making an intelligent choice among marketing strategies (Rust et al. 2001, 2004). However, financially quantifying the return on marketing is very challenging; many variables, which are difficult to quantify, influence decision-making in business-to-business marketing (see also Anderson and Narus 2004). Investigating which weight decision makers attach to the calculated (but probably inaccurate) cost numbers is interesting. It may provide a better understanding about the decision-making process within marketing.

Nederlandstalige samenvatting (Summary in Dutch)

De invloed van onnauwkeurige kosteninformatie op inkoopbeslissingen

De onderstaande tekst is een korte samenvatting van het management accounting onderzoek zoals dat beschreven is in dit proefschrift. In deze samenvatting zullen we eerst de gedachten en theorie achter het onderzoek bespreken. Daarna bespreken we de drie experimentele studies die zijn uitgevoerd voor dit onderzoek. Daarbij zullen de belangrijkste resultaten worden besproken en zal worden aangestipt op welke manier we het onderzoek in management accounting verder helpen.

In deze dissertatie onderzoeken we de invloed van onnauwkeurige kosteninformatie op het beslisgedrag van inkopers. We kijken naar inkoopbeslissingen waarbij inkopers een keuze moeten maken tussen een aantal alternatieven. Om de inkoper te ondersteunen bij het maken van een keuze verstrekken we kosteninformatie die gebruikt kan worden om alternatieven gemakkelijk met elkaar te kunnen vergelijken. De verstrekte kosteninformatie is echter niet nauwkeurig. Sommige informatie die wel relevant is bij het maken van een keuze is niet opgenomen in de kosteninformatie. Het is namelijk niet altijd mogelijk om alle informatie nauwkeurig om te zetten in kosteninformatie. Denk bijvoorbeeld aan kosten die ontstaan als de beloofde kwaliteit van de geleverde producten niet overeenkomt met de geleverde productkwaliteit. De kosten voor het leveren van een nieuw product kunnen misschien wel berekend worden, maar de kosten die ontstaan als een klant besluit om schadevergoeding te eisen of over te stappen naar een andere leverancier zijn veel moeilijker te berekenen. Een kostenberekening is dan ook vaak onnauwkeurig. In dit proefschrift onderzoeken we of, en wanneer, inkopers de informatie die niet is opgenomen in de kosteninformatie meenemen in inkoopbeslissingen. Specifieker geformuleerd, we onderzoeken welk gewicht inkopers bij het maken van een keuze tussen verschillende alternatieven toekennen aan de informatie, die niet, of onnauwkeurig, is opgenomen in de beschikbare kosteninformatie.

Inkoopbeslissingen zijn voorbeelden van multi-attribuut beslissingen. Inkopers moeten veel verschillende eigenschappen voor meerdere alternatieven met elkaar vergelijken en tegen elkaar afwegen voordat ze een weloverwogen keuze kunnen maken. Uit de psychologische besliskunde is bekend dat mensen moeite hebben met het maken van een weloverwogen multi-attribuut beslissing. Mensen hebben meer moeite met multi-attribuut beslissingen naarmate er meer criteria tegen elkaar moeten worden afgewogen, het aantal alternatieven groter is, er meer conflicterende attributen zijn, et cetera. Een van de uitgangspunten in dit onderzoek is dat mensen hun gedrag aanpassen aan de omstandigheden waaronder ze een beslissing moeten nemen.

Inkopers kunnen gebruik maken van Total Cost of Ownership (TCO) informatie om hun beslissingen te ondersteunen. TCO is een methode uit de management accounting literatuur waarbij de totale kosten over de gehele levenscyclus van een product worden berekend. Alle kosten vanaf de initiële inkoopbeslissing (of ontwikkeling van een product) tot op het moment waarop het product niet meer wordt gebruikt (en geen kosten meer veroorzaakt) worden bij elkaar opgeteld tot een financieel getal. Als dit voor meerdere inkoopalternatieven wordt gedaan kunnen al deze alternatieven heel gemakkelijk tegen elkaar worden afgewogen, er is immers nog maar een punt waarop de alternatieven met elkaar vergeleken hoeven te worden. Het nauwkeurig berekenen van kosten is echter moeilijk, niet alle informatie kan nauwkeurig worden omgezet in kosteninformatie. Wat zijn bijvoorbeeld de kosten van het niet kunnen leveren van een product doordat er een storing in het productieproces optreedt? TCO cijfers zijn vaak een goede inschatting van de kosten, maar bijna nooit een honderd procent nauwkeurige "vertaling" van alle relevante informatie in één financieel getal. Ondanks dat TCO informatie het maken van een inkoopbeslissing vereenvoudigt is het mogelijk niet verstandig om blindelings het berekende TCO getal te gebruiken. Zelfs als TCO informatie aanwezig is, is een inkoopbeslissing namelijk een multi-attribuut beslissing waarbij financiële informatie tegen niet financiële informatie zal moeten worden afgewogen. We onderzoeken welk gewicht inkopers toekennen aan het attribuut dat niet (nauwkeurig) is opgenomen in de TCO informatie bij het nemen van een inkoopbeslissing.

In totaal hebben we drie experimentele studies uitgevoerd, waar meer dan 2.000 mensen aan deel hebben genomen. Er hebben zowel studenten als praktijkmensen deelgenomen aan de experimenten. De experimenten hebben zowel in laboratoria als op beurzen plaatsgevonden. In alle experimenten hebben we onderzocht welk gewicht deelnemers toekennen aan het attribuut dat niet (of onnauwkeurig) is opgenomen in de gepresenteerde TCO informatie. Om dit te onderzoeken legden we deelnemers een inkoopbeslissing voor waarbij ze moesten kiezen tussen een aantal alternatieven. Op basis van de keuze die deelnemers maakten hebben we bepaald welk gewicht deelnemers toekenden aan de informatie die niet (of onnauwkeurig) was opgenomen in de TCO informatie.

In hoofdstuk 2 hebben we gekeken naar de invloed van de complexiteit van informatie op het gewicht dat mensen toekennen aan het attribuut dat niet was opgenomen in de TCO informatie. Mensen moesten een keuze maken tussen twee inkoopalternatieven die beschreven werden met behulp van een aantal attributen (e.g., levensduur, machine beschikbaarheid, electriciteitsverbruik). De onnauwkeurigheid in kosteninformatie was in dit experiment geoperationaliseerd door één van de attributen (e.g., machine beschikbaarheid) niet op te nemen in de TCO berekening. De complexiteit van de inkoopinformatie werd vergroot door het aantal attributen dat een alternatief beschrijft te vergroten. Zowel studenten als mensen uit het bedrijfsleven hebben deelgenomen aan dit experiment. Beide groepen reageerden (onafhankelijk van het niveau van complexiteit) tegenovergesteld op de informatie die niet opgenomen was in de TCO cijfers. Studenten kenden meer gewicht toe aan het attribuut dat niet was opgenomen in de TCO informatie. Praktijkmensen kenden echter minder gewicht toe aan het attribuut dat niet opgenomen was in de TCO cijfers. De resultaten duiden er op dat het niveau van complexiteit niet van invloed is op het beslisgedrag. Ervaring is daarentegen een belangrijke variabele om te verklaren hoeveel gewicht mensen aan toekennen kosteninformatie.

In hoofdstuk 3 hebben we twee experimenten uitgevoerd om de invloed van reflectie op het gewicht dat mensen toekennen aan het attribuut dat niet of onnauwkeurig was opgenomen in de TCO cijfers te onderzoeken. In het eerste experiment was de onnauwkeurigheid in kosteninformatie geoperationaliseerd door voor één attribuut een minimum of maximum schatting te maken van de kosten. Ondanks dat het misschien niet mogelijk is om een nauwkeurige kostenraming te maken, kan misschien wel een minimum of maximum schatting worden gemaakt van bepaalde kosten. De geschatte minimum of maximum kosten werden bij de berekende kosten voor de andere attributen opgeteld. Reflectie, geoperationaliseerd door inkopers te vragen na te denken over hun beslisstrategie, resulteert erin dat inkopers meer gewicht toekennen aan het attribuut dat als een minimum was opgenomen in de TCO informatie. Reflectie had echter geen invloed op het gewicht dat werd toegekend aan het attribuut dat als een maximum was opgenomen in de TCO informatie. In het tweede experiment hebben we reflectie geoperationaliseerd door inkopers te vertellen dat ze na afloop van het experiment hun beslissing waarschijnlijk zouden moeten verdedigen tegenover anderen. In tegenstelling tot het eerste experiment, was in het dit experiment, net als in hoofdstuk 2, één attribuut niet opgenomen in de verstrekte TCO informatie. We vonden hier geen ondersteuning voor de hypothese dat reflectie er toe leidt dat inkopers meer gewicht toekennen aan het attribuut dat niet is opgenomen in TCO informatie. De resultaten lieten echter wel weer een significant verschil zien tussen studenten en praktijkmensen. Praktijkmensen kenden ook hier weer meer gewicht toe aan de TCO informatie dan studenten.

In hoofdstuk 4 hebben we onderzocht wat de invloed van cognitieve belasting was op het gewicht dat mensen toekennen aan de informatie die niet of inaccuraat is opgenomen in TCO cijfers. De onnauwkeurigheid in kosteninformatie hebben we op twee manieren geoperationaliseerd. In het eerste experiment was wederom één van de attributen niet opgenomen in de kostenberekening. In het tweede experiment was onnauwkeurigheid geoperationaliseerd door de kosten voor bepaalde attributen te schatten in een range (e.g., kosten voor service bedragen € 5 tot € 7). Aan dit experiment hebben alleen studenten deelgenomen. Het gewicht dat deelnemers toekenden aan het attribuut dat niet (nauwkeurig) was opgenomen in de kosteninformatie leek niet te worden beïnvloed door de mentale belasting. Zowel onder lage als hoge cognitieve belasting kenden mensen dezelfde gewichten toe aan het attribuut dat niet (nauwkeurig) was opgenomen in de kosteninformatie.

Dit onderzoek heeft op verschillende manieren onze kennis binnen de management accounting vergroot. Onze belangrijkste bevindingen zijn:

- Studenten kennen meer gewicht toe aan het attribuut dat niet is opgenomen in de TCO informatie.
- Praktijkmensen kennen minder gewicht toe aan het attribuut dat niet is opgenomen in de TCO informatie. Dit geldt alleen voor beslissingen waarbij de complexiteit van de informatie hoog is.
- Reflectie op de gepresenteerde kosten informatie leidt er toe dat meer gewicht wordt toegekend aan het attribuut dat als een minimum is opgenomen in de TCO informatie.
- Meer ervaring leidt er toe dat minder gewicht wordt toegekend aan het attribuut dat niet is opgenomen in de TCO cijfers.

Deze resultaten laten zien dat onze veronderstelling dat de informatie die niet is opgenomen in de kosteninformatie ondergesneeuwd raakt als: (1) mensen niet reflecteren op kosteninformatie die opgenomen is als een minimum in kosteninformatie, (2) ervaren inkopers worden geconfronteerd met een hoge informatie complexiteit, (3) aan meer ervaren beslissers TCO informatie verstrekt wordt waarin niet alle attributen opgenomen zijn in de TCO informatie.

Daarnaast hebben we binnen dit onderzoek op verschillende manieren onnauwkeurigheid in kosteninformatie geoperationaliseerd, iets wat we nog niet zijn tegengekomen in de literatuur.

Op basis van de resultaten raden we managers in het bedrijfsleven aan om: (1) gebruikers van kosten informatie te laten reflecteren op de verstrekte kosteninformatie, (2) toe te lichten waarom TCO cijfers worden verstrekt, (3) de gepresenteerde kosten informatie zo eenvoudig mogelijk weer te geven, en (4) glashelder maken welke informatie (om welke redenen) niet is opgenomen in een kostenberekening.

In vervolg onderzoek kunnen de condities waaronder mensen worden beïnvloed door kosten verder worden onderzocht en kan ook meer kwalitatieve informatie worden verzameld over de manier waarop mensen een afweging maken. Andere interessante onderzoeksgebieden zijn de analyse van beslissingen in groepsverband, of het meten van de invloed van prestatiebeloning op het gewicht dat mensen toekennen aan het attribuut dat niet of onnauwkeurig is opgenomen in de TCO cijfers.

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