

# Accounting information for operations management decisions

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# Accounting information

for

operations management decisions

Peter Verdaasdonk

# Accounting information for operations management decisions

### PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de Rector Magnificus, prof.dr. M. Rem, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen op maandag 25 januari 1999 om 16.00 uur.

door

Petrus Johannes Adrianus Verdaasdonk

geboren te Breda

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## Preface

Mid 1994 I have started a Ph.D. project that has resulted in this thesis. During this project many persons have helped me to reach the result that you are about to read. I would like to thank all those involved. During my project I have worked at the Eindhoven University of Technology and at Baan Company NV. At the university I would like to thank Jacques Theeuwes and Hans Wortmann for their support and feedback during these years. I would like to thank Peter van Laarhoven and Poul Israelsen (Southern Denmark Business School) for helping improving my thesis. Working at Baan was very helpful in this project. Baan provided me the possibility to work at my project in a stimulating research environment. I thank Paul Giesberts and Martin Taal for this.

For me teamwork is important when doing research. Doing research with fun is only possible when you are able to play in a good team. In my project I have played in a very good team. There are two members of this team I would like to mention: Marc Wouters and Winfried van Holland. I must say that the ambition of Marc and his devotion for 'doing research' has inspired me in my research. I thank Marc for all the effort he has put in my project. Winfried has helped with object modelling issues in my thesis. I thank Winfried for all his effort, and the fun he created throughout the project.

I have known Kees Kokke for seven years already. In these years the relationship with Kees has evolved from 'boss', to 'master thesis supervisor', to 'colleague', to 'friend'. In these years Kees has given much advice about choices in life. I must say every one of them were excellent. Kees: thanks!

The most important person in my life is Saskia, my wife to be. Saskia has created all the conditions needed to finish my thesis. I admire her for her support and her ability putting herself in a second place by letting me being preoccupied writing my thesis. Last but not least, I would like to thank my parents for all the things they have done for me during the 28 years of my life.

Best, November 23<sup>rd</sup> 1998 Peter Verdaasdonk

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## **Chapter 1**

## Introduction

### **1.1 INTRODUCTION**

The objective of the research described in this thesis is to obtain knowledge about the incorporation of *ex ante* accounting information for the support of operations management decisions in information systems. Keywords in this project are accounting, operations management, and information systems. *Accounting* is usually divided into financial accounting (external reporting) and management accounting (internal reporting). This thesis focuses on management accounting. Zimmerman (1997) discerns two purposes of a management accounting system: to provide some of the knowledge necessary for planning and decision-making and to help motivate and monitor people in organisations. This thesis focuses on the first of the two purposes: the provision of knowledge for planning and decisions.

Operations management is defined as 'the design, operation, and improvement of production systems that create the firm's primary products or services' (Chase and

Aquilano 1995). Operations management decisions are not the same as decisions at the operational level. Within operations management decisions must be taken at different levels, ranging from, for example, operational decisions about hourly schedules of jobs in a work centre, via monthly decisions about aggregated master sales and production plans, to strategic decisions concerning production capacity and other technological decisions involved in engineering a new production plant. The decisions that are considered in this thesis are primarily related to production planning and control of manufacturing firms of standardised products. Moreover, we limit the scope to medium and short-term decisions with a time horizon of one-year maximum. These types of decisions have to be taken frequently, and are mostly standardised. Standardised means that the alternative courses of action are known, but there is uncertainty concerning the extent the courses of action contribute to the objectives given the specific situation the company is in at the moment the decision has to be taken. Examples of these objectives could be, e.g., product quality, service levels or profitability. The frequency of the decision-making makes it worthwhile to use information systems to calculate the extent different courses of action contribute to the specific objectives. Also, when the method is known how to calculate the consequences of the courses of action a basic premise has been fulfilled for implementing these decisions in information systems. Longer-term decisions usually do not comply with the conditions regarding frequency and standardisation. For these reasons, most of the present operations management information systems aim at the short-term and mediumterm decision-making. Therefore, we also choose not to consider long-term decisions but only short-term and medium-term decisions.

The final keyword is *information systems*. Today's trend in operations management information systems is to so-called ERP (Enterprise Resource Planning) systems<sup>1</sup>. ERP systems are integrated standard information systems. These systems aim at planning and control processes within organisations. The penetration of these systems is increasing rapidly. In recent years, many organisations have spent large sums on implementing these ERP systems. As an indication, in 1997 the total ERP market grew 20.2 percent to reach 14.4 billion US dollars in software licenses and maintenance fees (Weston 1998). The top 10 vendors alone grew 32.9 percent to 5.9 billion US dollars which accounted for 41

<sup>&</sup>lt;sup>1</sup> We consider Advanced Planning Systems (APS) to be a part of ERP systems.

percent of the entire marketplace. Table 1-1 gives an overview of these top 10 ERP vendors with their annual sales and market share in 1997.

ERP Vendor	SAP	PeopleSoft	Oracle	Computer Associates	Baan	J.D. Edwards	SSA	Geac Computers	IBM	JBA Holdings
Sales 1997 (× 1 million USD)	2,250	705	699	435	432	320	299	283	258	248
Market share (%)	15.6	4.9	4.8	3.0	3.0	2.2	2.1	2.0	1.8	1.7

Table 1-1: Top 10 ERP vendors (Weston 1998)

Let us consider an illustration of the problem area we focus on.

Byco is a manufacturer of bicycles. At Byco approximately 200 people are employed. In the year 1998, the total turnover of Byco equalled 30 million US dollars. About 35% of the total turnover was achieved in the far east. One of the strategic parts of the bicycles is the frame. In the frame-manufacturing group about 65 people are employed. The people are working in daily shifts.

Each year, in the early spring, the high season starts. This year the demand for bicycles (and the frames) exceeds all expectations. Production is already fully occupied. The management of Byco is confronted with the following alternatives:

- 1. To refuse all extra sales orders.
- 2. To change temporarily from one to two shifts.

The employees council has given a positive advice to use a two shifts system in the frame-manufacturing group. Before making a final decision, the management of Byco is interested in the financial consequences of each of the decisionalternatives. The management is aware of the existence of the following consequences of a change from one shift to two shifts:

- 1. Extra surcharge on labour expenses as a result of working in two shifts.
- 2. Additional expenses on energy.
- 3. Extra machine hours per day.
- 4. Additional services from the security company.

When the financial impact of the decision-alternatives described above has to be calculated, an insight is required in incremental<sup>2</sup> costs and opportunity costs. Incremental costs are those that differ between alternatives. Opportunity costs are the benefits forgone as a result of choosing one course of action rather than another. Of course, the knowledge to perform this calculation has been known for decades. However, one of the major problems considered here relates to the retrieval of relevant accounting data. Incremental costs and opportunity costs can be obtained by making a judgement of all cost types in a specific situation regarding a decision-alternative. This evaluation can be performed by humans. However, a formal procedure to retrieve the relevant costs based on objective parameters is not available. This prevents a generic implementation of the relevant cost technique into information systems. A generic implementation would require an uniform procedure to retrieve relevant costs per decision-alternative plus an uniform procedure to store accounting data so the data can serve multiple purposes. Multiple purposes refer to multiple operations management decisions plus other purposes regarding internal reporting and external reporting.

In this chapter we explain why the research objective described is a research topic. We argue that present ERP systems lack the ability to generate *ex ante* accounting information for operations management decision support in a structured and generic way. We show that there are fundamental problems underlying this lack of functionality. This makes the research project of interest to both academics and professionals in the field of accounting, operations management, and information technology. From an accounting perspective this research is interesting since the research relates to one of the important areas of research discerned by Atkinson *et al.* (1997). This area is the use of managerial accounting information for short and medium-term decision-making. Furthermore, research shows that a key cost / managerial accounting issue to practitioners in both the 1980s and today relates to information system issues are of high priority to managers, it is not the main focus of any of the 152 management accounting research articles of North American accounting researchers surveyed by Shields (1997). Moreover, they conclude that many existing textbooks and courses also do not highlight these issues as important. Therefore,

 $<sup>^2</sup>$  In this thesis we do not make a distinction between the terms 'incremental' and 'differential' costs.

they argue that research into information systems offers the promise of substantive contributions to the management accounting research literature. Shank (1997) also addresses the importance of information system issues for management accounting today. He defines 13 structural issues of architecture in strategic cost management. Six of the 13 have a strong systems content. These issues vary from 'client / server with relational databases', to 'extensive data warehousing', and 'enterprise wide systems (Oracle, SAP, Baan, PeopleSoft)'. Finally, from an accounting perspective, this thesis addresses the old question which accounting technique to use for long-term policy and short-term policy. From an operations management point of view this project is interesting, since the project deals with the question how to obtain relevant accounting information for decisions. The relevancy of this question on the operations research models used by operations management has been raised by Thomas and McClain (1993). Finally, from an information system perspective this research is interesting, since this research extents the effort to broaden the scope of accounting data recorded in (accounting) information systems.

The outline of this chapter is as follows. In Section 1.2 the role of information for operations management is discussed together with the extent to which managers appreciate their information systems fulfilling that role. In this section we conclude that present information systems do not support the operations management decisions with accounting information. Section 1.3 describes three reasons why present information systems do not fully meet the requirements for the generation of accounting information for operations management decision support. Each reason is described and relevant literature regarding these reasons is discussed. As a result the research objective and research questions are stated (Section 1.4). The research design and methods are explained in Section 1.5. Finally, in Section 1.6 the outline of the whole thesis is given.

### **1.2 INFORMATION FOR OPERATIONS MANAGEMENT**

For many years the information needs of managers have been researched. Although knowledge of information need is widespread, managers are not always satisfied with the information supplied to them by their information systems. This is especially true for their decision-making tasks. The information needs and the way these needs are fulfilled in present systems is discussed in this section.

### **1.2.1** THE ROLE OF INFORMATION

Information is useful for reducing uncertainty in operations management decision-making. Decision-making in organisations takes place in the context of uncertainty or disagreement over both the objectives and consequences of action (Hopwood 1980). If, for instance, the objectives for action are clear and undisputed, and if the consequences of actions are also known, decision-making can then proceed in a computational manner (see also Figure 1-1). In this situation it is possible to calculate to what extent the courses of action contribute to the objectives defined beforehand. However, when the consequences of action become more uncertain, the potential for computation diminishes. In this situation, the decisions have to be made in a judgmental manner, with stakeholders subjectively assessing the array of possible consequences in the light of the agreed objectives. Just as the consequences of action could vary in the extent of certainty, so can the objectives for action. If the consequences of the presumed actions are known and clear, disagreement or uncertainty over objectives results in a political, rather than a computational, rationale for action. This situation can be characterised by bargaining and compromise. And when, in addition, the consequences of action are in dispute, decision processes can become even more complex and be characterised as an inspiration of nature (Hopwood 1980).

### **Objectives for action**

Consequences		Relative certainty	Relative uncertainty
of action	Relative certainty	Computation	Bargaining
or action	Relative uncertainty	Judgement	Inspiration

# Figure 1-1: Uncertainty and decision-making process (Hopwood 1980)

The type of operations management decisions that are discussed in this thesis, e.g., master production scheduling, capacity adjustments, outsourcing, working overtime, number of shifts, batch sizes, inventory levels, or capacity utilisation levels, have clear objectives and clear consequences of actions. As such these decisions can be positioned in the 'computation area' of the framework of Hopwood.

In many organisations the frequency and the complexity of the operations management decisions mentioned increases. This justifies the use of information systems for these decisions. Hopwood refers to accounting information systems in the 'computation area' as

'answer machines', which can calculate optimal courses of action. As mentioned before, decisions can have a wide variety of objectives. Examples of these objectives can be product quality, throughput time or profit. In this situation accounting cannot just calculate financial optimal courses of action, but must take a new role even within the computation area. This role would be providing information as to the financial impact of a range of operational decisions, so that if not the financial best, then at least better decisions about actions can be made (Chapman 1997).

### **1.2.2 INFORMATION NEEDS**

The usefulness of management accounting for decision-making in the context of management accounting systems<sup>3</sup> has been a point of study by many researchers. Mia and Chenhall (1994) state that the role of the management accounting systems has evolved from a historic orientation incorporating only internal and financial data to a system meant for attention-direction and problem solving tasks. In that new, future oriented role these systems also need to incorporate external and non-financial data focussing on marketing concerns, product innovation and predictive information related to decision areas. Several studies have focussed on the relationship between contextual variables<sup>4</sup>, management accounting information characteristics and management performance. In these studies management accounting information has been characterised by breadth of scope, timeliness, levels of aggregation and integrative nature. Table 1-2 gives an overview of the information characteristics considered important by these managers nowadays. Studies in this area are, e.g., Gordon and Narayanan (1984), Chenhall and Morris (1986, 1995), Mia and Chenhall (1994), Mia (1993), Gul (1991), Gul and Chia (1994), Chia (1995), Chong (1996), and Fisher (1996). The main conclusion from these studies for this thesis is that managers indeed consider future oriented information for decision-making useful when facing uncertainty.

<sup>&</sup>lt;sup>3</sup> The word 'system' is used here in the sense of method. System does not necessarily mean information system here.

<sup>&</sup>lt;sup>4</sup> Examples of these contextual variables are perceived environmental uncertainty, task uncertainty, organisational interdependence, task interdependence, strategy, organisational characteristics (centralised / decentralised, organic / mechanistic forms), functional differentiation (marketing / production), span of control, and locus of control.

Others have researched the use of accounting information in operations management (e.g., Bruns and McKinnon 1993; Fry *et al.* 1995; Scapens *et al.* 1996; or Jönsson and Grönlund 1988). There has been a lot of empirical research in specific management accounting aspects of operations management, such as *performance measurement and control* (e.g., Abernethy and Lillis 1995; Kaplan and Mackay 1992; Perera *et al.* 1997; Young and Selto 1993; Israelsen and Reeve 1998), *costing systems* (e.g., Anderson 1995a; Gosse 1993; Jazayeri and Hopper 1997; Patell 1987; Shields 1995), and *cost drivers* (e.g., Anderson 1995b; Banker and Johnston 1993; Banker *et al.* 1995; Dupoch and Gupta 1994; Foster and Gupta 1990). Swenson (1995) has investigated the usefulness of Activity-Based Costing for decision-making in U.S.A. manufacturing firms.

Information dimension	Characteristic		
Scope	External information		
	Non-financial information		
	Future-oriented		
Timeliness	Frequency of reporting		
	Speed of reporting		
Aggregation	Aggregated by time period		
	Aggregated by functional area		
	Analytical or decision models		
Integration	Precise targets for activities and their		
	interrelationship within sub-units		
	Reporting on intra-sub-unit interactions		

Table 1-2: Information characteristics (Chenhall and Morris 1986)

The literature stated above gives indication that both academics and professionals in operations management and accounting are well aware of their needs of relevant accounting information for decision-making. In the following subsection the availability of this relevant accounting information in present information systems is considered.

### **1.2.3** AVAILABILITY OF INFORMATION

Research shows that the required accounting information for operations management decision-making is not always present in current information systems. Corbey (1995), for instance, has encountered this problem in his research in the design of management accounting information for operations management. Therefore, he recommends further research into the design of information systems. Other research also shows that organisations are not completely satisfied with their present (management) information systems in that area. For instance, the outcome of a survey of 44 U.S. manufacturing plants indicated that managers agreed that their accounting information system completely fulfilled the requirements for external reporting and cost control (Karmarkar *et al.* 1990). However, when asked about the quality of their accounting systems for supporting operations management decisions, they were significantly less satisfied with their systems. Another survey of 298 U.S. plant managers and 102 CFOs (Chief Financial Officers) supports these findings (Sullivan and Smith 1993). Table 1-3 shows the results of this survey.

	Plant	CEO
	manager	Cro
Inadequate for decision-making	52%	46%
Inadequate for costing / pricing	53%	50%
Inadequate for worker performance evaluation	30%	34%
Unsatisfactory operating performance measures	33%	32%
Inconsistent with firm strategy	18%	13%
Not meaningful for competitive analysis	27%	29%
Other	17%	4%

Table 1-3: Key problems with cost management systems in the U.S.(Sullivan and Smith 1993)

In this section we have argued that the requirements regarding accounting information for decision support functionality in information systems are well known. However, this knowledge cannot be found in present information systems. Notably, research has shown that managers are not satisfied at all regarding this aspect of their information systems. In the following section an explanation is given for this deficiency.

## **1.3** ATTRIBUTING CAUSES OF SHORTCOMINGS IN PRESENT INFORMATION SYSTEMS

Several research projects have been carried out investigating why the present information systems do not fulfil the requirements of the managers. Johnson and Kaplan (1987) argue that the requirements of financial accounting are dominating the requirements of management accounting in US firms. Riebel (1994) subscribes to this opinion. Scapens *et al.* (1996) have performed a combined survey and case research among members of CIMA (Certified Institute of Management Accountants, UK) and investigated, among other things, the opinion of Johnson and Kaplan that management accounting system requirements have been dominated by external reporting needs. They have concluded that present information systems have such rich databases that both internal and external reporting tasks could be performed. So there seems to be a contradiction between the research projects of Johnson & Kaplan and Riebel on the one hand and of Scapens *et al.* on the other.

An explanation of this contradiction can be found in the way managers take decisions. Most managerial decisions involve diagnostic or predictive procedures (Brown 1984). Diagnosis in managerial decision-making involves attributing particular circumstances as causes of past events and assessing the validity of those attributions. Prediction in managerial decision-making involves forecasting the occurrence of future events under particular circumstances and assessing the validity of those forecasts. For diagnosis and prediction different types of information are needed. Here, the distinction between ex ante information and ex post information is used. Following, e.g., Gordon and Narayanan (1984) ex ante information pertains to future events, as contrasted to ex post information, which relates to past events. In the diagnostic procedures ex post information is used for both 'attributing circumstances as causes' and 'assessing validity'. In the predictive procedures of decision-making ex ante information is used for 'forecasting the occurrence of future events' and ex post information is used for 'assessing the validity of the forecasts'. We argue that most of the present information systems fulfil the requirements for ex post information. This opinion is then consistent with the findings of Swenson (1995). In that research, information systems that include Activity-Based Costing are considered as decision support information. This type of information can typically be denoted as diagnostic information. Furthermore, we argue below that present information systems cannot generate ex ante accounting information for operations management decision support. This is equivalent to saying that *ex post* accounting information dominates *ex ante* accounting information in present information systems. In their research, Johnson and Kaplan (1987), and Riebel (1994) refer mostly to a lack of *ex ante* functionality. In the research by Scapens *et al.* only *ex post* functionality is considered. This explains partly the differences in conclusions.

Based on the previous we conclude that there is a need for information systems that are able to generate *ex ante* accounting information for operations management decision-making. However, the question still remains why present information systems are not able to generate *ex ante* accounting information for operations management decisions.

We discern three causes why present information systems cannot generate *ex ante* accounting information for operations management decisions. Literature on these causes is described and explained in the next subsections. The three causes or problem(area)s that are discerned are:

- 1. Accounting theories for decision support are difficult to implement in information systems.
- 2. There are discussions in the accounting literature about which accounting information to use for decision support.
- 3. Present data structures are inappropriate.

# **1.3.1** ACCOUNTING THEORIES FOR DECISION SUPPORT ARE DIFFICULT TO IMPLEMENT IN INFORMATION SYSTEMS.

The concepts in the accounting techniques to support decisions cannot easily be used in information systems. To explain this argument, first the technique to support operations management decisions must be described. This technique is known for decades. The technique is called 'the relevant cost technique'. The relevant costs of a decision-alternative consist of the incremental costs plus opportunity costs. *Incremental costs* are those that differ between alternatives. *Opportunity costs* are defined as 'the benefits foregone as a result of choosing one course of action rather than another'. Determining relevant costs per decision-alternative can be done by humans, but it is much more difficult to incorporate in information systems. The first reason is that relevant costs are always situational dependent. This means that for each decision-alternative each cost must be judged on relevancy.

Incremental costs are usually made operational by means of the behaviour of costs. The behaviour of costs is defined relative to some activity, such as the number of units produced, hours worked, or kilometres driven (Zimmerman 1997). Thus, the behaviour can be fixed or variable. Fixed costs are defined as costs that are independent of an activity. Variable costs are defined as additional costs incurred when an activity is expanded. Costs that vary with a particular decision-alternative are called incremental costs for that decision-alternative. When one wants to use these concepts in information systems, one thus has to define the incremental costs for each activity / type of decisionalternative combination. Furthermore, when time dimensions are included the number alternatives for a decision is increasing rapidly, and so are the incremental cost combinations. For instance, compare two imaginary decisions both on order acceptance. In the first decision the order concerned consumes one hour of capacity of an employee that has a 6-month contract. In the second decision, the order has a total workload of 9 months for the same employee. It is clear that in the second situation some of the labour costs of the employee may be considered relevant, whereas in the first situation they are not. Although the example is extremely simple, it shows that incremental costs could also differ within the same type of decision. This implies that a pre-definition regarding which costs are incremental for each decision-alternative would result in an explosion of possibilities (not even including the differences between each company).

Operations research models concerning operations management problems that incorporate financial optimisation functions usually make such a pre-definition of relevant costs considered in the decision problem. In other words, in these models assumptions are made regarding the relevancy of costs. Financial information is used, for instance, in inventory control models and production planning. The objective of virtually all inventory control models is to minimise costs (Lee and Nahmias 1993). In most situations, minimising costs will result in the same control policy as that obtained by maximising profits. When uncertainty is present the traditional approach has been to minimise expected costs. Costs that are discerned in these models are usually holding costs, ordering costs, and penalty costs. Of course, in these models a wide variety in the estimation of the cost function can be found (e.g., by introducing quantity discounts, costs of perishable items, inflation, distinction between fixed and variable ordering cost components, cost of transportation, etc.).

The explicit pre-definition of relevant cost can also be found in operations research models for production planning. Thomas and McClain (1993) discuss financial trade-offs in production planning in the most common operations management models. In these models cost information is involved by comparing the marginal cost of production with the marginal benefit. The costs that are considered in these models usually include:

- □ Cost of oversupply, including inventory holding costs, obsolescence, etc.
- □ Regular production cost, by product category.
- □ Cost of alternative methods of production, using overtime or subcontracting, for example.
- □ Cost of changing the level of production, e.g., by subcontracting, or hiring additional workers.
- □ Cost of not satisfying demand (or not satisfying demands on time).

In these models regular production cost can take many mathematical forms, depending on the particular situation. Often, production costs are treated as linear. If set-up cost or set-up time is important, they may be included in the objective function. The cost of not satisfying demand is also discussed in many operations research papers.

As illustrated with the examples of inventory control problems and production planning, the relevant cost technique is made operational by the pre-definition of incremental costs. This can be done when one searches for the financial optimum. However, we have argued that pre-definition of relevant cost regarding to decisions can lead to enormous amounts of relevant cost per activity / decision-alternative combinations. For this reason we argue to research how the relevant cost technique can be converted to a set of procedures that are able to determine dynamically the incremental costs of a decision-alternative based on objective criteria.

A second problem appears when the opportunity costs concept has to be implemented. The concept of opportunity cost assumes full transparency of information. This implies that the decision-maker is aware of all possible decision-alternatives. However, in reality the decision-maker does not always have this full insight in information. For instance, in most situations alternatives do not arrive simultaneously. Consider, for example, a decision regarding order acceptance. Accepting an order could imply that a potential future order cannot be accepted due to scarceness of resources. However, will there be a potential order that cannot be executed? In other words, the 'not-chosen alternative' is unknown. This implies that the decision-maker has to make a judgement regarding the existence of

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opportunity costs. This judgement is not formalised in such a way that it can be incorporated in an information system. Therefore, we argue that research is needed on how the process to determine opportunity costs can be formalised so that it can be used in information systems.

# **1.3.2** DISCUSSIONS ABOUT WHICH ACCOUNTING INFORMATION TO USE FOR DECISION SUPPORT.

In management accounting two types of decision support calculations can be discerned. The main difference between the two types of methods is the difference in valuation of the efforts needed for a decision-alternative. There is not a fundamental difference in the valuation of the revenues of a decision-alternative. For this reason, here, only the valuation of efforts is discussed. The first type of calculation for decision support is based on resource consumption, which is a concept that considers all efforts (resource usage) to obtain a certain output and values these efforts. Activity-Based Costing is an example of this type of technique. The usage of resources for each of the alternatives is compared. Differences in resource consumption are valued at some rate. For example, if one alternative uses more man-hours for set-ups, the difference could be valued at a rate of the average cost of direct man-hours. Or, as another example, if one alternative uses more  $m^2$ for storage, this extra resource consumption would be valued at some rate per  $m^2$ . The second type of calculation is based on resource transition, which is a concept that only considers the financial impact of the *acquisition* of resources to obtain for a certain output. In other words, this concept only considers the total cash flow consequences of acquisition. In the accounting literature the expression 'resource spending' is used for this concept of resource transition. The relevant cost technique is an example of this technique. For example, using more man-hours without the need to contract more than already committed to, would not be valued. The same for using more  $m^2$  for extra storage if this space is available (committed costs) and could not be used otherwise (opportunity costs). When the impact of a decision, e.g., an investment, is relatively long (several years) the financial impact calculated according to a resource consumption method should be equal to a resource transition method. The difference between resource consumption and resource transition is discussed in more detail in Chapter 3.

Although there is not an agreement in the academic world of accounting, the general opinion is that resource consumption based techniques cannot be used for short-term decision-making. The reason for this is that resource consumption based techniques also

take into account cost of resources that are not being influenced by the decision-alternative (fixed costs). However, is it possible to maintain such a strict opinion regarding the applicability of the techniques? A contradiction could occur between a resource transition based calculation for short-term decision-making and a resource consumption based cost calculation (like Activity-Based Costing) for long-term decision-making. Bakke and Hellberg (1991) give an example of a situation where the product that is the less profitable in the long-run (based on resource consumption) proves to have the highest contribution margin (based on resource transition) at the bottleneck. This means that in the short-run the accounting information indicates to produce as much as possible of that particular product, whereas the calculation in the long run indicates to produce none. In other words, when should we end the production of this particular product? In Chapter 3, the contributions from the literature regarding these discussions are discussed in detail. Here, we limit this discussion to the conclusion stated by Wouters (1994). The calculation based on short-term controllable elements only can be problematic because of complex interactions between different decisions. The consequences of a series of short-term decisions taken independently can be quite different from the sum of the predicted effects of those individual decisions. For example, doing fewer activities and reducing resource consumption (e.g., machine hours) may not lead to resource transition (e.g., selling of current equipment). But after taking several of such decisions, resource consumption may have decreased sufficiently to enable resource transition. A decision to enlarge or shrink capacity (thus resource transition) will often have been induced by preceding decisions that lead to increased or decreased resource consumption. Similar interactions may exist for resource transition on the demand side of the organisation. The existence of these financial interaction effects is situational dependent. Present techniques for short-term decision-making do not consider these costs as relevant for the calculation; present techniques for longer-term decisions do consider these but also all other cost as relevant. Although a human decision-maker may be able to determine the different consequences of a decision-alternative, an information system is not since the procedures to retrieve such complex relevant information are not formalised. Therefore, we argue for a revised technique (resource transition based) that is able to deal with these dynamics in controllable and uncontrollable costs, and is based on a set of formal procedures that can be implemented in an information system. We focus on the development of such a technique in this thesis. It is obvious that when the functional requirements (which accounting information to use) for an operations management decision support system are unclear, large-scale implementation in information systems is blocked.

### Introduction

The discussion which accounting information to use is not only being held in the field of accounting but also in the field of operations management (see Thomas and McClain 1993). They argue that in fact, all of the costs are difficult to estimate. Average costs contain fixed costs that do not vary with the decisions at hand. True marginal costs are difficult to obtain, and which costs are marginal changes through time. This remark refers to the vagueness caused by the dynamic behaviour of controllable / uncontrollable cost as discussed above.

### **1.3.3 PRESENT DATA STRUCTURES ARE INAPPROPRIATE.**

The architecture of present information systems, and more specifically the way data is stored, cannot fulfil both the requirements for external reporting and internal reporting. In present standard information systems the accounting data storage (methods derived from the general ledger) is constructed to fulfil the external reporting needs. This issue has been addressed by, e.g., Riebel (1994), McCarthy (1982), and Johnson and Kaplan (1987). This could lead to inaccuracies or absence of information regarding, e.g., product costs or decision-alternatives. This does not imply that only external reporting functionality is served in these systems. It could result in situations where the databases underlying the applications could still supply the required information, as suggested by Böer (1996) and Borthick and Roth (1997), or encountered by Scapens *et al.* (1996). However, one should realise that in this way only one aspect of the internal reporting system could be served, namely *ex post* information generation. In order to be able to generate *ex ante* information, future oriented data are required. The general ledger is developed to provide *ex post* information and thus does not contain the data necessary for the purposes considered in this thesis.

We have argued that the general ledger is not suited to supply the data for the *ex ante* application domain. However, there are more methods to record accounting data: the REA model and the 'Grundrechnung'. The first method (model), the so-called Resource – Event – Agent (REA) model only records *ex post* accounting data (McCarthy 1979, 1982). The purpose of this registration technique is to record accounting data in such a way that it can sustain the requirements of relevant accounting information. McCarthy demonstrated that by capturing the essential characteristics of a business event, multiple classification schemes can be supported, including traditional information, e.g., financial statements that adhere to Generally Accepted Accounting Principles (GAAP). The REA model is thus presented as a substitute for the general ledger. The REA model is aimed at recording past

occurrences, and not at making projections of the future. In other words the REA model is related to *ex post* accounting information only. More about the research concerning the REA model can be found in Chapter 4.

The second method, independent of the previous one, is called 'Grundrechnung'. Early research has been carried out by the German researcher Schmalenbach and has been extended by another German researcher Riebel. Riebel has developed a technique for profit analysis and decision support, called 'Einzelkosten- und Deckungsbeitragsrechnung' (Riebel 1994). This financial performance measurement technique resembles what generally is known as the contribution margin technique. The main difference is that 'Einzelkosten- und Deckungsbeitragsrechnung' starts with building hierarchies of cost objects (a very simple example of such a hierarchy could be, for instance, company brands – products). Costs and revenues are now traced down into the hierarchy as deep as possible, without introducing any apportioning of costs. The general ledger cannot supply the 'Einzelkosten- und Deckungsbeitragsrechnung' technique with the required information. For this reason, Riebel (1994)<sup>5</sup> has extended the ideas regarding the 'Grundrechnung' of Schmalenbach. 'Grundrechnung' is a method that prescribes accounting registration rules to accomplish purpose neutrality. Purpose neutrality of accounting data means that the use of accounting data is not limited to one application, but can be used for a whole range applications. Sinzig (1983) describes a relational data model based on the idea of 'Grundrechnung' for one specific organisation. As such, the model is able to supply the data needed for the techniques of Riebel. The 'Grundrechnung', in contrast with the REA model is not a substitute for the general ledger. Unfortunately, recent research indicates that the approach of Riebel lacks application in practice. (Weber and Weissenberger 1997). Weber and Weissenberger suggest that the required, detailed registration technique could be blamed for this. More about the research of Riebel regarding the registration of accounting data can be found in Chapter 4.

Based on the literature stated above the conclusion can be drawn that a deficit in knowledge exists how *ex ante* accounting data needed for decision support functionality should be incorporated in present accounting data models. This research is aimed at

<sup>&</sup>lt;sup>5</sup> From de late 1940s till the mid 1990s, Riebel has published his research in many German (academic) journals. The 1994 article is the only article Riebel has published in an academic journal in the English language.

solving this deficit. A close junction is sought with the present models to avoid the main pitfall of all accounting data models: a too restricted application domain. This should enable the model to supply relevant data for operations management decisions (*ex ante*) and relevant data for *ex post* purposes. Since realised *ex ante* data becomes *ex post* data it would be convenient that the methods to store *ex ante* data equal the methods to store *ex post* data.

### **1.3.4** CONCLUSIONS

We have discerned three causes or problem areas why present information systems are not able to generate *ex ante* accounting information for operations management decisions. The first problem area relates to a formalisation problem of the accounting theory. Concepts from the accounting theory (incremental costs and opportunity costs) cannot automatically be implemented in information systems. The reason is that there are not any formal procedures how to determine whether costs are incremental. Moreover the opportunity concept requires full transparency of information, which is not always present. The second problem area relates to discrepancies in management accounting information between long-term and short-term operations management decisions. The separation between controllable and uncontrollable costs is often of a dynamic nature. For this reason there are discussions in the accounting literature which accounting technique to use for short-term and medium-term decision-making. The third problem area relates to the recording of relevant accounting data in systems. In present systems the general ledger is the dominant registration technique for accounting data. This registration method does not incorporate any ex ante data, which are essential for the application domain considered in this thesis. Other models (the REA model and 'Grundrechnung') also do not contain this ex ante data. In the next section, the above is used to define the research objective and the research questions.

Chapter 1

## **1.4 RESEARCH OBJECTIVE AND QUESTIONS**

In this section the research objective and research questions are defined. These are based on the conclusions drawn in the previous section. The research objective of this thesis is defined as:

Research objective

□ To obtain knowledge about the incorporation of *ex ante* accounting information for the support of operations management decisions in information systems.

In this area, we have shown that the main focus should be on the accounting technique for operations management decision support and the models of accounting data. For this reason the following research questions are defined:

- 1. What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?
- 2. Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?
- 3. What are the implications of the accounting technique for the known accounting data models?

The three research questions refer to the three problem areas discerned in the previous section. The first research question refers to the difficulties to convert the accounting theory to information systems. The second research question refers to the discussions in the accounting literature which accounting information to use for decision-making. The third research question refers to the problem of inappropriate data structures.

### **1.5 RESEARCH DESIGN AND METHODS**

The research described in this thesis forms a part of a broader research program of the management accounting research group at the Eindhoven University of Technology. The outcome of the current research is best understood, when placed in the light of the broader research program. In the total research program, the definition of accounting information for operations management decision support has been an important research topic. Wouters and Verdaasdonk (1997, 1998) give an overview of these research efforts. They

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present about 30 projects in which empirical research has performed, among others, to the question on how and which accounting information could be used for operations management decision-making. Separate results are published by, for example, Corbey (1991, 1994, 1995), Corbey and Jansen (1993), Dirks (1994), Van der Veeken (1988) and Wouters (1993a, 1993b). Theeuwes and Adriaansen (1994) reflect on these and other, additional, results and present an integrated accounting framework to measure the economic consequences of manufacturing-improvement decisions.

### **1.5.1** TOTAL RESEARCH DESIGN

One of the main objectives of the broader program is 'to obtain knowledge about the use of *ex ante* accounting information for operations management decisions'. This research objective can be described along the ideas of the so-called conditional normative accounting methodology (CoNAM) as described by Mattessich (1995). Mattessich considers accounting to be an applied science. In this opinion, the mission of research in accounting should be the *application* of the research findings to specific goals. The CoNAM is therefore aimed at the development of tools that prove to have added value for professionals. The conditional normative accounting theory recognises different information goals (norms) but enables the formulation of empirically confirmable relation between those goals and the means to achieve them. This theory is objective insofar as it 1 discloses the underlying value judgements and 2) empirically tests whether the recommended means leads to the desired ends.

A basic premise underlying the total research program is that if operations management aims at choosing the optimal decision-alternative for the organisation they should make use of (amongst others) *ex ante* accounting information. 'Amongst others' explicitly refers to the opinion that in making optimal decisions for organisations other types of information should also be involved (e.g., product quality or lead-times). This leads to the conclusion that maximising (minimising) financial results (costs) does not automatically lead to the best solution for the company. That is why, in this opinion, the accounting information is limited to the financial consequence of a decision. The statement above can also be written differently as 'when operations management strives to optimal decisionalternatives for the organisation they should have the availability of *ex ante* accounting information'. This statement is what Mattessich calls 'condition'. This condition also applies for the current research project. Although prescribed in the CoNAM, the condition has not been tested empirically in the present research project. The condition has been accepted from the beginning, based on the prior research results.

Based on the prior research and literature review, one of the major bottlenecks in the operational use of *ex ante* accounting information for operations management has been the lack of support by the present information systems (see Subsection 1.2.3). This recognition of the inability of information systems to support operations management decisions with *ex ante* accounting information has lead to the definition of current research project.

In the current research project a normative information system design has been developed to supply *ex ante* accounting information for operations management decisions. The research design in relation to the information system design is described in the next subsection. In the CoNAM the information system design is called the 'means' that should contribute to the overhaul goal (or 'end'). This 'end' is the pursuit of optimal decisions.

The outcome of the present research is an information system design. According to the CoNAM an empirically test should be performed whether the 'means' developed results in the 'end' intended. This empirical test has not been performed. This is due to time constraints. The empirical research should test the hypothesis that the information system design supplies the proper *ex ante* accounting information for operations management decisions to managers who pursue optimal decisions. This test should then be based on the value-judgements of the users of the information system (the operations managers). However, the empirical research to test this hypothesis would require 1) a full implementation in an ERP system, 2) the implementation of the ERP system in a real organisation and 3) the analysis of the use of the model as part of the ERP system during operations management decision-making. This research effort would require several additional years. For this reason the empirical test of the normative model is excluded from the present research and postponed to future research projects. In the final chapter (Chapter 6) suggestions for future research are discussed in more details.

### **1.5.2 CURRENT RESEARCH DESIGN**

The knowledge of incorporation of accounting information is based on the normative design of the information system. The CoNAM does not give directions to develop the normative (information system) design. Therefore, the research methodology for the development of software systems of Dolan *et al.* (1998) has been used. Dolan *et al.* 

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(1998), based on Gacek *et al.* (1995), define the output of a software development process as:

- □ A collection of system stakeholders' need statements.
- □ A collection of software and system components, connections and constraints.
- □ A rationale, which demonstrates that the components, connections and constraints define a system, that if implemented, would satisfy the collection of system stakeholders' need statements.

The research strategy addresses these outputs in three subsequent phases. In the first phase, 'Requirements analysis', the requirements of the stakeholders involved are retrieved. In the second phase, 'Architecture design', the information system design is developed. The third phase, 'Rationale of the architecture design', a demonstration is given of the information system design. All three phases address to the three research questions defined in Section 1.4. However, an intrinsic elaboration of the three research questions can be found in Phase 2.

### Phase 1: Requirements analysis

The outcome of the first phase, the requirement analysis, is a collection of system stakeholders' need statements. In Table 1-4 the stakeholders and their roles / concerns are stated. In this table five stakeholders are mentioned. The customer has not been involved in this project. The reason for this is that the information system design is mainly in a conceptual phase. This makes it very premature to involve the customer as a stakeholder. The user has been involved indirectly. The stakes of the user have been based on the elaboration of five operations management decisions. The knowledge to elaborate these decisions is obtained from prior research in operations management decisions, literature review, and ERP consultants. The operations management decisions that have been elaborated are 'setting the MPS', 'order acceptance', 'determining lot sizes', 'capacity expansion', and 'determining safety stock levels'. These decisions have also been elaborated in order to understand the problems in incorporating *ex ante* accounting information of operations management decision support in information systems.

The requirements of the architect, software developer and the maintainer have been supplied by researchers employed at ERP systems developer and vendor Baan Company NV. The researcher and employees of Baan have collaborated in a joint project aimed at including *ex ante* accounting information for operations management decisions in future

ERP systems. In this joint project, the researcher was employed at the research department on a half-time basis. Due to the fundamental problems of incorporating *ex ante* accounting information in ERP systems, the co-operation was not aimed at developing specific products. This joint project was aimed at understanding the problem area, so that a realistic design could be developed which would be consistent with other future ERP components. The employees of Baan Company NV involved are all working on projects related to future ERP systems. These employees have taken the role of architect, s/w developer, and maintainer. In this role they ensured the stakes as defined in Table 1-4. These stakes come foreword implicitly. For instance, the choice of using the object-oriented methodology United Modelling Language (UML) ensured compatibility with other ERP components. Moreover, consistency was guarded by concepts and terms used in the documentation.

Stake	Stakeholder	Roles / concerns
Financial	Customer	• schedule and budget tracking
		• risk assessment
		<ul> <li>requirements traceability</li> </ul>
Development	Architect	complete consistent architecture
		• requirements traceability
		• support for trade-off analysis
	Software	• select / develop s/w components
	developer	• maintain compatibility with existing
		systems
Support / customisation	Maintainer	• maintain compatibility with existing
		systems
		• receive guidance on s/w modification
		and family evolution
Usage	User	• performance, reliability,
		compatibility, usability,
		• accommodate future requirements

Table 1-4: Stakeholder roles (Dolan et al. 1998)

Introduction

### Phase 2: Architecture design

In the second phase, the architecture design of the information system for operations management decisions has been constructed. The total design consists of two parts. The first part of the design is concerned with the generic accounting technique to support operations management decisions. The second part of the design is concerned with the modelling of the accounting data. The aim is to obtain an object model that can be used by the technique to support the decisions on the one hand and serve (limited) *ex post* purposes on the other. The total design is constructed by means of several cycles of deduction and operationalisation. *Deduction* is a process of building concepts based on the requirements analysis. *Operationalisation* is a process of converting the concepts into concrete designs. For each part of the design, such cycles can be discerned. Both are described below.

#### Generic accounting technique to support operations management decisions

The generic accounting technique to support operations management with *ex ante* accounting information is a technique that can be implemented in information systems. Generic means that the technique must be able to supply relevant *ex ante* accounting information for all types of operations management decisions in the setting defined previously. The technique must thus exceed the level of an explicit elaboration of a limited set of operations management decisions. The technique retrieves relevant accounting data in a concise and consistent way. The decisions elaborated in Phase 1 have been used to build the generic concept. The remaining information sources that have been used are literature, ERP consultants, and academic researchers.

### Object model design

The generic model to support operations management decisions plus the basic *ex post* functionality determine the requirements for accounting data modelling. The sources that have been used to construct the model were academic researchers, information technology professionals and literature. For modelling purposes, the object modelling technique UML (Unified Modelling Language) has been used. A limited prototype has been built to check if the object model is technically feasible. The emphasis of the prototype has been on the empirical test of the static object model. Static refers to the object classes and its interconnections. The object oriented language JAVA has been used to construct the programming code of the prototype. When the model was translated into programming code, the model could be evaluated on the desired functionality. If bottlenecks were identified, the source was investigated. The sources could either be identified in the

programming code or in the object model. In the later situation the object model had to be changed for implementation purposes. By doing so, the validity of the requirements was always guarded. This process has been executed several times, until a desired level of completeness had been reached.

### Phase 3: Rationale

In the third phase two decisions have been elaborated in detail to obtain a rationale that demonstrates that the components, connections and constraints define a system, that if implemented, would satisfy the collection of system stakeholders' need statements. The decisions 'setting the Master Production Schedule (MPS)' and 'order acceptance' have been used as that rationale.

### **1.6 OUTLINE OF THIS THESIS**

This thesis is outlined according the phases discerned in the previous section (see also Figure 1-2). In the next chapter (Chapter 2), the requirements of the relevant stakeholders of the system are stated. These requirements are retrieved from the elaboration of five operations management decisions with *ex ante* accounting information. In the following two chapters the information system design is stated. Firstly, in Chapter 3 the generic model to support operations management with *ex ante* accounting information is stated.Secondly, in Chapter 4 the knowledge obtained from this model and the requirements of Chapter 2 are incorporated in an object model. In Chapter 5 the models from the two previous chapters are applied when elaborating the decisions of 'setting the MPS' and 'order acceptance'. The elaboration of these two decisions is meant as a test whether the model could function as a mature tool to supply *ex ante* accounting information in a more realistic (real life) information system setting. Finally, in Chapter 6 the main conclusions and limitations of this research project are stated. Moreover, directions of future research are given.



Figure 1-2: Outline of this thesis

**Requirement analysis** 



## Chapter 2

## **Functional requirements**

### 2.1 INTRODUCTION

This chapter deals with the first phase of the research strategy: the requirements analysis. Chapter 1 has explained which roles of the stakeholders are emphasised in this research project. In this chapter the emphasis is put on the 'users'.

In the first chapter reasons have been stated why present information systems lack *ex ante* accounting information for operations management decisions. These reasons are 1) difficulties in implementing present accounting techniques in information systems, 2) discussions in accounting about which accounting information to use for decision support, and 3) inappropriate data structures in present systems. It is clear that these problems should be overcome in the new system design. The requirements stated in this thesis are therefore, aimed at resolving these problems.
In this chapter we analyse what type of *ex ante* accounting information can be used for operations management decision-making. This analysis provides the basis to state the functional requirements of the system. The type of accounting information to use is retrieved by elaborating *ex ante* accounting information for several operations management decisions.

The knowledge concerning the accounting information to use for each decision has been obtained by analysing prior research concerning accounting information for operations management decisions, literature review, and discussion sessions with ERP consultants. Firstly, we have analysed how a specific operations management decision is supported (in information systems) with non-financial information. Furthermore, we have researched how and which *ex ante* accounting information could be relevant for that decision. In a next step the analyses described has been used to determine how the information could be supplied by an information system. This step has resulted in so-called requirements. This process has been executed until no additional requirements were found. This point has been reached after five operations management decisions. Finally, the requirements per decisions have been generalised to one set of requirements an information system must fulfil to support operations management decisions with *ex ante* accounting informations with *ex ante* accounting information.

In the next section (Section 2.2), the accounting information regarding these five operations management decisions are discussed. The decisions that have been elaborated are: 'setting the master production schedule', 'order acceptance', 'determining lot sizes', 'capacity expansion', and 'determining safety stock levels'. Each decision is discussed in a separate subsection. In the final section (Section 2.3) a generalisation has been made of the requirements per decision into one total set of requirements for the information system design. These generic requirements are: 'objectivity of accounting data', 'resource consumption', 'resource transition', 'cash transition', and 'context information'.

# 2.2 ANALYSIS OF OPERATIONS MANAGEMENT DECISIONS

In this section five decisions are elaborated. Here, one step of a larger decision-making process is investigated, namely calculating the expected financial impact of a limited number of specified decision-alternatives. After operations management has identified a problem plus the alternate solutions, managers choose which of these alternative courses of action to implement. Financial consequences are one set of inputs for making that

decision and are the only ones dealt with here. The elaboration is carried out to establish the functional system requirements.

Each decision is described in three parts. In the first part: 'description', the decision is explained. The second part: 'accounting information', deals with the financial aspects of the trade-off made within the particular decision. In the final part: 'requirements', the requirements are made explicit. Figure 2-1 gives an overview of the accounting information that is relevant for the decisions examined. In this figure, the decisions are characterised by means of control variables and accounting information. The control variables are the variables the decision-maker can influence when making the decision. In the column 'accounting information' the relevant financial consequences are summarised.

# 2.2.1 SETTING THE MASTER PRODUCTION SCHEDULE (MPS)

# Description

The Master Production Schedule is an agreement between Production and Sales about the quantities to sell and to produce for the next period(s). The decision setting the Master Production Schedule is thus concerned with production (and sales) planning. *Production planning* is defined as 'the process of determining a tentative plan for how much production will occur in the next several time periods, during an interval of time called the planning horizon.' Production planning also determines expected inventory levels, as well as the workforce, and other resources necessary to implement the production plans. Production planning is done by using an aggregated view of the production facility, the demands for products, and even of time (Thomas and McClain 1993).

The objective of the decision setting the MPS is twofold (Giesberts 1993):

- □ Volume co-ordination.
- □ Mix co-ordination.

The objective of volume co-ordination is to absorb medium-term fluctuations in the market demand. This objective is realised by setting the available capacity level and determining the production volume (in hours) for specified capacity types in the production process, specified per period. Volume co-ordination focuses on medium-term and short-term fluctuations in the demand. For this reason, capacity is controlled by means of working overtime, changing number of shifts, hiring and firing temporary personnel, or subcontracting (see also Theeuwes and De Vos 1991).

Functional requirements

Decision	Control variables	Accounting information
Setting the MPS	<ul> <li>Acceptance of demand.</li> <li>Acquisition and employment of resources.</li> </ul>	<ul> <li>Cash outflow resulting from acquisition of materials.</li> <li>Cash outflow resulting from acquisition of capacity.</li> <li>Cash inflow resulting from sales.</li> </ul>
Order acceptance	<ul> <li>Acceptance of demand.</li> <li>Acquisition and employment of resources.</li> </ul>	<ul> <li>Cash outflow resulting from acquisition of materials.</li> <li>Cash outflow resulting from acquisition of capacity.</li> <li>Cash inflow resulting from sales.</li> <li>Missed cash inflow resulting from cancelling forecasted orders.</li> <li>Financial target information.</li> </ul>
Determining lot sizes	<ul> <li>Order quantity.</li> <li>Number of setups / deliveries.</li> </ul>	<ul> <li>Cash outflow due to acquisition of resources needed for setup activities.</li> <li>Cash outflow due to acquisition of resources needed for start-up activities.</li> <li>Cash outflow due to acquisition of storage capacity.</li> <li>Cash outflow due to replenishment of obsolete stock.</li> <li>Cash (in / out) flow resulting from removal of obsolete stock.</li> <li>Missed cash inflow of missed sales.</li> <li>Opportunity cash flow of capital.</li> </ul>
Capacity expansion	• Acquisition of resources (e.g., human labour, machinery, materials).	Cash outflow resulting from acquisition of capacity.
Determining safety stock levels	• Increase / decrease stock of intermediate or end products.	<ul> <li>Missed cash inflow due to missed sales.</li> <li>Opportunity cash flow of capital.</li> <li>Cash outflow due to acquisition of storage capacity.</li> <li>Cash outflow due to replenishment of obsolete stock.</li> <li>Cash (in / out) flow resulting from removal of obsolete stock.</li> </ul>

Chapter 2

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Figure 2-1: Overview operations management decisions

The objective of mix co-ordination is to obtain the required service level and possibly the required delivery times of individual end products. This objective is realised by determining the production of end products and intermediate products in the production process.

# Accounting information

In a specific time frame, the MPS decision determines the output of the system and thus the operations cash inflow. The cash inflow can be influenced by a trade-off of which products to produce when. At the same time this trade-off involves materials to purchase and to use, and production capacity to purchase and to consume. This will result in an operations cash outflow (see also Figure 2-1).

The *ex ante* accounting information for this decision presents the result of a specific course of action, instead of including the information in some kind of financial goal function. The reason for this is that due to the complexity of this decision, accounting information can only serve as one type of information on which the decision is based. When several feasible MPS scenarios are possible the cash flow of each plan can be compared with one other.

# Requirements

The basic accounting requirement to evaluate the decision 'setting the MPS' is the measurement of the cash inflows and cash outflows involved, meaning cash flows that differ between alternative courses of action. This implies that in a MPS simulation these cash flows have to be identified. Using cash flows instead of costs would resolve one of the major problems for using *ex ante* accounting information in information systems: the operational use of incremental costs. Here, incremental costs are not indirectly measured via resource consumption, but directly via resource transition.

Cash inflow is caused by resource transition (e.g., sales items) from the company to its sales markets. Cash outflow is caused by resource transition (e.g., raw material, human labour, or capacity) from the procurement markets. This implies that *ex ante* information is needed about the relationships with the outside world (customers and suppliers) and *ex ante* information is needed on how resource outflow results in resource inflow. The relationship with the outside world must be described in terms of 'resources for money'.

Functional requirements

*Ex ante* contracts could be used here. Company rules should give information on how external demand is satisfied: by purchases or by production processes. If the demand is satisfied by production processes additional information is needed. This additional information concerns on knowledge about the production processes. This knowledge consists of descriptions how specific output resources lead to demand for specific input resources. This knowledge can be incorporated by means of so-called recipes. These recipes represent the normative resource consumption for specific output (required input for specific output). In most ERP systems this type of information is included by means of bill of materials and routings.

With the help of the information requirements described above the resource transition patterns can be revealed. The resource transition patterns can easily be converted to cash flow patterns. This would result, then, in the *ex ante* accounting information. In Section 2.3, the requirements stated above are generalised in into the (generic) requirements 'resource consumption', 'resource transition', and 'cash transition'.

# **2.2.2 ORDER ACCEPTANCE**

# Description

Order acceptance is the sales activity, which at an operational level decides upon acceptance or rejection of potential sales orders. From a production control point of view order acceptance determines the workload faced by production (Ten Kate 1995). Therefore, the objective of the order acceptance is to promise products / services to customers so that their conditions regarding quantities, delivery times, etc. can be met. In MRP II concepts the 'available to promise' (ATP) feature deals with the possibility to accept or reject customer orders, based on available product / production capacity availability (see Baker 1993). The available to promise is a (time-phased) vector that expresses how many products (or capacity) can still be delivered at specific, future moments in time. This vector is calculated by means of the number of products for which real customer orders are known.

# Accounting information

The order acceptance decision often deals with the execution of the sales part of the MPS decision-alternative. As argued above, operations management uses the MPS (ATP) to judge if orders can be accepted or not. Therefore, from an accounting point of view it

would be logical to follow an identical procedure. The MPS can now be used to determine if an order attributes to the financial goals set in the MPS. When the available to promise is sufficient to sell the products, an evaluation has to be made, that gives an indication whether accepting the order is financially the right thing to do. Doing the right thing financially is concerned with the financial benefit obtained by accepting the order. The financial benefit can be calculated by comparing the incremental revenues with the incremental costs. This financial value should then be compared with some kind of financial target. This target could be predefined targets (minimum margins or minimum sales prices) or opportunity costs. Opportunity costs could occur when other orders cannot be accepted due to this decision caused by scarceness of resources. The opportunity costs consists of the missed benefit of the missed order. See also Wouters (1997) on this topic.

# Requirements

The evaluation of the financial impact of the decision 'order acceptance' should be performed based on predefined guidelines regarding, sales prices, delivery times, etc. These guidelines could be derived from predetermined plans, e.g., the MPS.

The opportunity effect can be determined by incorporating information about the alternative orders. However, here a complication occurs. In most situations the alternative orders are not known simultaneously. This implies that the opportunity effect cannot simply be determined by comparing the alternatives. Again the MPS could be used here. If the master schedule is still realistic, it can be used for estimating the financial impact of accepting an order and as a consequence, blocking a planned order. In Section 2.3, we generalise the opportunity effect into the requirement 'context information'.

# 2.2.3 DETERMINING LOT SIZES

# Description

The objective of the decision 'determining lot sizes' is to find a balance between efficiency in the production process (as few setups as possible) and a minimum of cycle stock. The demand for small(er) batches leads to lower cycle stocks and therefore lower cost of capital and risk of obsolescence. The demand for production efficiency would lead to large batch sizes and thus an, on average, high cycle stock level. The efficiency in the production process increases, since more capacity is assigned to production and a minimum of capacity is assigned to setups. An additional advantage here is that the start-up losses (waste) are also decreased.

Functional requirements

# **Accounting information**

A lot of research effort has been spent on research into the financial effect of the lot size determination. Lee and Nahmias (1993) estimate the number of papers appeared in journals concerning the single product inventory problems well into thousands. However, most of these models are concerned with the search for optimal solutions. Again, the decision support described here, only deals with the retrieval of the financial impact when determining a specific lot size.

Each batch (lot) is supposed to require a setup activity and invokes a start-up activity. The *setup activity* refers to an activity to change, e.g., a piece of machinery from one configuration to another. The start-up activity refers to the initial run aimed at fine-tuning the specified configuration. The setup activity usually requires capacity of, e.g., machinery, energy, equipment, or human labour. This demand for capacity could lead to acquisition of these resources, resulting in cash outflows. Reducing the number of setups would reduce the demand for these resources, and possibly reduce the outgoing cash flows. The start-up activity could result in so-called start-up losses. These losses consist of, e.g., material, energy, and capacity of machinery, equipment and human labour. Reducing the number of setups would result in a reduction of the start-up activities. In the time frame considered this could result in avoiding the losses mentioned, and thus avoiding possible outgoing cash flows. Of course, when the number of setups is increased the opposite effects could occur.

Other financial effects of the lot size decisions are related to the cycle stock, risk of obsolescence, and missed demand. These are discussed next.

The lot-size determines the cycle stock and thus the demand for storage capacity. The higher the average lot size is the higher the demand for this storage capacity. In the time period considered, the lot size could influence measures to expand / reduce storage capacity. The accompanying cash flows are thus avoidable. A second effect of the occurrence of cycle stock is related to the opportunity cost of capital. The opportunity cost of capital is related to all cash in and cash outflows. A decrease of the lot size would imply that on average the purchase of resources could be postponed as opposed to the situation with a higher lot size. This implies that in the first situation on average less capital is invested in the organisation. This effect is expressed by means of the opportunity cost of capital (see also Van der Veeken 1988 or Veltman and Van Donselaar 1993 regarding this financial consequence).

The higher the cycle stock, the higher is the risk of obsolescence. The financial impact of obsolete stock could be either the additional outgoing cash flow resulting from the resources needed to re-produce this stock, a cash inflow due to the sale of this obsolete stock, or in situation of shortage, the missed cash inflow of missed sales. Additionally, the product that has become obsolete should be removed, resulting in outgoing cash flows.

The final effect is related to the missed production capacity due to setups. If capacity cannot be expanded, this could lead to customer orders not fulfilled. This effect can be expressed as a missed cash inflow.

# Requirements

Most requirements for this decision have already been discussed in the previous subsections. These requirements are related to the specification of the production processes within companies. The knowledge obtained here is the explicit recognition of recipes for setup and start-up activities. When a batch is actually planned, these types of activities could lead to purchase of resources.

Another type of requirements which has been discussed above is the insight in missed production (and thus sales) due to the setup, start-up activities and replenishment of stock that has become obsolete. The same difficulties apply here as with the order acceptance decision. Since the alternatives do not arrive simultaneously, insight must be given by a master plan.

A new requirement concerns information about the moments in time that resources are actually paid. These moments are used to determine opportunity cost of capital. Furthermore, information must be available concerning the risk of obsolescence, and information concerning the removal of obsolete stock. For some situations this could imply cash inflow due to the sale of this stock, in other situations cash outflow for the removal of this stock.

In Section 2.3, the requirement for recipes is generalised to 'resource consumption', 'resource transition', and 'cash transition'. Again the opportunity effect of a decision is generalised to the requirement 'context information'. The time-phased moments of cash flows are captured by the requirement 'objectivity of accounting data'.

Functional requirements

# 2.2.4 CAPACITY EXPANSION

# Description

The objective of the decision 'capacity expansion' is to enlarge the available capacity temporarily, in order to cope with short-term fluctuations in the demand. (NB: other possibilities to comply with this goal could be, e.g., yield management, the use of seasonal stock, or changing delivery dates). The decision 'capacity expansion' could be a part of other decisions such as 'setting the MPS', or even 'order acceptance'. Examples of capacity expansion possibilities are working overtime, increase of the number of shifts, hiring temporary personal, or outsourcing.

# **Accounting information**

The accounting information that is relevant here is the total outgoing cash flow as result of the expansion alternative.

# Requirements

The information needed here is the total outgoing cash flow associated with different measures. The total cash flow resulting from a specific capacity expansion measure depends on various variables. Corbey and Tullemans (1991) refer to the economic commitment as one of the most important variables. The economic commitment is defined as the total cash flow associated with a specific kind of measure. This cash flow is, amongst others, dependent of the (minimum) term of commitment of a specific alternative. For instance, governmental policy could oblige to hire temporary personal for at least for a minimum number of hours, or demand a change in shift to last at least a fixed number of periods. This implies that the capacity expansion should be evaluated based on the total additional cash outflow, instead of resource consumption (which is actually used). The generic requirements 'resource transition' and 'cash transition' deal with the requirements stated here (see Section 2.3).

# 2.2.5 DETERMINING SAFETY STOCK LEVELS

# Description

The objective of the decision 'determining safety stock levels' is to determine the amount of inventory on hand, on the average, to allow for the uncertainty of demand and the uncertainty of supply in the short-run (Silver *et al.* 1998). This decision is only relevant when demand is not deterministic. There are two extreme implications of an organisation temporarily running out of stock:

- □ Complete lost sales: This implies that any demand is lost, when demand cannot be fulfilled from stock.
- □ Complete backordering: This implies that customer orders are fulfilled when sufficient replenishment of the products is achieved.

# Accounting information

The financial trade-off that has to be made is the trade-off of the costs of safety stock versus the cost of not having safety stock. The cost of not having safety stock is dependent of the two extreme situations described above. In the first situation when there is a complete loss of sales, the financial impact of running out of stock equals the missed cash inflow of the missed demand. At the same time, 'savings' are made since there are no cash outflows for obtaining unsold products. In the second situation, when backordering is allowed, missed cash inflow does not play a role. Here, only opportunity cost of capital could play a role, since the sale is postponed, thus the cash inflow is also postponed.

The costs of safety stock are determined by holding costs. These holding cost consist of storage costs, opportunity cost of capital, and the risk of obsolescence of the safety stock. The storage costs are related to the consumption of storage capacity in the warehouse. Whether this consumption leads to additional cash outflow depends on the type of storage capacity used. For instance, when the company owns a warehouse, with no restrictions regarding the capacity, or even if the warehouse is rented with the same conditions, additional consumption does not lead to cash outflow. However, when the company rents a warehouse per square metre, additional consumption does lead to additional cash outflow.

There is also an opportunity cost of capital resulting from the cash outflow of obtaining the safety stock. This cost is determined by time difference between the moment the safety stock is acquired and the moment the safety stock is replenished after being used. Finally, the financial impact of obsolescence of stock is the cash outflow resulting from acquiring new safety stock plus some additional cash flow (inflow or outflow) caused by removing the obsolete stock.

# Requirements

There are not any new requirements regarding the accounting information needed. Again, the relationships with the outside world are important, and so are the production process relationships. Information is needed concerning the alternatives of not having safety stock (loss of sales or planned capacity usage). Again, master plans could be used to supply the relevant information needed.

# **2.3 FUNCTIONAL REQUIREMENT STATEMENT**

In this section the requirements defined above are generalised into five basic functional requirements. These requirements should ensure that the information system design is able to generate *ex ante* accounting information for operations management decisions.

#### **Requirement 1: Objectivity of accounting data**

The use of accounting data for operations management decision support is only one of the many possible accounting application domains. Therefore, we must prevent that the use of ex ante accounting information for operations management decision support is dominant in the information system design. The dominance of one application over the others can be avoided by only including accounting data that can be measured objectively. All other information must be derived from this data. This implies that the information system design must exclude the introduction of accounting artefacts, such as, classification schemes, costs, or depreciation. Therefore, the semantics used in the information system design must have a close relationship with reality. This could imply that implementation choices have to be made which are not relevant and therefore, cannot be justified for the application domain considered, but are relevant for other application domains. For example, the type of decisions considered (short-term and medium-term decisions) only needs totals in incoming and outgoing cash flows due to the decisions. However, for cash management or auditing purposes the planned or actual due dates must be known. Since, the total cash flow can be derived from the separate cash flows these separate cash flows are included in the model. Another example relates to the registration of *ex post* data. Realised ex ante data becomes ex post data. Since many applications in accounting are related to *ex post* data, it would be convenient that the methods to store *ex ante* data equal the methods to store *ex post* data.

#### **Requirement 2: Resource consumption**

The information system design must be able to determine the resource consumption needed to fulfil specific demand. Examples of demand could be sales items, or intermediate products. The resource consumption defines the amount of resources needed to fulfil this demand. Examples of this consumption could be labour hours, machine hours, kilograms of raw material, etc. The information system design must be able to incorporate *ex ante* resource consumption relations and must be able to record *ex post* consumption relations. *Ex ante* resource consumption relations can refer to recipes or planned (future) consumptions. *Recipes* give a generic prescription how to obtain specific output out of specific input. Planned (future) consumptions refer to a recipe that is about to be carried out in the future. In both *ex ante* relationships a normative expectation is recorded regarding resources to use for specific resources to obtain. The *ex post* resource consumption is related to realised (historic) production processes.

### **Requirement 3: Resource transition**

The information system design must discern an incoming resource flow (acquisition) and an outgoing resource flow (sales). This physical flow between the organisation and its markets is called resource transition. Outgoing flows are determined by external (customer) demand. Incoming flows are influenced by external demand or by internal demand (resource consumption). Therefore, the information system design must be able to translate the external demand pattern / consumption pattern into an incoming resource transition pattern. Consumption could lead to the acquisition of resources. The buffer between consumption and transition is formed by the stock of a specific resource. Again *ex post* and *ex ante* resource transition is considered. *Ex ante* resource transition refers to agreements made with the outside world about future resource flows. *Ex post* refers to realised resource flows.

#### **Requirement 4: Cash transition**

The information system design must be able to translate the resource transition (inflow and outflow) into a cash outflow or a cash inflow pattern. This cash flow is called 'cash transition'. This requirement is valid for both *ex ante* and *ex post* cash transitions. *Ex ante* here means the incorporation of financial aspects of potential resource transitions. *Ex post* here means the incorporation of financial aspects of realised resource transitions. Theeuwes and Adriaansen (1994) stress that contract information should provide the conditions to predict if, and within which time frame, a reduction or expansion in resource

consumption will lead to a reduction or expansion in cash flows. This contract thus combines a particular resource flow with all corresponding (future) cash flows.

# **Requirement 5: Context information**

The information system design must incorporate accounting information about long-term plans. These long-term plans give information about the courses of actions that the organisation wants to follow. Shorter-term decisions should be checked against these longer-term plans. The longer-terms plans thus supply financial target information for shorter-term decisions. Context information is thus concerned with information regarding future directions of a company. These future directions can be expressed by means of, e.g., customers / regions that have to be supplied, sales prices that are applicable, or profit margins that have to be achieved.

The five requirements defined in this chapter are used to build the information system design. This design is described in the following two chapters.

Chapter 2

Architecture design



# **Chapter 3**

# Generic accounting model to support operations management decisions

# 3.1 INTRODUCTION

In this chapter the first part of the information system design is presented: the generic accounting model to support operations management decisions. This model gives answers to the first and second research question defined in Chapter 1:

- □ Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?
- □ What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?

In the management accounting literature there is an ongoing discussion about dealing with short-term and long-term decisions in a consistent way. Management accounting emphasises that relevant costs and revenues are those that differ between alternatives and these are specific for a particular decision in a certain situation at a specific moment. Sometimes many costs and revenues can be considered to be relevant ('long-term decisions') and other times few costs and revenues matter ('short-term decisions'). So, for each decision the relevant financial consequences should be determined. However, some authors argue that such a strict separation of different decisions may not be realistic and short-term and long-term decisions interact.<sup>6</sup> The accumulation of several short-term decisions may have a long-term impact that is not in line with long-term preferences. The point is especially clear when long-term and short-term decisions are contradictory. Imagine, for example, that the full costs of making a component are above the purchase price of the same component, suggesting that in the long run the component could better be purchased outside. However, the short-term relevant costs could very well be below the purchase price, because many costs are unavoidable in the short-run. How can the organisation ever achieve a change in the long run (e.g., one year), if in the short-run each time (say, every month) a decision is made to maintain the status quo? In other words, accounting information could direct to different decision-alternatives when decisions are taken independently, as opposed to the direction accounting information would suggest when those individual decisions are considered as a whole. The issue is addressed in the literature mostly in an anecdotal or even emotional way, without clear conceptual resolution. See, e.g., Kaplan et al. (1990), Cooper (1990), Shank and Govindarajan (1989), Bakke and Hellberg (1991), and Wouters (1994). For example, Shank in Kaplan et al.

<sup>&</sup>lt;sup>6</sup> 'Long-term' here does not refer to strategic decisions. The chapter concerns tactical and operational decisions in operations management. Following the strategic-tactical-operational framework of Anthony (1988) strategic planning is concerned with the effectiveness of the production function and is about questions like 'How do we construct our production system?', 'Where do we locate our (production) facilities?', etc. The scope of strategic planning captures several years, or more. At the tactical level (management control), decisions are concerned with the efficiency of the production function, to be obtained within the constraints set by the strategic decisions. Examples of such decisions are 'How do we expand our capacity temporarily?', 'Should we make finished goods on inventory?', etc. Decisions at the operational level (task control) are focussed for a much shorter-term. It addresses questions such as 'What jobs do we have to work on?', 'What jobs have priority?', etc. The differences between these types of decisions are of a gradual nature.

(1990, 19): 'When does the long run happen? What morning do you get up and say, today's the long-run, now I'm going to do something about that loser?' Only looking at short-term relevant costs 'will lead you to keep everything. It will lead you to add products, it will lead you to never drop anything, it will lead you to always make instead of buy.'

There is another related area in the literature that discusses the relationship between longterm decisions and short-term decisions in the context of capacity planning. These decisions relate to financial optimisations problems concerning how much capacity to install (long-term) and decisions on how to use the available capacity (short-term). More specifically, this literature discusses which costs should be used for capacity usage problems. A consideration is made if capacity cost (full cost) information can be used as a proxy for (difficult to determine) opportunity costs (relevant cost). With respect to the current research this would be very interesting since if the hypothesis that capacity cost approximate opportunity cost is true, full costs could be used for short-term decisionmaking. Full cost information then automatically brings shorter-term decisions in congruence with longer-term policy. Studies that conclude that capacity costs may act as an approximation opportunity costs assume that there are no economies-of-scale (a nearly linear production cost function), and all assumptions prior to the capacity installation decision are met in reality (certainty in demand). Studies in this area are, e.g., Miller and Buckman (1987), Balachandran and Srinidhi (1988, 1990), Whang (1989), Dewan and Mendelson (1990), Stidham (1992), Banker and Hughes (1994), Balakrishnan and Sivaramakrishnan (1996), Gietzman and Mohanan (1996), Gietzman and Ostaszweski (1996), and O'Brian and Sivaramakrishnan (1996). However, the situations considered in this thesis do not comply with the constraints of the linear production cost function, and the condition of certainty in demand. For this reason, capacity cost cannot be used as a proxy for opportunity cost in this thesis.

The solution to the problem area described above is found in the introduction of the hierarchical planning concepts from the operations management into management accounting. The objective of hierarchical planning is to deal with uncertainty and to reduce complexity by decomposing decision problems. Decisions on a higher level are constraints for decisions on a lower level. (See, e.g., Hax and Meal 1975; Bitran and Hax 1977; Meal 1984; Bertrand *et al.* 1990; Bitran and Tirupati 1993; Giesberts 1993; Fransoo *et al.* 1995; and Schneeweiss 1995.) Such planning concepts could well be used to deal with short-term and long-term financial trade-offs in a consistent way. However, in the literature on

hierarchical production planning not much has been developed regarding financial tradeoffs. This is done in this chapter.

The second problem area in this thesis is related to the difficulties in translating accounting theories to information systems. It is difficult to deal with concepts as fixed costs, incremental cost, and opportunity cost in an information system in a consistent way without introducing redundancy of data. This is due to the dynamics facing organisations. Costs that are fixed for one decision may be variable to another. This dynamic behaviour of cost can be handled by humans, but not easily in information systems. The model must be formulated in such a way that the economic reasoning can be performed by an information system and presented to a decision-maker. The solution has been found in separating physical effects from economic valuation (analogous to Riebel (1994)). The model aims to measure the effects of each alternative course of action unambiguously, traceable to realised, calculated, or approximated cash flows. To trace the cash flow associated with a particular course of action, the resource flow is analysed. Since resource flows of the alternatives cannot be compared easily, the cash flow is used as a common denominator.

The technique or model that is described in this chapter is called the Hierarchical Cash Flow Model (see also Verdaasdonk and Wouters 1998a). The model is based on concepts developed by Theeuwes and Adriaansen (1994) and Greenwood and Reeve (1992). In these models (cash flow models) decision-alternatives are evaluated on their impact on the cash flow. The Hierarchical Cash Flow Model extends the cash flow models by also including the opportunity costs of a decision-alternative. The Hierarchical Cash Flow Model deals with the financial evaluation of short-term and long-term decisions in a consistent way. The model assumes a hierarchical ordering of planning decisions. Constraints from higher level (long-term) decisions aim to make lower level (short-term) decisions consistent with those decisions (Hax and Meal 1975; Bitran and Hax 1977; Meal 1984). However, deviations from the higher level plan are allowed, because conditions change, new information becomes available and there may be sound reasons for departing from the higher level plan (Schneeweiss 1995). Incremental implementation and modification of predetermined plans is assumed (Winter 1996). The relevance of the higher level plan is in its information value. That plan can be used to assess the incremental costs and opportunity costs of lower level decisions. To clarify the basic concept, consider the following example: Capacity level adjustment needs to be decided three months ahead, based on the Master Production Schedule (MPS). In the MPS capacity

is reserved for particular product groups. Accepting an order that was unforeseen in the MPS would involve opportunity cost, which might be hard to estimate only on the basis of received orders. The MPS is then used to assess which future orders would have to be refused because of accepting an unforeseen order. To conclude, the following conditions are defined for application of the Hierarchical Cash Flow Model:

- □ The Hierarchical Cash Flow Model requires a predetermined plan. Lower level decisions plan the usage of available capacity in greater detail (e.g., determining the available capacity within constraints of business planning; Master Production Scheduling within constraints of available capacity; order acceptance within MPS constraints; machine scheduling within order constraints).
- □ Lower level decisions can deviate from the higher level plan because conditions change and new information becomes available. For instance, orders are accepted that have lower sales prices than planned, or orders with lower sales prices are accepted since demand for products decreases.
- □ There is incremental implementation and modification of a predetermined plan. Several lower level decisions together cover the higher level plan and these decisions are not made simultaneously. In other words: lower level decisions 'step by step' detail and modify previous plans. Therefore, each individual lower level decision may have opportunity costs that can only be assessed on basis of that decision's impact on the remaining availability for later decisions.
- □ Despite uncertainty, the higher level plan is sufficiently accurate to use for assessing the opportunity costs of individual lower level decisions.

The remainder of this chapter is structured as follows. In Section 3.2 definitions of concepts used in the model, such as resources and contracts, are presented. Section 3.3 is about the unambiguous, physical consequences of operations management decisions. These consequences are divided into a physical effect and an opportunity effect. The physical effect is a consequence of a decision regarding the amounts of various resources sold, purchased, created, and consumed. The opportunity effect is the consequence of executing one alternative instead of the other. The opportunity effect is also expressed in quantities related to the resource flow. Unfortunately, all the effects over all resources have different units of measure. Therefore, the effects of different alternatives cannot be compared easily. For this reason, a common denominator is needed. This common denominator is found in a financial value. Section 3.4 deals with the conversion of the physical effects into a financial value. This conversion is performed by considering the cash flow consequences of the effects mentioned. Cash flows do not distort the

unambiguous measurement of the effects of an alternative. The total concept is applied in an example. This example is described in Section 3.5. Finally, in Section 3.6 the conclusions drawn from this chapter are given.

# **3.2 Reference model of manufacturing organisations**

This section is about the definition of terms used in this chapter. The model presented is about organisations that pursue making a profit. To accomplish this goal, these organisations can make use of input resources (e.g., equipment, human, and material) to obtain output resources (e.g., products, and services), which are sold to customers. As such the model is applicable for organisations producing standardised goods in predefined processes. In the model, an organisation is thus considered as a group of resources fitted together to make profit. If not created by the organisation itself resources are obtained from the procurement market in supply-contracts against payment. If not kept in the organisation the output resources are sold in demand-contracts to the sales market also against payment. As a result of this interaction between the organisation and the markets there is a resource flow and an operating cash flow. This thesis only refers to this cash flow and not to the *financing cash flow* that the organisation may have with financial markets. Financing cash flows are to attract, repay, invest or de-invest funds, and to pay or receive interest and dividends. The different resource flows and cash flows are depicted in Figure 3-1. The modelling of resources flows and cash flows resembles the registration method of (financial) transactions in the Variability Accounting concept as described by Israelsen (1994).

In the subsequent sections, we argue that we use cash flows to evaluate the impact of a decision-alternative. The impact of the type of decisions that are discerned, short-term and medium-term decisions, is the totals of relevant incoming and outgoing cash flows as a result of the decision-alternative. That total may consists of separate payments, but we use the words 'cash flow' for the total cash flow, the sum of the separate payments. For instance, suppose that due to a decision-alternative we have to buy some raw material that amounts 1,000 EURO, and this purchase transaction results in two payments. The first amount, a prepayment of 250 EURO, is due 10 days after placing the purchase order; the remaining amount, 750 EURO, is due 30 days after receiving the raw material (together

with the invoice). The term 'cash flow' as we use it refers to the total cash flow of the transaction, in this case 1,000 EURO.<sup>7,8</sup>.



Figure 3-1: Cash flow model

A *resource* is defined as 'an object that is scarce and has utility and is under control of an enterprise' (Ijiri 1975, 51 - 52). Resources are objects which are used by, or which are the outcome of the creation function of an organisation. A resource is counted by means of its quantifier<sup>9</sup>. Of course, the quantifier of each resource has an unit of measure (pieces, hours, kilograms, etc.).

The quantifier of a resource can be altered 1) when resources enter or leave the organisation, or 2) when resources are consumed or created by the creation function of the organisation. The first possibility – a resource entering or leaving the organisation –

<sup>&</sup>lt;sup>7</sup> In the accounting literature the terms cost of acquisition and revenue might be used to indicate these total cash flows.

<sup>&</sup>lt;sup>8</sup> In Chapter 4 when we model accounting data, we only record the separate (planned and actual) payments. The reason for this is that the total cash flow resulting from a resource transition can easily be derived from the separate payments. Moreover, insight in the separate payments might be needed for other accounting purposes (see also the requirement 'objectivity of accounting data' of Chapter 2).

<sup>&</sup>lt;sup>9</sup> For ease of reading we will use the term 'resource' as much as possible instead of the term 'the quantifier of a resource'.

requires a contract. A *contract* is defined as 'an agreement between the organisation and a partner in a specific market, in which the conditions regarding the transition of a resource are specified'. A contract does not need to be an explicitly written agreement. The minimum requirement that is posed to a contract is that a supplier and a buyer have agreed that the supplier supplies specific resources and the buyer pays a specific amount of money for those. When a contract refers to an incoming resource flow from the procurement market, the contract is called a *supply contract*. When a contract refers to an outgoing resource flow to the sales market, the contract is called a *demand contract*. The dual relationship in each contract between the organisation and a partner is called a *give – take* relationship (similar to Geerts and McCarthy 1997)<sup>10</sup>. The *give-relationship* refers to the outgoing flow; the *take-relationship* refers to the incoming flow. There are several conditions regarding a contract. One condition is particularly relevant and mentioned here: the financial condition. This condition is specified by:

- □ Start-up period.
- □ Termination period.
- **D** Economic commitment.

The *start-up period* is defined as 'the time interval needed between the construction of the contract and the completion of the resource transition'. The *termination period* is defined as 'the time period needed to end the contract'. The termination period can be instantiated as a minimum contract period, a variable period dependent on the contract period already elapsed, or just a fixed period. Figure 3-2 gives a graphical representation of these contract characteristics. *Economic commitment* is defined as 'the total cash flow concerned with the resource transition'.

The creation function of the organisation provides the second possibility to alter the quantifier of resources. The *creation function* is defined as 'a set of activities'. An *activity* specifies the required quantities of input resources and the resulting output resources. As such an activity is responsible for resource consumption and resource creation. *Consumption* refers to the process of the decrease of the quantifier of a resource; *creation* refers to the process of the increase of the quantifier of a resource. The relationship of each activity with input and output resources is a specific form of a *give – take relationship*: namely an *input – output relationship*. The *input-relationship* refers to the resources that

<sup>&</sup>lt;sup>10</sup> This type of relationship is elaborated in Chapter 4.

are used by the activity; the *output-relationship* refers to the resources that are created by the activity.



**Figure 3-2: The contract parameters** 



We discern contracts and contract potentials. Contracts are agreements between the organisation and its suppliers / customers regarding resource transitions and the cash transitions. Contracts can be final or planned. *Final contracts* refer to committed agreements with the external partners. *Planned contracts* are forecasted contracts based on a forecasted demand. Contract potentials are agreements about possible (future) resource transitions and the cash transitions. The same distinction is made for activities and recipes. A recipe is a specification of a possible (future) activity. Figure 3-3 gives a graphical representation of the different types of contracts and activities.



Figure 3-3: Overview contract / activity types

A planned demand contract becomes final when forecasted demand, that is represented in this contract, is realised. Or in other words, the demand contract becomes final when a customer commits itself and the organisation to the sales transaction. Planned supply contracts or planned activities only become final when the moment to execute cannot be postponed anymore (e.g., due to lead-times). An example of this latter situation is the ordering of materials to be used for production in the next period, which cannot be postponed anymore due to the delivery time of the materials.

External demand for resources is modelled in the give-relationship of the demand contracts. Internal demand is modelled in the input-relationship of the activities. Each type of demand for these resources can be satisfied or supplied by 1) the output-relationship of activities or 2) the take-relationship of supply contracts. The difference over time between the demand and the supply of a resource is called stock. Figure 3-4 gives a graphical representation of the information model of the process model. The dashed arrows point to the part of the resource flow that is specified in the specific contracts or activities. For example, the resources purchased are specified in the take-relationship of a supply contract. The customer demand for a number of that same resource is specified in the give-relationship of the demand contract. The difference in quantities (supply is greater than demand) is expressed in the figure by means of the stock symbol.



Figure 3-4: Process model and information model

Processes in the organisation can be controlled by means of plans. A *plan* concerns a set of contracts to acquire / sell resources and activities to consume / create resources, and a plan directs the organisation to specific goals. The complexity of controlling manufacturing processes is reduced by introducing concepts of hierarchical planning. In hierarchical planning higher level plans set constraint for lower levels. The hierarchical level is determined here by the level of aggregation. *Aggregation* is defined as 'replacing multiple, separate elements in one combining element' (Giesberts 1993). Examples of elements that can be aggregated are:

- □ Resources (into family resources).
- **Customers (into customer groups).**
- Geographical areas (into regions).
- □ Time moment (into periods).

For example, 1) the master schedule is based on family items and family work centres whereas order acceptance is based on real items, or 2) sales plans are based on sales regions whereas the order acceptance is based on individual orders of actual customers in a specific location. *Planning* thus means making plans. These plans are made, based on new information with the older plans (if any) as a reference point. This means that planning could vary from executing previous contracts / activities as pre-planned, to specifying older aggregated plans into more detailed plans, to introducing new contracts / activities when cancelling the pre-planned contracts / activities. Specific examples could be: accepting orders for a sales item as foreseen, specifying the manufacture of specific quantities of individual products, completely according to the plans for the family item, or introducing a new forecast and at the same time cancel the old plan.

The plans are used to specify the planned use of resources. Information about planned use is used in the model to determine opportunity costs. The planned use is expressed by means of the *reservation* of a resource. The reservation is for a particular 'destination', and can be 'planned' or 'final'. This latter is denoted as the *status* of the reservation. *Destination* indicates for which selling or consumption purpose the resources are planned to be used. *Status* specifies whether or not the destination of the resources can be changed in the planning processes. The status *planned* means that the destination, if there is any, may be changed. The status *final* means that the destination of a resource cannot be changed. The status becomes final, when the destination is a final demand contract / activity and when replenishment is not possible because of lead-time restrictions or scarcity of the resource.

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# **3.3 DETERMINING THE PHYSICAL IMPACT OF A DECISION:** RESOURCE FLOWS

In this section we describe the model that determines the physical effects of a decisionalternative. The model starts with a change in the demand for resources<sup>11,12</sup>. The generality of the model allows that this change in demand can vary from, e.g., a complete new forecast on a aggregated product level for the coming period, to detailing such a forecast, to accepting customer orders as forecasted, to accepting orders that were not forecasted, etc. We argue that the effect of a change in demand for resources leads to a change in consumption of other resources and / or a change in the acquisition of resources. On their turn, these effects could result in other future effects. For instance, due to scarcity acceptance of one order might result in the loss of an order in the near future. Due to an order quantity rule the acceptance of one order results in an increase of the stock of particular resources, which might have use in the near future. Due to the cancellation of planned demand contracts of one geographical region, possibilities arise for other regions, etc. In our model we determine the effects of all of these types of decisions in an identical way. We first determine what the effect is of a decision-alternative on the consumption of resources and the transition of resources (demand and supply contracts). Then we consider the effect of this decision-alternative on future courses of action. This future oriented effect is determined by means of the plan. If an organisation does not have a plan concerning its courses of action, then obviously this latter effect cannot be determined.

In the description of the model we assume the presence of a plan. This plan consists of a set of activities, supply contracts, and demand contracts. These activities and contracts can be final and planned. The logic of determining the physical impact of a decision is discussed by means of an increase in the demand. However, the same logic applies when a decrease in demand would occur. The increase in demand is modelled as the insertion of a new (planned or final) demand contract. When the demand for resources increases, this

<sup>&</sup>lt;sup>11</sup> A decision-alternative could also result in technical changes in production processes. Although this possibility is not excluded from the model, we do not discuss this area in this thesis.

<sup>&</sup>lt;sup>12</sup> Remember that 'resources' actually refer to 'quantifier of a resource'.

demand can be fulfilled by means of one of the following six possibilities, which are explained below:

- □ The output-relationship of a final activity.
- □ The take-relationship of a final supply contract.
- □ The output-relationship of a planned activity.
- □ The take-relationship of a planned supply contract.
- □ The give-relationship of a recipe.
- □ The take-relationship of a contract potential.

If these options cannot fulfil the demand for resources, it is impossible to meet the increase of the demand. The presented sequence of means to fulfil the demand for resources suggests using stock of resources first. If this option cannot satisfy the demand for resources additional production is suggested. Finally, if all of this cannot fulfil the demand additional purchases are recommended.

The options to fulfil the demand for resources are depicted in Figure 3-5. Figure 3-5 begins with 'Start'. This figure represents a decision-tree. This decision-tree can be considered as a flow chart for which all decision options are elaborated. In this figure we describe how an increase in demand for resources can be fulfilled together with the consequences of each option. Figure 3-5 only discusses the effect of an increase in the demand on the consumption of resources (activity) and the transition of resources (demand and supply contracts). The future consequences of this increase in demand is explained afterwards (Figure 3-6 until Figure 3-9). The **bold** letters in this (and the following figures) are only relevant to Section 3.4, where the physical consequences (resource flows) are converted into cash flows. We note that the procedure described in this section has to be completed for all resources involved with the decision-alternative. The options 'Start 2' refers the decision tree depicted in Figure 3-6. The option 'Start 1' indicates that another decision tree, explained further on, leads to an increase in demand. The remaining of the figure is explained below. The headers refer to the options mentioned above.

# Demand is fulfilled by means of 1) a final activity or 2) a final supply contract

Resources specified in the output-relationship of final activities or in the take-relationship of final supply contracts indicate that the organisation has been committed to produce or purchase the resources specified. In other words, the decision-maker can be confident that these resources are on stock at a specified moment in time. If the resources supplied by final activities or final supply contracts have a reservation with status final this implies that these are required by a final demand contract, or a final activity. In other words, these resources cannot be used for the increase of the demand, since they are needed for other destinations that may not be cancelled. Resources supplied by final activities or final supply contracts with status planned may be used to satisfy the increase of demand. The reservation with status planned is cancelled, and the resources are reserved for another destination: the newly inserted demand. The status of this reservation may be planned or final, depending on the status of the demand contract (planned or final), or –if the demand is internal– the status of the activity (planned or final) that requires these resources as input resources. Due to space limitations, the changes in reservations are not shown in Figure 3-5.

Demand is fulfilled by means of 3) a planned activity or 4) a planned supply contract Resources specified in the output-relationship of planned activities or in the takerelationship of planned supply contracts indicate that the organisation has made plans to produce or purchase the resources specified. However, the organisation does not have made commitments for these activities and / or supply contracts yet. The resource specified in the take-relationship of the planned supply contract, or the output-relationship of the planned activity may have reservation with status planned but also with status final. An example of a planned supply contract with resources that have reservations with status final is a scarce resource for which a final demand contract exists but that is not purchased yet. If these resources have reservations with status final, they may not be taken into account for fulfilling the increase in demand. This implies that only planned activities and / or planned supply contracts are considered that have specified resources having reservations with status planned. These planned activities and planned supply contracts can be, e.g., aggregated activities or supply contracts. In the situation of an activity this could mean that an organisation has made plans to produce a certain amount (totally) in a specific period of that specific output resource.

When the demand and supply of resources are matched, the planned activities or planned supply contracts are copied to new instances (new planned activities or new planed supply contracts). The reason for this is that we want to identify these activities or supply contracts, since these can have other characteristics then the existing ones. For instance, these activities or supply contracts can get status final, whereas the existing activities or supply contracts still could have the status planned. For this reason, the planned activity or planned supply contract is copied to a new activity or supply contract (status not specified here) for a maximum quantity. This maximum quantity needs some explanation. The

resource considered is needed for a certain amount due to an increase in demand. However, an activity or a supply contract might have minimum order quantity rules. The maximum quantity is now determined as the maximum of the number of resources in the increase of the demand and the minimum order quantity that applies for that specific activity or supply contract. As a result we have a new (planned or final) activity or a new (planned or final) supply contract that supplies that number of resources. The reservation of the existing planned activity / supply contract is cancelled for that same quantity. When the minimum order quantity exceeds the number of resources that were specified by the demand, then we have to make a distinction between the resources that were demanded and the additional resources (positive difference between the maximum quantity and the resource demanded). The first quantity of resources is reserved for the destination of the demand that we are planning with status planned or final. The additional resources do not get a reservation yet. We will come back to this point later. The newly inserted activity causes an internal demand via its input-relationships. This created demand has to undergo the (same) procedure of the increase of the demand once again. Again, the cancellation of reservation is not depicted in Figure 3-5.

# Demand is fulfilled by means of 5) a recipe or 6) a contract potential

In the final two options the decision-maker can decide to insert unplanned activities or unplanned purchases. These possibilities are specified in the recipes (activities) and contract potentials (supply contracts). The recipe or the contract potential needed is copied to a new activity or new supply contract for a maximum quantity. The required quantity of resources is reserved for the destination of the demand with status planned or final. Additional resources are not yet reserved. Again, the new planned activity causes an internal demand via its input-relationship. This created internal demand has to undergo the same procedure of the increase of demand.

To conclude, for each change in demand for resources the model determines how the demand is fulfilled. In this way the model determines the resource consumption and resource transition effect of a decision-alternative.

We have seen that during the process of matching supply of resources with the demand for resources, planned reservations have been cancelled. To recall, a reservation connects the demand for resources (by means of a demand contract or an activity) to the supply of resources (by means of a supply contract or an activity). The effect of cancelling the reservation can be described for a:

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- □ Planned demand contract.
- □ Final demand contract.
- □ Planned activity.
- □ Final activity.
- □ Planned supply contract.
- □ Final supply contract.

We discuss the consequences below.

#### Consequences for 1) a planned demand contract or for 2) a final demand contract

When the reservation is cancelled of resources (specified in the output-relationship of activities or the take-relationship of supply contracts) for the destination planned or final demand contract, this implies that this demand is not satisfied anymore. If this demand still has to be fulfilled, e.g., the demand contract is final, then this demand has to be re-planned in order to try to satisfy this demand after all. For instance, a customer orders a product today. He likes to have the product delivered next month. The company usually purchases this product from one of its suppliers. The lead-time is only one week. However, the company still has one product on stock (from a past delivery). This product is given a reservation with status planned. The status is planned, since it only becomes final when it is not possible anymore to order additional units (one week before the actual delivery). When the next day another customer orders the same type of product and wants it to be delivered tomorrow, the reservation of the product on stock is cancelled; the reservation is made with status final for the new customer. Since the first customer still needs the product, re-planning has to be performed (meaning the insertion of a new planned supply contract).

Another example relates to the consequences that we have seen above when new activities or supply contracts are inserted for the maximum quantity. We have argued that the quantity that was needed for the newly inserted demand was reserved for this demand, and that the additional resource did not get a reservation yet. Suppose that a plan specifies a planned demand contract for 100 pieces of a particular resource and a planned supply contract of also 100 pieces of that same resource. A new demand is inserted for one resource. This demand can now be satisfied by means of the planned supply contract. The minimum order quantity is five pieces. The planned supply contract is copied to a new planned supply contract for the quantity five pieces. The reservation of the five resources in the old planned supply contract for the demand is cancelled (the reservation remains for the other 95). One resource of the new planned supply contract is reserved for the new demand, the other four are not yet reserved for. The cancellation of a reservation implies the cancellation of the old planned supply contract for five pieces (this is discussed below) and the cancellation of the planned demand contract for one resource. The demand for the other four resources remains. Planning now ensures that the four resources of the new planned supply contract are reserved for this destination. In this way the additional resources due to an order quantity rule are still reserved for.

# Consequences for 3) a planned activity

When the reservation is cancelled of the output resource of a planned activity for its destination (demand contract or activity), two options exist. In the first option we check if there might be other demand for these resource. This demand could be specified in contract potentials, or 'suddenly' emerges from demand contracts that were not allowed to be cancelled (see the description of the two previous consequences). In the second option the activity is just cancelled. Note that the cancellation of a planned activity also results in the cancellation of the reservation between the input resource of the planned activity and its suppliers (supply contract or activity). This cancellation is treated in the same way as all other cancellations.

# Consequences for 4) a final activity

When the reservation is cancelled of the output resource of a final activity for its destination (demand contract or activity), also two options exist. The first option is the same as the option described for the planned activity. In this option a check is made to find out if there is another demand for this resource. In the second option we determine if there are future supplies of these resource by means of a planned activity or a planned supply contract. If there are, these future planned activities or planned supply contracts can be cancelled.

# **Consequences for 5) a planned supply contract**

When the reservation is cancelled of the resources specified in the take-relationship of a planned supply contract and its destination (demand contract or activity) again two possibility exists. The first possibility is to check if there still is another demand for this resource (see also the consequences on planned and final activities). If there is no unsatisfied demand for this resource, the planned supply contract has to be cancelled.

# Consequences for 6) a final supply contract

When the reservation is cancelled of the resources specified in the take-relationship of a final supply contract and its destination (demand contract or activity) again the possibility has to be examined if there still is some unsatisfied demand. If there is not, we examine if there are future planned supplies (activities or supply contracts) that might be cancelled. If this is also not possible, then we examine if the final supply contract can be terminated. This latter option is possible for, e.g., human labour contracts, or lease contracts.

The consequences mentioned above are formally expressed in Figure 3-6 until Figure 3-9. As stated above, these formal procedures have to be executed as soon as option 'Start 2' is encountered in Figure 3-5. In the formal procedures which start in Figure 3-6 we have made a distinction between the effect upstream the resource flow (effect on the output-relationship of activities and take-relationships of supply contracts) and the effect downstream the resource flow (effect on the input-relationship of activities and give-relationship of demand contracts). Both have to be determined.

When reservations are cancelled, the effect can be traced to final supply contracts, planned supply contracts, final activities and planned activities. These four options are also indicated in Figure 3-6. The effects that arise when resources are supplied by a final supply contract or a final activity are further explained in Figure 3-7 ('Start 5'). Planned supply contracts are just cancelled, and so are planned activities. (NB: We have left out the option to search if there still is other demand for these resources. The reason for this is that if there would be demand for this resource, it would come foreword during re-planning options as we show in Figure 3-9).

In Figure 3-7 we further explain what happens upstream the resource flow when resources are supplied by means of final activities or final supply contracts. The intention of the procedures in this decision tree is to determine what to do with resource for which the reservation has been cancelled. However, a problem occurs when we want to determine this effect for resources supplied by final activities or final supply contracts. This problem is caused by the generic description of the model that ensures that all resources and cancellations of reservations have to undergo the same procedures. We explain this problem by means of an example. The output resource of a final activity had been reserved for a specific planned demand contract. During a decision-alternative, a new final demand contract is inserted for that specific resource (specified in the output-relationship of the final activity). First of all, in the logic of the model the 'old' reservation is cancelled and a

new reservation is made for the output resource for the destination: the new final demand contract. Secondly, the cancellation of the reservation ensures that the model starts to determine the future effect of this cancellation. Here we only discuss the effect upstream. However, the cancellation of the reservation does not lead to a future effect upstream. (Later we show that there is a downstream effect resulting from cancelling the planned demand contract). Now consider another decision-alternative that also leads to the cancellation of the reservation of the output resource of a final activity. However, this output resource is not needed anymore (there is not a demand for this resource). This cancellation does lead to a future effect upstream the resource flow. Namely we have the availability over a resource (meaning a resource with no reservation), and we have to determine what we are going to do with this resource. The problem here is that both situations are identical characterised in model (cancellation of a reservation, and a final activity or a final supply contract). For this reason we involve another characteristic. This characteristic is the new reservation. In this way a selection is made between the two situations. In Figure 3-7 the selection is expressed by means of the options 'resources used by alternative' (first situation) and 'resources not used by alternative' (second situation). As a result only those resources remain in the procedure that are related to final activities and final supply contracts, which do not have reservations anymore.

For these resources we examine if there might be other demand for these resources. This demand would have to be specified as a contract potential. For instance, when the decision results in the cancellation of the reservations of all hours of a piece of machinery, we might want to sell the resource. When there is not a contract potential for this resource included in the model, three possibilities remain: there is a future planned supply contract, there is a future planned activity, or there are no future planned resource supplies. When one of the first two possibilities (there is a future planned supply contract or a future planned activity) is true we just cancel the planned supply contract or the planned activity. Note that when we cancel a planned activity this would involve the cancellation of the reservation of input resource specified by this activity and the resources delivered by their suppliers (activities or supply contract). For these cancellations the decision tree of Figure 3-5 has to be completed once again ('Start 2'). The consequences when there are no planned future resource supplies are elaborated in Figure 3-8.

Figure 3-8 examines if the resource considered is supplied by a final activity or a final supply contract. When the resource is related to a final supply contract it might be possible

to end the contract (e.g., in case of human labour). This concludes the effect upstream the resource flow. Next we describe the effects downstream the resource flow.

Figure 3-9 describes the physical effect of the cancellation of reservations downstream the resource flow. Downstream these effects can be noticed in demand contract or activities. Both can be examined if they can be cancelled or not. If they cannot be cancelled, a new demand arises in the system. This implies that the decision tree of Figure 3-5 has to be completed once again ('Start 1').

So far, the effect of a decision-alternative is described in terms of resource flows associated with changes in supply contracts, demand contracts, and activities for each possible alternative course of action. For an easy comparison of those alternatives, the next step is to convert the resource flows (resource transition) into cash flows (cash transition). This conversion is discussed in the following section.



Figure 3-5: Consequences of satisfying the demand for resources

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Figure 3-6: Physical effect of cancellation reservations upstream (I)



Figure 3-7: Physical effect of cancellation reservations upstream (II)



Figure 3-8: Physical effect of cancellation reservations upstream (III)



Figure 3-9: Physical effect of cancellation reservations downstream

#### **3.4 DETERMINING THE FINANCIAL IMPACT OF A DECISION: CASH** FLOWS

This section describes how the resource flows triggered by a decision can be converted into cash flows. The cash flow effect of an alternative is always expressed in relation to the initial plan, which generates an expected cash flow. Each alternative course of action may change the expected cash flow. The effect of each alternative is thus expressed relative to the original plan. Alternative courses of action might be changes of the plan, but might also be detailing and execution of the original plan.

#### **3.4.1** THE FINANCIAL CONSEQUENCES OF A DECISION

The outcome of all the decision trees is a set of seven possible changes in the supply and demand contracts of an organisation, indicated by the **bold** letters (A) through (G) in the decision trees. The financial equivalent of the resource transition specified in these contracts is discussed here. We distinguish two types of effects. The first type of effect, which we call the incremental effect, is determined without using the reservation logic described in the previous section. The second type of effect is called the opportunity effect. An effect is called an opportunity effect for a decision when the effect is determined with the help of the reservation logic.

#### The financial impact related to the incremental effect (effects A and B):

The incremental effect of a decision appears in new demand contracts (A), and / or newly planned supply contracts (B). The insertion of new demand contract leads to an incoming cash flow (cash transition). This incoming cash flow is specified in the take-relationship of the demand contracts. The insertion of a new supply contract leads to an outgoing cash flow (cash transition). This outgoing cash flow is specified in the give-relationship of the new supply contract.

#### Financial impact related to the opportunity effect (effects C, D, E, F, and G):

All the other changes in contracts are related to the opportunity effect. Again, an effect is categorised as an opportunity effect when the reservation logic is used to determine the effect.

Demand contracts established on a higher hierarchical level can be involved in a decisionalternative by: the insertion of a new demand contract (D), and / or the cancellation of a demand contract (G). Option D leads to an increase of the incoming cash flow. Option G leads to a decrease of the incoming cash flow. A decrease of the incoming cash flow is presented as a negative incoming cash flow.

Supply contracts established on a higher hierarchical level can be involved in a decisionalternative by: cancellation of a planned supply contract (C) and cancellation of a future planned supply contract (E). Both option C and E lead to a decrease of the cash outflow. Therefore, the accounting information is presented as a positive outgoing cash flow. The final possibility relates to the termination of a final supply contract (F). When a final supply contract is ended, this leads to a lower outgoing cash flow, relative to the plan. This cash flow is specified in the give-relationship of this final supply contract. The accounting information of this option is presented as a positive outgoing cash flow. Furthermore, as result of a premature ending of the contract a penalty cost might apply. This penalty cost is a special characteristic of a contract. This penalty cost is presented as an outgoing cash flow.

The total effect of a decision-alternative, converted to financial values is now expressed as:

Incremental effect		
Cash inflow (A)	Cash outflow (B)	Cash flow gross balance
Opportunity effect		
Created cash inflow (D)	Reduced cash outflow (C)	Opportunity cash flow balance
Missed cash inflow (G)	Reduced cash outflow (E)	
	Reduced cash outflow (F)	
Total		Cash flow net balance

This financial overview must be constructed for each alternative that is relevant for a particular decision. The alternatives can be compared on the basis of the cash flow net balance.

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#### 3.4.2 REMARKS

The financial overview could be presented in many different ways. Only the cash flow net balance of each alternative course of action could be presented, or different elements of the cash flow net balance could be presented for each alternative. These could be grouped along the different effects C, D, E, F and G. The cash flow net balance could also be grouped along different levels of certainty. It could be important for a decision-maker to differentiate between expected cash flow effects with a high level of accuracy (for example, cancelling almost certain demand, or making final decisions on supply contacts) and effects with lower levels of accuracy (for example, cancelling demand that cannot be forecasted accurately, or reserving resources from planned supply contracts for uncertain demand contracts). We did not elaborate this possibility.

The plan needs to have 'some' degree of reliability. So reversibly, if the plan was only used for making some final decisions that could not longer be postponed, but thereafter the plan soon becomes completely unreliable, the situation changes. In this later situation there is not much informational value in still using that plan for assessing opportunity costs, since the opportunities in that plan are no longer accurate.

One opportunity effect has not been taken into account. This effect is called the opportunity effect of capital. *Opportunity effect of capital* is defined as 'the forgone opportunity of using capital for another purpose' (Zimmerman 1997). An example of such an opportunity could be earning interest on a bank account. These effects are not considered here just for simplicity reasons. However, the effect can be taken into account since, as will be shown in the next chapter, in the object models to implement this HCFM the dates per cash flow incorporated. Therefore, the opportunity costs of capital can be calculated.

This concludes the Hierarchical Cash Flow model. In the following section an example of the Hierarchical Cash Flow Model is given. The purpose of this simple example is just to illustrate the concepts and procedures of the HCFM.

# **3.5** Example of financial trade-offs in a hierarchical framework

This section describes a relative simple example of the HCFM. The purpose of the example is just to illustrate how the HCFM works. The example is not meant as a means to prove the correctness or usability of the HCFM. Suppose an organisation produces and sells one product (Z) to various customers. The production process consists of two phases (see also Figure 3-10). In the first phase the raw material (X) is processed in activity 1. Activity 1 needs the input resources human labour and raw material X. The outcome of activity 1 is an intermediate product (Y). In the second phase, the intermediate product (Y) is transformed by activity 2 into (Z). Activity 2 needs the input resources human labour and the intermediate product.



Figure 3-10: Overview production process

The recipe of Z is 1 piece of Y and 2 hours of human labour. The recipe of Y is 1 piece of X and 1 hour of human labour. There are three employees who can execute Activity 2. All three employees are contracted for 40 hours per period for an unspecified period of time. The employees are compensated with an annual salary of 30,000 EURO. A year consists of 50 periods. The employees get paid per period. Temporary workers perform Activity 1. These employees can be hired by the hour. The compensation paid for each hour equals 10 EURO. Temporary workers have to be contracted 2 periods in advance. The price for X equals 2 EURO per piece.

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Furthermore, the following information is available:

Туре	Start-up period /	Order quantity
	lead -time	
Contracting temporary worker	2 periods	1 hour
Contracting X	1 period	50 pieces
Activity 1: producing Y	1 period	15 pieces
Activity 2: producing Z	1 period	1 piece

The stock on hand for each resource at moment t = 0 equals zero. The forecasted demand for Z is stated in the next table. This forecast is made in total and is specified to the destinations 'Holland' and 'Germany'.

Period	4 5		6	7
Holland	5	10	20	20
Germany	5	10	60	70
Total	10	20	80	90

For each market segment different prices apply. In Germany, the sales price of product Z equals 100 EURO. In Holland, this price equals 75 EURO.

The production organisation has to make a final decision about contracting the temporary workers. For this reason a plan is made, based on the data available. Activity 2 is planned by means of a heuristic that schedules production as late as possible. This results in the following schedule for Z (output Activity 2):

Ζ				
Period	4	5	6	7
Planned Demand	10	20	80	90
On hand (beginning of period)	0	10	50	30
Output (Z) Activity 2	20	60	60	60
On hand (end of period)	10	50	30	0

The output of Activity 2 leads to an internal demand for input resources Y. Due to leadtime restriction Y must be available one period in advance. This demand for Y is satisfied by means of Activity 1. Activity 1 is only executed for fixed order quantities of Y (multiple of 15 pieces).

Y				
Period	3	4	5	6
Input (Y) Activity 2	20	60	60	60
On hand (beginning of period)	0	10	10	10
Output (Y) Activity 1	30	60	60	60
On hand (end of period)	10	10	10	10

Consequently, the output of Activity 1 causes an internal demand for the input resources X and 'Temporary worker'. These input resources also need to be available one period in advance. Resource X is only ordered in multiples of 50 pieces. This results in:

X				
Period	2	3	4	5
Input (X) Activity 1	30	60	60	60
On hand (beginning of period)	0	20	10	0
Take X	50	50	50	100
On hand (end of period)	20	10	0	40

X					
Period	1	2	3	4	5
Take X		50	50	50	100
Contract X	50	50	50	100	

Temporary worker				
Period	2	3	4	5
Input Activity 1	30	60	60	60
Take Temp. work.	30	60	60	60

Temporary worker						
Period	0	1	2	3	4	5
Take Temp. work.			30	60	60	60
Contract temp. work.	30	60	60	60		

The lead-time / start-up period of both input resources is expressed by means of the period differences between the availability (indicated by 'take') of both resources and the moment they are contracted (indicated by 'contract').

The physical consequences together with the cash flow consequences of the planning cycle explained above would be recorded in the Hierarchical Cash Flow Model as follows (NB: the reservation is expressed by means of the status and the destination. The status can have the value 'final' or 'planned'. The abbreviation of final is 'Fi'; the abbreviation of planned is 'Pl'. When resources do not have a destination, the destination is indicated with '0'):

Plan	Planned demand contract:										
Nr.	Give	Reservation	Period	Resource	Resource	Period	Reservation	Take			
	(#)							(Euro)			
1	5	Pl Germany	4	Z	Cash	4	-	500			
2	10	Pl Germany	5	Z	Cash	5	-	1,000			
3	60	Pl Germany	6	Z	Cash	6	-	6,000			
4	70	Pl Germany	7	Z	Cash	7	-	7,000			
5	5	Pl Holland	4	Z	Cash	4	-	375			
6	10	Pl Holland	5	Z	Cash	5	-	750			
7	20	Pl Holland	6	Z	Cash	6	-	1,500			
8	20	Pl Holland	7	Z	Cash	7	-	1,500			

Plan	Planned supply contract:											
Nr.	Give	Reservation	Period	Resource	Resource	Period	Reservation	Take				
	(Euro)							(#)				
1	100	-	2	Cash	Х	2	Pl Activity 1	50				
2	100	-	3	Cash	Х	3	Pl Activity 1	50				
3	100	-	4	Cash	Х	4	Pl Activity 1	50				
4	200	-	5	Cash	Х	5	Pl Activity 1	60				
							Pl 0	40				
5	300	-	2	Cash	Temp. w.	2	Pl Activity 1	30				
6	600	-	3	Cash	Temp. w.	3	Pl Activity 1	60				
7	600	_	4	Cash	Temp. w.	4	Pl Activity 1	60				
8	600	-	5	Cash	Temp. w.	5	Pl Activity 1	60				

Fina	Final supply contract:										
Nr.	Give	Reservation	Period	Resource	Resource	Period	Reservation	Take			
	(Euro)							(#)			
1	600	-	0	Cash	Empl. 1	0	Pl 0	40			
2	600	-	0	Cash	Empl. 2	0	Pl 0	40			
3	600	_	0	Cash	Empl. 3	0	Pl 0	40			

Planned activity:								
Nr.	Output	Reservation	Period	Resource	Resource	Period	Reservation	Input
	(#)							(#)
1	15	Pl Germany	4	Z	Y	3	-	20
	5	Pl Holland	4	Z	Empl. 1	3	-	40
5	20	Pl Activity 2	3	Y	Х	2	-	30
	10	Pl 0	3	Y	Temp. w.	2	-	30

Generic accounting model to support operations management decisions

The financial value of this plan can be calculated by considering the changes in the resource cash. This result in the following:

Incremental effect				
A: Sale resource Z	B: Purchase resource X	Cash flow gross balance		
18,625 Euro	- 500 Euro			
	B: Purchase temp. worker			
	- 2,100 Euro	16,025 Euro		
Opportunity effect				
		Opportunity cash flow balance		
		0 Euro		
Total		Cash flow net balance		
		16,025 Euro		

The reason for making the plan has been to be able to make a final decision about contracting the temporary worker. At moment t = 0, the final decision is made to hire 30 hours of the temporary worker. The due date is in period 2. The decision leads to a final supply contract. The physical effect of hiring the temporary worker is then recorded as:

Final supply contract:								
Nr.	Give	Reservation	Period	Resource	Resource	Period	Reservation	Take
	(Euro)							(#)
4	300	-	2	Cash	Temp. w.	2	Pl Activity 1	30

The old planned supply contract (nr. 5) is deleted. This financial effect of this decisionalternative is then determined as:

Incromontal o	ffact	
incrementat ej	B: Purchase resource temporary worker - 300 EURO	Cash flow gross balance - 300 EURO
Opportunity eg	ffect	
	C: Cancel planned supply contr. Temp. w.	Opportunity cash flow balance
	+ 300 Euro	+ 300 Euro
Total		Cash flow net balance
		0 Euro

The cash flow net balance of 0 EURO indicates that the hiring of a temporary worker is completely according to the plan.

Next, the company receives at the beginning of period 4, an order from a Dutch customer of 15 pieces Z. This order is due at the end of the period. The sales price of Z equals, 75 EURO.

The effect of this decision is recorded as:

Final demand contract:								
Nr.	Give	Reservation	Period	Resource	Resource	Period	Reservation	Take
	(#)							(Euro)
1	15	Fi Holland	4	Z	Cash	4	-	1.125

To execute the final demand contract, the decision-maker has to cancel two planned demand contracts (e.g., nr. 2 and nr. 5). The financial effect of this alternative would then be:

Incremental effect			
A: Sale resource Z 1,125 Euro	Cash flow gross balance 1,125 EURO		
Opportunity effect			
G: Missed sale	Opportunity cash flow balance		
- 375 Euro	- 1,375 Euro		
G: Missed sale			
- 1,000 Euro			
Total	Cash flow net balance		
	- 250 Euro		

The decision-maker now has to make a judgement about this order. But what is the consequence of the alternative of not accepting the order? This alternative could mean that the present order is an additional order and that not accepting this order would leave the plan unchanged. This alternative would have a cash flow net balance of 0. The decision-maker could compare one alternative that has a cash flow net balance of -250 EURO with an alternative that has a cash flow net balance of 0.

However, the alternative of not accepting the present order could also affect the original plan. Suppose the order comes from a regular customer in Holland, but just a bit more then expected. Not accepting this order would involve cancelling a planned demand contract (nr. 5). This leads to the following effect.

Incremental effect		
Opportunity effect		
G: Missed sale		Opportunity cash flow balance
	- 375 Euro	- 375 Euro
Total		Cash flow net balance
		- 375 Euro

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The decision-maker has to compare the first alternative that has a cash flow net balance of -250 EURO with the second alternative that has a cash flow net balance of -375 EURO. These financial figures form the financial input to the decision problem.

#### **3.6** CONCLUSIONS

In the beginning of this chapter we have addressed the following two research questions:

- □ Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?
- □ What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?

In this chapter we have described the Hierarchical Cash Flow Model (HCFM) that answers both questions. The HCFM deviates from the Cash Flow Model since the HCFM model includes opportunity effects of a decision-alternative whereas the cash flow model does not. We have illustrated the model with an example.

The HCFM consists of a set of procedures (represented in decision trees) that is able to retrieve incremental costs and opportunity costs (cash flows) just based on the interaction between the organisation and its markets (resource transition). This implies that it is not necessary to pre-define general conditions for the incremental costs in relation to cost drivers. This makes the HCFM a generic accounting technique to supply ex ante accounting information for operations management decisions. The HCFM makes a strict distinction between the physical effect of a decision and the financial effect of a decision. The HCFM is able to trace a change in external demand for a resource (resource transition) to a change in resource consumption. Eventually, this change in resource consumption could lead to a change in resource transition (acquisition). The logic if demand for resources leads to a change in resource transition is implemented with activities, contracts, and reservation. Activities implement resource consumption, contracts implement resource transition. The reservation concept indicates if resources are available for the decision-alternative. If not, new contracts or activities may be issued to obtain the resources needed. Accounting information only emerges when new contracts are issued (cash transition). In other words, incremental costs are determined dynamically, based on the specific situation of the organisation. Incremental costs are thus considered as cash flows that arise due to new contracts inserted by a decision-alternative.

The opportunity costs are included in the model by means of hierarchical planning. Hierarchical concepts are included in the model by means of reservation. When resources are used, planned usage has to be cancelled<sup>13</sup>. The planned use is implemented by means of the reservation concept. This planned usage that is cancelled is traced by means of activities and reservation to all the corresponding (demand and supply) contracts. If possible, these planned contracts (resource transition) are cancelled. The corresponding cash flows now act as opportunity costs for the decision-alternative considered. In this way the reservation logic (context information), the activity logic (resource consumption) and the contract logic (resource transition and cash transition) make an operational use of the opportunity cost concept possible. The opportunity cost concept is thus implemented in the same way as the incremental cost concept. A formal description of the determination of the opportunity effect is given by means of the decision trees.

However, this opportunity cost concept deviates from the opportunity cost concept in accounting theory. In this theory, opportunity costs are defined relative to a decision, whereas the HCFM defines opportunity costs relative to a decision-alternative. This implies that the accounting theory suggest to evaluate a decision by means of a complete recalculation of a plan (other wise you cannot determine the opportunity costs). The HCFM however, determines the opportunity costs by means of an incremental adjustment of a plan. This way of determining the financial effect of a decision has also a better fit with planning concepts from the operations management.

Hierarchical planning ideas have been used to solve the 'classical' dilemma in management accounting between short-term and long-term decision-making. Decisions are decomposed into sub-problems that can be solved sequentially. A higher level decision has always a broader scope than the lower level decisions. Lower level decisions work within the constraints of the higher level plan. As such, hierarchical planning enables the decision-maker to have a broader scope than just the separate alternatives. Higher level,

<sup>&</sup>lt;sup>13</sup> When the actual decision is completely in correspondence with the plan, we still consider this as a plan that cannot be executed anymore. Therefore, we have opportunity costs for this decision.

long-term decisions are coupled with lower level, short-term decisions through constraints and through a financial valuation of capacity utilisation. At higher hierarchical levels, resources are reserved for specific usage. Lower level decisions actually use the reserved resources. In order to determine the opportunity effect, the usage of lower level decisions should be checked with the reservations made by the higher level decision. Due to the generic description of the model, the model can be used everywhere in the hierarchy of decision-making.

Moreover, the advantage of the HCFM is that the model dynamically determines which costs are incremental for a decision. This ensures that the discussion regarding the static view on controllable versus uncontrollable costs can be avoided. Moreover, the longer-term plans provide the target (opportunity costs) for shorter-term decisions. In this way the effect of shorter-term decision can be made visible in the light of the longer-term plan.

The conclusions described above shows that the HCFM complies to the requirements defined in Chapter 2. The requirement regarding objectivity of accounting data only becomes relevant to Chapter 4 of this thesis.

The HCFM only applies to organisations that pursue making profit. The model assumes standardised products and services created by standardised manufacturing processes out of standardised resources. The model only applies to situations where previous higher planning level decisions are sufficiently accurate to be used as a basis for assessing the opportunity effects of successive lower level decisions. This implies that the environment of the organisation (sales and procurement markets) must be relatively stable regarding the conditions assumed. The model is only relevant for situations where lower level decisions consume reserved capacity step-by-step, so lower level decisions interact but not simultaneously. In the model the incremental financial impact of each alternative course of action is calculated, instead of a complete plan regeneration. The HCFM might have a broader application domain than described here. However, this has not been researched.

The system borders of the HCFM should be defined based on the control structure of the organisation considered. Based on the control paradigm, the system borders can be defined on, e.g., departmental level, division level or organisational level. When the HCFM is applied on departmental level or divisional level, it is possible that 'fake' contracts have to be introduced to indicate that an internal delivery has taken place. At the organisational

level these 'fake' contracts are neutralised, since for each 'fake' demand contract a 'fake' supply contract exists.

The HCFM makes operational use of the relevant cost theory for operations management decisions in information systems possible. The challenge here has been defining the effects of a decision in such a way that not only human decision-makers are able to deal with the relevant cost concept but also information systems. We have seen that the HCFM gives answer to two of the three research questions defined in Chapter 1. In the next chapter we deal with that final research question: 'What are the implications of the accounting technique for the known accounting data models'. In that chapter a design of an object model is presented that is able to provide the data needed by the HCFM.

### **Chapter 4**

# **Object model to analyse cash flow changes of operations management decisions**

#### 4.1 INTRODUCTION

In this chapter the second part of the information system design is presented: the object model to analyse cash flow changes of operations management decisions. This model gives answer to the third research question defined in Chapter 1: *What are the implications of the accounting technique on the known accounting data models*. In the previous chapter a generic technique, called the Hierarchical Cash Flow Model (HCFM) has been defined to support operations management decisions with *ex ante* accounting information. In this chapter we present an object model that is able to carry out the procedures of the HCFM, and is able to supply the relevant data (see also Verdaasdonk 1998).

The HCFM could just be implemented in software. However, one of the main pitfalls in the development of accounting information systems is the narrow focus on one specific accounting application domain. In the first chapter this pitfall has been identified as one important reasons why present information systems lack *ex ante* accounting information for decision support functionality. In the past (and the present), this has too often led to information systems in which usually one accounting application domain (i.e., financial accounting) dominates the other accounting domains (Johnson and Kaplan 1987; Riebel 1994). Riebel (1959, 1994) and McCarthy (1980) plead for information systems that can serve multiple accounting applications. In these systems, the data registration technique is separated from the data manipulation technique or application domain. Riebel (1994) calls the database in which the application-independent data is stored: *purpose neutral database*. McCarthy (1979, 1982) pursues identical goals. As a result there are several 'purpose neutral' registration techniques for accounting data<sup>14</sup>.

Therefore, the research question, posed at the beginning of this chapter, is split into two separate questions:

- Can existing data models be used for the Hierarchical Cash Flow Model? And if not:
- □ What extensions have to be made in order to make the support of operations management decisions with *ex ante* accounting information possible?

The existing accounting data models are described in the next section (Section 4.2). In this section the main attention is on the works of McCarthy (1979, 1982), Riebel (1994), and Sinzig (1983, 1994). We argue that these known accounting data models only record *ex post* data. For this reason, they cannot be used for the HCFM. Therefore, we have to extend the research effort into the definition of accounting data storage to the *ex ante* application domain. In Section 4.3 the model is described that is able to provide *ex ante* accounting information. In that section a static model is described in which the relevant real world phenomena are captured that are needed for the HCFM. This model is explained in several parts. Each part is presented in three stages: a description of the relevant functionality that requires the specific part of the model, the requirements that are fulfilled, and finally the model itself. In Section 4.4 the dynamic model is described. The dynamic model gives some examples how the relevant information needed by the HCFM

<sup>&</sup>lt;sup>14</sup> We believe that purpose neutrality is a concept that is difficult to prove. For this reason the term *multiple purpose* is used here.

can be obtained by means of the static model. In the final section (Section 4.5), conclusions are drawn from the total model.

#### 4.2 LITERATURE REVIEW

Since the early beginning of the development of information systems for the accounting domain, the requirements derived from financial accounting have been dominant. The fundamental method of financial reporting is double-entry accounting, implemented with the general ledger. This method has the following characteristics (McCarthy 1980):

- Data concerning economic transactions and objects are recorded against the chart of accounts. The chart of account thus constitutes the basic classification scheme for accounting data.
- □ All economic transactions and objects are measured primarily in monetary terms.
- $\Box$  Equality of entry is to be maintained (debits = credits).
- The characteristics of similar transactions and objects are aggregated across time and segments.

However, since the 1960s, extension of the conventional accounting model to accommodate a broader spectrum of management information needs has become a topic of research interest. The arguments for research into this area had been found in the weakness of the traditional accounting model. McCarthy (1980, 628) formulates the following weaknesses of the traditional model (see also Belkaoui 1992, 110; and Hollander *et al.* 1996, 49 - 54):

- □ Its dimensions are limited. Most accounting measurements are expressed in monetary terms a practice that precludes maintenance and use of productivity, performance, reliability, and other multidimensional data.
- Its classification schemes are not always appropriate. The chart of accounts for a particular enterprise represents all the categories into which information concerning economic affairs may be placed. This will often lead to data being left out, or classified in a manner that hides its nature for non-accountants.

- □ Its aggregation level for information is too high. Accounting data is used by a wide variety of decision-makers, each needing different degrees of quantity, aggregation, and focus, depending on their personalities, decision styles, and conceptual structures. Therefore, information concerning economic events and objects should be kept in the most elementary form possible to be aggregated by specific users.
- □ Its degree of integration with other functional areas of an enterprise is too restricted. Information concerning the same set of phenomena will often be maintained separately by accountants and non-accountants, thus leading to inconsistency as well as information gaps and overlaps.

Two schools can be discerned in the research area of accounting information systems: an American school and a German school. Most of the American research effort into accounting information systems has been influenced by Sorter (1969). Sorter suggested reporting financial information in such a way that the application domain was maximised. The reporting technique at that time (called the value theory) did not satisfy this need according to Sorter. Sorter therefore defined the 'events theory'. The *events theory* proposes to report financial information in such a way that insight is being given into the events that change the balance sheet of an organisation. This call has led to research into the domain of accounting information systems<sup>15</sup>. The result of research into the area can be found in a broad spectrum of articles in accounting journals and books, which we will discuss next.

The German research effort into accounting information systems is mainly influenced by Riebel who, in his turn, was influenced by Schmalenbach. In the German literature the question how accounting data can be used for multiple accounting purposes is very old. Schmalenbach (1948, 66) questions: 'Dabei entsteht die Frage, ob man verschiedene Kostenrechnungen mit verschiedenen Wertansätzen nebeneinander aufstellen oder ob man

<sup>&</sup>lt;sup>15</sup> Dunn and McCarthy (1997) clarify the relationship between the events ideas of Sorter and the modern semantic models of enterprise economic phenomena. They argue that the events theory is a reporting method rather than a proposal to reorient transaction-processing systems. For this reason, they argue that current research into database accounting has no connection with the events theory. In some situations they even speak of misinterpretation of the ideas of Sorter.

stattdessen eine Grundrechnung aufstellen soll, die man dann für die verschiedenen Zwecke durch ausserbuchliche Zweckrechnungen verändert' ['The question rises if we should create application specific accounting systems with specific valuation systems or if we should create a basic recording system that provides data that can be calculated to specific purposes']. Riebel (1959, 1994) has extended the ideas of Schmalenbach. He propagates to use the ideas of the 'Grundrechnung' to obtain multiple accounting views with one set of data. A realisation of such a system is described by Sinzig (1983, 1994).

Figure 4-1 gives a graphical overview of the history of research into accounting information systems. In this figure only research is considered in which information systems have been built. This figure shows that the outcome of the research effort (the accounting information (AIS) adaptations) was mainly driven by the advances in database systems technology and in conceptual modelling formalisms. However, some argue that the development from relational databases to object-oriented databases is not a progress at all (see, e.g., Date 1995, 631).

The remainder of this section briefly discusses the research projects mentioned. For an extended overview of this research see Murthy and Wiggins (1993), Sakagami (1995), Weber and Weissenberger (1997), and Dunn and McCarthy (1997). Due to the importance of the research effort of Sinzig and of McCarthy, however, these are described in more detail. Analogous to Murthy and Wiggins (1993) the review is divided into three parts: implementation models (models that could only be implemented using specific Data Base Management Systems), semantic models (models that aim at incorporating semantics of the application domain in the database schema), and object-oriented models (models that incorporate both the structural and the behavioural aspects in a model).



(increasing representational capabilities)

## Figure 4-1: Overview of history in research into financial information systems (Adapted and modified from Murthy and Wiggins 1993)

NB: The figure is slightly adjusted, since in the original figure only the American research effort in into accounting information systems was considered. Moreover, object-oriented modelling techniques do not prescribe the usage of object-oriented database technology. For this reason the dashed arrow is included.

#### 4.2.1 IMPLEMENTATION MODELS

The implementation models can roughly be divided into hierarchical models, network models, and relational models. Colantoni *et al.* (1971), Lieberman and Whinston (1975), and Haseman and Whinston (1976) proposed to use a hierarchical data model for accounting applications. A hierarchical data model has the goal of representing and implementing pair-wise relationships between record types. The main drawback of this model is its reliance on explicit links between record types to answer queries and its access path dependency. Later, Haseman and Whinston (1977) proposed to use a network data model (a model strongly related to the hierarchical data model) to represent the accounting data. Finally, the relational model arose and became the dominant (implementation) data model, due to its strong theoretical foundation in the theory and relational algebra, simplicity, ease of querying (using languages like SQL), and access path independence (Ochuodho 1992). Everest and Weber (1977) finally presented a relational model for a financial accounting and a managerial accounting application domain. Their main emphasis has been on normalisation aspects in their relational model.

#### 4.2.2 SEMANTIC MODELS

Two important semantic models are discerned. The first model has been developed by the German school mentioned; the second model has mainly been developed by the American school. Both are described below.

The central point in the model of the German school is the strict separation of the application domain from the registration domain. This segregation is done to prevent that only one application may determine the data recording principles. The data registration method is developed by two researchers, independently of each other, around the same time at the end of the 1940s. In Germany this model is called 'Grundrechnung' and is developed by Schmalenbach. The principles are described in, e.g., Schmalenbach (1948, 1956). In the USA the model is called 'Basic Pecuniary Record' and is developed by Goetz (1949). Riebel (1994) has extended this work and gives the following principles in recording accounting data:

- □ No heterogeneous classification or summarising of elements that is needed separately for applications.
- □ No arbitrary division and allocation of accounting data.

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- □ Recording an entry at the lowest level possible in the hierarchy, without introducing arbitrary allocations.
- □ Characterisation with all attributes of interest and importance.

The basic principles are implemented with the so-called identity principle ('Identitätsprinzip'). This principle defines costs as cash expenditures resulting from a particular decision. Revenues are defined accordingly. For this reason, costs can be referred to as negative decision-consequences, measured by cash values that are objective parts of contracts with other parties. This implies that all costs (expenditures) and revenues have to be recorded according to at least one pre-defined decision object. This equals the method of pre-definition of incremental cost and revenues for a decision. The 'Grundrechnung' does not address issues from the financial accounting domain. Therefore, the 'Grundrechnung' does not intend to replace the general ledger.

Sinzig (1983, 1994) has used these ideas of Riebel in data registration to develop a relational database model that is able to provide relevant data for the 'Einzelkosten- und Deckungsbeitragsrechnung'. As discussed in Chapter 1, the 'Einzelkosten- und Deckungsbeitragsrechnung' is German contribution margin technique to analyse profitability of a range cost objects. The database design was called *purpose neutral database*, since the database was not designed for one specific accounting purpose. The relational database developed by Sinzig was specifically designed for one organisation (Riebel and Sinzig 1981; Sinzig 1983). This would indicate a lack of generality of the model. Nevertheless, the implementation sustained the concepts of Riebel regarding the 'Einzelkosten- und Deckungsbeitragsrechnung'. Later, Riebel *et al.* (1992) and Sinzig (1994) reported that the model had reached a generic form when implemented in the ERP system R2 (standard software) of SAP AG.

The most significant American semantic model, resulting from the research into accounting information systems, is called the REA (Resource, Event and Agent) model. This model is developed and described by McCarthy (1979, 1982). The REA model is a means to describe the real world in terms of resources, event, agents and the relationships between them. The REA model is based on Chen's Entity-Relationship model (Chen 1976). The REA model is able to fulfil all kinds of (financial) reporting functionality. Figure 4-2 gives the Entity-Relationship (E-R) model; the basics of the REA model.



Figure 4-2: The REA model (McCarthy 1982)

*Resources* are defined as 'objects that are scarce and have utility and are under the control of an enterprise' (Ijiri 1975, 51 - 52). *Events* are defined as 'a class of phenomena which reflect changes in scarce means resulting from production, exchange, consumption and distribution' (Yu 1976, 256). An event always influences the state of resources. This influence is expressed by the *flow* relationship. *Agents* are defined as 'persons and agencies who participate in the economic events of the enterprise' (McCarthy 1982, 563). For each event two participants (agents) can always be discerned: inside the enterprise and outside the enterprise. According to the REA philosophy, the occurrence of an event has always a double effect. These effects can be described in a 'give' and a 'take' event (Geerts and McCarthy 1997). From the inside agent's perspective the 'give-event' is related to a decrease of resources, the 'take-event' is related to an increase. Since ultimately, each 'give-event' is always related to at least one 'take-event' the relationship between them is called a *duality*. For instance, the event 'purchase' of the resource 'car' has a relation to the (multiple) event(s) called 'cash disbursement' that are associated with the resource 'money'.

The REA model is successful in providing a universal framework for accounting systems by means of generalisation. The REA model is meant an uniform registration technique for a range of applications from both the financial accounting and the management accounting. McCarthy (1982) has shown that the REA model is able to support multiple classification schemes including, traditional information schemes such as the balance sheet and the profit and loss account. Some examples can be found in which the REA model is

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applied for managerial accounting purposes. For instance, Grabski and Marsh (1994) describe the conceptual linkage between the REA model and the Activity-Based Costing method. The REA model aims at replacing the general ledger by offering the functionality of the general ledger plus providing additional functionality for other accounting domains. However, the functionality of the REA model described gives indication that the application domain of the REA model is focussed on reporting (*ex post*) functionality only.

When the 'Grundrechnung' and the REA model are compared, the conclusion can be drawn that the REA model complies with the rules of the 'Grundrechnung'. Therefore, the difference between the REA model and the 'Grundrechnung' is limited. However, the REA model has at least two advantages over the 'Grundrechnung'. The first advantage is that the REA model provides an alternative for the general ledger. The second advantage is the generality of the REA model. The REA model can be applied for every organisation instantly. The 'Grundrechnung' provides a set of rules / principles that has to be made operational per company. The 'Grundrechnung' does not give specific guidelines concerning the elements to which costs are recorded. The elements are only mentioned in specific examples without any generalisation. The REA model is very clear in this respect. In the REA model business events are used.

The REA model does not record any data for the *ex ante* application domain discussed in this thesis. The 'Grundrechnung' does record some *ex ante* data, but only for the purpose of the 'Einzelkosten und Deckungsbeitragsrechnung'. This data relates to the costs of replacement of resources (or cost objects in the 'Grundrechnung' terminology). These costs are considered to be a characteristic of the cost object. For example, the purchase price of a kilogram of raw material.

#### 4.2.3 **OBJECT MODELS**

Object-oriented modelling is way of thinking about problems using models organised around real-world concepts. The fundamental construct is the object, which combines the structural aspect of data and behavioural aspect in a single entity. The structural aspect of an object relates to the identity of the object, its relationship to other objects, and its attributes. The behaviour of an object is captured in its operations that allow an object to carry out actions. Objects show behaviour by executing operations in response to received messages (Taylor 1995). Object models thus deviate from so-called data-structures and procedural programming, where the data and operations are completely separated.

Object-oriented modelling has many advantages with respect to the development, operation and maintenance of information systems. In the area of (accounting) information system design, object-orientation is believed to be the most interesting area of research in 1990s (Murthy and Wiggins 1993).

Several methods are available how to structure the process of developing object-oriented software. These methods prescribe several stages in the development process and the presumed result of each stage. Moreover, the methods supply notation conventions on how to capture the real world semantics. Examples of these methods are the Object Modelling Technique (OMT) by Rumbaugh *et al.* (1991), Booch by Booch (1994), or the Object-Oriented Software Engineering (OOSE) by Jacobson and Christerson (1992). However, in the late 1994, the designers of the methods mentioned started to combine their methods into one coherent method. This method is called Unified Modelling Language (UML); see, e.g., Fowler and Scott (1997) for a description of this method. The UML technique is used in this thesis. In Appendix A the notation convention of the UML is given.

The structure of the methods consists of four stages (Rumbaugh *et al.* 1991): analysis, system design, object design, and implementation. During the first stage the *analysis model* is stated. The analysis model is a concise, precise abstraction of what the desired (target) system must do. During the second stage, the *system design*, high level choices are made about the system's architecture. An example of such a choice is the division of the target system into subsystems. In the third stage the *object design (model)* is developed. This model is derived from the analysis model and contains implementation details. The focus of the object design is on data structures and algorithms needed to implement the system design. The final stage is called the *implementation phase*, where the object design is translated into programming code.

An object-oriented model generally includes four aspects: identity, classification, polymorphism, and inheritance (Rumbaugh *et al.* 1991). *Identity* means that data is quantified into discrete, distinguishable entities called objects. *Classification* means that objects with the same data structure (attributes) and behaviour (operations) are grouped into a class. A class is an abstraction that describes the properties important to an application. An object is an instance of a class. *Polymorphism* means that the same operation may behave differently for different classes. For instance, if all chess pieces were modelled as a class, the operation 'move' would have a different impact on each piece. *Inheritance* is the sharing of attributes and operations among classes, based on a

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hierarchical relationship. In other words, each subclass inherits the attributes and operations of the superclass. Moreover, each subclass also incorporates its own attributes and operations. For instance, the subclass [FourWheelDrive] could inherit from the superclass [Car], meaning that the 'four wheel drive' is a car, but has specific properties of its own. The four aspects of the object model: identity, classification, polymorphism, and inheritance ensure the tight connection between data structure and behaviour.

Very few publications use object-orientation in their modelling of accounting data. McCarthy (1995, 1996) and Geerts (1997) show some results of the translation of the REA model into an object-oriented model. In these contributions the REA pattern is used as a domain-specific pattern for the analyses and design of accounting information systems.

#### 4.2.4 CONCLUSION

The present review of the literature on accounting data modelling has shown that the most important models record *ex post* data only. The application domain considered in this thesis requires *ex ante* data. In relation to the first research question of this chapter this implies that the present accounting data models cannot be used for the HCFM as they are at this moment. Extensions have to be made. The extensions are based on the requirements defined in Chapter 2. The resulting model is presented in the next section. We have shown that research in accounting data modelling should be related to object-oriented models. For this reason, the model described in the next section is an object model.

## 4.3 OBJECT MODEL FOR OPERATIONS MANAGEMENT DECISION SUPPORT

In this section the object model is given to support operations management decisions with *ex ante* accounting information. The object-model is described in five parts. Each part of the object model is described in three stages:

- $\Box$  The functionality that is modelled.
- □ The requirements that are fulfilled.
- □ The implementation choice made in the object design.

The requirements referred to have been defined in Chapter 2. These requirements are:

- □ Objectivity of accounting data.
- □ Resource consumption.

- □ Resource transition.
- □ Cash transition.
- □ Context information.

#### 4.3.1 THE CORE OF THE MODEL

#### Functionality

The core of the model expresses the past, present and future resource flows of an organisation. Resource flows are modelled within the organisation and between organisations. In the latter case, the term exchange is used. An *exchange* is defined as 'an action whereby the entity foregoes control over some resources in order to obtain control over other resources' (Ijiri 1975, 61). In the model we express an exchange by means of an dual relationship between contract and resource<sup>16</sup>. This exchange relationship is a specific example of the 'give' and 'take' relationship as described by Geerts and McCarthy (1997). The first relationship specifies the subject of the exchange. For a sales transaction this would be the object being sold; for a purchase transaction this would be the object being sold; for a purchase transaction this would be the object being sold; the resource is money. This exchange of resources is expressed by means of the classes [Contract] and [Resource], and the interrelationships (associations) between these classes (see Figure 4-3). In this model 'money' is a specific instance of the class [Resource]<sup>17</sup>.

<sup>&</sup>lt;sup>16</sup> One of the basic principles of the REA model is the exclusion of artefacts. In the REA model contracts have been considered as such an artefact. Since the existence of contracts is one of the main premises to obtain decision support functionality, contract are modelled here. We note that Weber (1986) also stated the necessity to model commitments in the REA model. Riebel (1994) also stated the necessity to model commitments in information systems.

<sup>&</sup>lt;sup>17</sup> Note that we can model the individual cash flows here, instead of the total cash flow associated with the resource transition. See also Chapter 3, Section 2.



**Figure 4-3: Exchange of resources** 

Each part of the exchange relationship is characterised by means of a quantity and two types of dates. The quantity represents the quantifier of the resources involved in the exchange. The quantity is modelled with the class [Quantity]. Time is modelled by means of the class [CalenderUnit]. The planned due date relates to the expected date of the resource inflow or outflow. The actual date refers to the realisation date of these flows. The class [QuantityPerDate] is used as a combination element between the classes mentioned. The aggregation relation of the class [CalenderUnit] expresses the possibility to deal with all kinds of moments in time, ranging from seconds to minutes, to hours, to days, to weeks, to months, etc.

Each contract has an attribute called 'status'. This status indicates whether a contract is 'final' or 'planned'. 'Final' means that the organisation has committed itself to the execution of the exchange specified in the contract. 'Planned' means that the organisation has only intentions to execute an exchange in the future.

For planning purposes, we need to make a distinction between types of resources. We discern tangible resources and intangible resources. Tangible resources can be divided into materials and capacity. Examples of capacity are machinery-hours and employee-hours. Services are intangible resources. Money is categorised as material.

The reasons why we have to make a distinction between types of resources only become clear when we explain activities (later on in this Section). However, here we give some examples how we model purchase and sales transactions of these resources. Since cash flows are not yet relevant, we only consider the non-cash resource flow.

When we model the purchase transaction of machinery an instance of the class [QuantityPerDate] combines instances of the classes [Contract], [Quantity], [Resource], and [CalenderUnit]. The value of the attribute 'amount' of the instance of the class [Quantity] equals 1. This value expresses that we have purchased 1 piece of machinery. The two association relationships between the instances of the classes [QuantityPerDate] and [CalenderUnit] refer to the (planned and actual) date the machinery is received (start date). When we want to sell the machinery we need new instances of the classes [Contract], [QuantityPerDate], [Quantity], and [CalenderUnit]. The association relationships between the instances of [QuantityPerDate] and [CalenderUnit] now refer to the planned or actual date that the machinery flows out of the organisation.

When we model the purchase transaction of materials we need instances of the classes [Contract], [QuantityPerDate], [Quantity], [Resource], and [CalenderUnit]. We record the number of materials purchased (in kilograms, in pieces, etc.) by means of the attribute 'amount' of the instance of the class [Quantity]. The two association relationships between the instances of the classes [QuantityPerDate] and [CalenderUnit] refer to the dates (planned or actual) the material is received by the organisation. When we sell the materials we need new instances of the classes [Contract], [QuantityPerDate], [Quantity], and [CalenderUnit]. The association relationships between the instances of [QuantityPerDate] and [CalenderUnit] refer to the planned or actual date the material flows out of the organisation.

Hiring an employee would be included in the model with instances of the classes [Contract], [QuantityPerDate], [Quantity], [Resource], and [CalenderUnit]. The attribute 'amount' here expresses the number of hours hired. The number of hours always relates to a specific period. This period is specified by means of the association relationships (planned and actual) between the instances of the classes [QuantityPerDate] and [CalenderUnit]. For instance, if the attribute of the class [Quantity] equals '40 hours' the corresponding instance of the class [QuantityPerDate] would be associated with the instance 'week 1' of the class [CalenderUnit]. Or, if the attribute of the class [Quantity] equals '2,000 hours' the corresponding instance of the class [QuantityPerDate] would be associated with the instance 'year 1999' of the class [CalenderUnit].

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The increase and decrease of resources within the organisation is modelled by means of the classes [Activity], [QuantityPerDate], [CalenderUnit], [Quantity], and [Resource], and the interrelationships between these classes. An *activity* creates a specific set of output resources (give) out of input resources (take). This part of the model resembles the previous part. The only difference is that the class [Activity] substitutes the class [Contract]. Moreover, the class [Activity] has an attribute called 'status'. This attribute indicates whether the organisation has been committed to the activity (final) or only plans to execute the activity (planned). The planned due date and the actual dates refer to the moments in time the input resource must be available (planned and actual) and the moment the output resource becomes available (planned and actual). The difference between the actual date of the input resources and the actual dates of output resources thus expresses the actual lead-time of the activity. It is clear that planned due dates can be used for expressing the planned lead-time.

Past and present resource flows are registered by means of the concepts final activities and final contracts. Future resource flows are registered by means of the concepts planned activities and planned contracts.

Here the difference between the types of resource becomes important. An activity specifies the input resources needed to obtain the output resources. However, when an activity needs, e.g., 5 hours of a piece of machinery, the activity can only find machinery expressed in pieces. The model described is aimed to be incorporated in ERP systems. In these systems we assume that we have advanced scheduling logic that is able to project all capacity resources on a calendar to obtain capacity hours. However, here we do not have this functionality. Therefore, we have modelled a specific solution that gives us the required functionality. We acknowledge that, e.g., for system performance reasons this solution could be inconvenient.

When piece of machinery is purchased an activity is started that converts the input resource machinery into the output resource machinery hours. The input-relationship of this activity refers to a specific instance of the class [QuantityPerDate]. This instance is associated to the instance of the class [Quantity], the instance of the class [Resource] which is the specific machinery. The attribute 'amount' of the instance of the class [Quantity] equals '1'. Moreover, the instance of the class [QuantityPerDate] has association relationships with instances of the class [CalenderUnit]. These associations represent the actual / planned date the input resource is needed for this activity. The

output-relationship of the activity refers to multiple instances of the class [QuantityPerDate]. Each instance of [QuantityPerDate] is associated with instances of the classes [Quantity], [CalenderUnit], and [Resource]. The instance of the class [Resource] is called 'machinery hours'. Each instance of the class [QuantityPerDate] with its associations to other instances represent a number of hours in a specific period. The period is specified by the instances in the class [CalenderUnit]. Note that in this way capacity hours of machinery is modelled the same way as capacity hours of humans.

Related to this functionality is the logic how to handle this capacity per resource type. The resource types 'employee' and 'capacity' have the knowledge they can offer (if asked) only those hours that are related to instances of the class [CalenderUnit] that represent the present or the future. Hours related to the past are forgone. This functionality does not relate to materials. The quantity of specific materials present in an organisation at a specific moment in time (stock) can be calculated by means of the value 'amount' of all instances of the class [Quantity] that express an increase of this material minus the value 'amount' of all instances of the class [Quantity] that express a decrease of this material. Note that these instances thus relate to the past and the present.

We have argued that we also have intangible resources. Intangible resources are modelled with the class [Service]. In the object model services differ from activities. The main difference between a service and an activity is that a service is an intangible resource, whereas an activity specifies the way to obtain a resource. For instance, when an organisation wants clean windows (resource window with a specific attribute 'clean') they can purchase the service 'cleaning windows'. This service changes the attribute of the resource 'window' from 'dirty' into 'clean'. From an accounting perspective this company is just interested in the intangible resource, since they have to pay for it. The company that actually cleans the windows would be interested in the process. Reason for this could be to control efficiency or to determine how many input resources are required to 'produce' the resource for the market. For this reason they model the input resources (bucket, water, employee) for the activity 'cleaning window' to obtain the service that is of interest to the customer.

#### Requirements

The core of the object model fulfils multiple requirements. Resource consumption is implemented by means of the class [Activity] and its association. Resource transition is implemented by means of the give-relationship of demand contracts, and the take-
relationship of the purchase contracts. The requirement cash transition is implemented by means of the other part of the dual relationships just mentioned. The requirement objectivity of accounting data is also taken into account, since all the accounting data (cash flows) are stored without any apportioning.

## **Implementation choices**

The classes [Activity] and [Contract] have exactly the same association relationships with other classes. Moreover, the role of these relationships is similar in both situations. Therefore, an abstract class [CapacityUser] is introduced (see Figure 4-4). This class does not have instances of its own. The class [CapacityUser] is then subclassed into [Contract] and [Activity]. The uniform operations and attributions of both latter classes are incorporated into the superclass [CapacityUser]. For example, the attribute 'status' and the relationships to the class [QuantityPerDate].



Figure 4-4: The core of the model (I)

The classes [Service] and [Resource] share common behaviour. The most important example of this behaviour is that both can be involved with purchase / sales transactions. Therefore, a new class is introduced in which this joint behaviour is combined. This class

is an abstract class and thus does not have any instances of its own. This new (abstract) class is called [AbstractResource]. The specific behaviour is then incorporated in the specialised classes [Resource] and [Service], respectively. The class [Resource] can be subclassed into the classes [Capacity] and [Materials]. However, for ease of reading throughout the thesis, we have not incorporated these subclasses in the figures.

## 4.3.2 CONTRACT

## Functionality

The contract<sup>18</sup> specifies the conditions of the exchange of resources between the company and the supplier / customer. The suppliers / customers are called agents [Agent]. The agent that 'receives' does not automatically have to be the agent that 'gives' as well. For this reason a dual relationship exists between the [Agent] class and the [Contract] class. The contract specifies the commitment a company has made with the outside world. A contract can be specified by the agreement date, termination date, and the termination period.

In a company two types of agreements can be discerned. The first agreement type is expressed by means of the contracts. In the contracts the company records all its commitments. A specific characteristic of such a contract is the penalty that might have to be paid when ending the contract prematurely. The second agreement type is called 'contract potential'. In this agreement type the company records the agreed conditions of possible (future) resource exchanges. For example, agreements with suppliers regarding prices for resources, conditions for employees (already in service) for working overtime, or conditions regarding the supply of temporary workers. A difference between a contract and a contract potential is that the resources specified in the contract potentials cannot have planned and actual due dates. Due to similarity found with the activity class, the implementation choices that have been made are discussed in the subsection concerning the activities (Subsection 4.3.3).

## Requirements

The implementation of the concept contract ensures that the resource transitions and cash transitions can be recorded. The contract potentials provide information about conditions

<sup>&</sup>lt;sup>18</sup> For simplicity, we suggest here that a contract can have only one subject. This is not completely true. Each contract can have multiple contract lines. A contract line is defined by the values of all the conditions.

of future exchanges. In these potentials, the conditions by which sales and purchase transaction can take place are specified. This results in *ex ante* functionality. Forecasted sales and purchases are recorded in instances of the class [Contract]. The value of the attribute status of these instances would thus be 'planned'.

## **Implementation choices**

Contract potentials are discerned from contracts with the help of an attribute 'potential'. This attribute indicates whether the contract is potential or not. The penalty is presented as an attribute of the class [Contract]. This could well be modelled as a separate class, when there are several different ways to calculate the penalty. For instance, the penalty could be dependent of the contract period elapsed or of the cancelled future cash flows. These calculation methods could then be incorporated in a [Penalty] class. However, this is not elaborated here.

Other conditions regarding the contract concept are implemented in the model depicted in Figure 4-5.



Figure 4-5: Contract

## **4.3.3 ACTIVITY**

## Functionality

The activities within the company create certain output resources using a given set of input resources. As defined, activities can be 'final' or 'planned'. Therefore, activities can be used to register past, present, and future creation processes within the organisation. Activities can also be used to specify normative relationships between input and output resources. These normative relationships are called 'recipes'. A recipe is an activity that does not have a planned or actual due date. A recipe just gives guidelines on how to create output resources out of specific input resources.

## Requirements

Planned and final indicate whether the activity is (just) planned or actually carried out. The activities implement the requirement of resource consumption. The recipes enable the model to make projections of potential future resource consumption and creation.

## **Implementation choices**

Recipes are discerned from activities with the help of an attribute 'recipe'. Furthermore, the recipe concept is implemented by introducing a new class: [QuantityPer]. The already defined class [QuantityPerDate] inherits from this new class. A recipe is always related to the classes [Activity] and [QuantityPer]. In the previous subsection, identical behaviour has been found for the contract potentials. This type of agreement also does not have planned and actual due dates. For this reason contract potentials is also associated with the class [QuantityPer]. The planned or final activities / contracts are always related to the classes [Activity] / [Contract] and [QuantityPerDate]. This implementation choice changes the core of the model slightly. The implications are depicted in Figure 4-6.



Figure 4-6: The core of the model (II)

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Both recipes and contract potentials require relationships with instances of [QuantityPer], whereas contracts and activities require relationships with instances of [QuantityPerDate]. Other combinations, e.g., recipe associated with an instance of [QuantityPerDate] are not allowed. This does not show from the object model. Therefore, the implementation in programming code has to deal with this constraint.

## 4.3.4 **Reservation**

#### Functionality

For each (set of) quantifier(s) of a resource the planned usage is recorded. This function ensures that a resource is not given away more then once. Moreover, when the planned usage is known, this usage can be compared with the actual usage by a decision-alternative. In the HCFM this comparison is used to trace the opportunity effect. This planned usage is recorded by means of the reservation. The *reservation* is characterised by means of the attribute status. This status can be 'final' or 'planned'. *Planned* means that a demand exists for a resource. *Final* means that there is a demand for the resource that may not be promised to other demands. A reservation becomes final when a final demand contract / activity needs the resource and that replenishment is not possible due to lead-time restrictions or scarcity of the resource. The resources are always necessary for a specific demand: destination. The destination can be the input to activities or the give-relationship of demand contracts.

## Requirements

The reservation deals with the registration of the planned and actual use of resources. The concept is used to determine the opportunity effect plus to ensure that resources are not given away more than once. The reservation contributes to the requirement 'context information'.

#### **Implementation choices**

One extra class is introduced here: [Reservation]. The class [Reservation] has an attribute called 'status'. The status can have the value 'planned' and 'final'. The class [Reservation] has two association relationships to the class [QuantityPerDate]. The first relationship indicates if a resource is reserved. The second relationship indicates where the resource is going to be used (destination). This relationship relates the supply of resources (by activities and supply contract) to the demand for resources (by demand contracts and activities). This leads to the model as depicted Figure 4-7.



**Figure 4-7: Reservation** 

## 4.3.5 QUANTITY

## Functionality

Each quantity has a unit of measure. For planning purposes these quantities often must be converted to other units of measure. For this purpose conversion ratios must be known.

## Requirements

This functionality is additional to the specified requirements.

## **Implementation choices**

The implementation is similar to Fowler (1997). Fowler introduces a [ConversionRatio], which actually contains a number that specifies the conversion ratio, from one unit to another. This is depicted in Figure 4-8.



## **Figure 4-8: Conversion**

This concludes the implementation choices to obtain an object model for the reference model. For clarity reasons, the model has been explained in multiple parts. In Appendix B an overview of the total model is given. The object models presented give a static description of the relevant accounting phenomena that are needed for the Hierarchical Cash Flow Model. With the help of the object models described the planned / realised purchase transactions, production processes, and sales transactions of a company are

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described in terms of contracts, activities, and resources. The object model described ensures the requirements of objectivity of data since the knowledge of the models of Riebel and McCarthy has been used. The object model provides the generic accounting technique the relevant data, needed to calculate the financial impact of a decisionalternative. However, the functionality that deals with the calculation of the impact of a decision-alternative has not yet been modelled. This is done in the next subsection, where the dynamic description of the model is given.

## 4.4 DYNAMIC MODEL FOR OPERATIONS MANAGEMENT DECISION SUPPORT

In this section we give two examples of the dynamic model. The dynamic model shows how the relevant information needed by the HCFM can obtained by means of the static model. The dynamic model shows the behaviour of the system and the objects in it. We introduce a new class that regulates the demand for and the supply of resource. This class is called the [ResourceManager]. This class has only one instance, a so-called singleton. This class deals with all questions regarding the matching of demand for and supply of resources. The dynamic model is presented by means of so-called 'use case' A use case 'elicits requirements from users in meaning full chunks' (Fowler and Scott 1997). An use case is presented in a so-called 'use case diagram'. An use case diagram is 'an ordered list of events between different objects possibly assigned to columns in a table'. In the header of an use case diagram the objects relevant for the use case are presented. Each object is able to call methods on other objects. The messages between two object are made visual by means of an arrow. Above the arrow the message (method) is given. The use cases presented below discuss some of the functionality of the HCFM, expressed in methods that belong to the object classes. Therefore, a use case gives insight in the operations designed for the execution of the HCFM, and how these work on the objects.

#### Use case 1: Making a plan to sell and purchase 40 resources X (see Figure 4-9)

In this use case the focus will be on the creation of a master plan concerning the sale of 40 pieces of resource X and the resulting consequences. The user (decision-maker) inserts a new demand contract for 40 pieces of X at moment T (by means of [new]). The demand contract asks the resource manager (RM) if he is able to supply 40 pieces of resource X at moment T. This question is asked to the RM with the method [plan (40, X, T)]. The RM asks the resource X to give a list of all the possibilities how this demand can be satisfied

[getCapacityUsers()]. The result could be a list of planned / actual activities, planned and actual supply contracts, recipes and contract potentials. In this use case, for simplicity we assume that the result is only one contract potential. The RM now asks this contract potential to create a new planned supply contract, called plannedSC1 [createPlannedContract()]. The contract potential creates a new supply contract provided with most of the information from the potential contract. Now that the supply contract is known, the RM asks the supply contract to make a reservation for destination 'demand contract' and status 'planned' [reserve()]. We return to the user. The user asks the demand contract to calculate the cash flow gross balance, given the planned supply contract [getCashFlowGrossBalance(plannedSC1)].

Note that when there are more options to fulfil the demand (meaning that the method [getCapacityUsers()] gives a whole list of options, all these options can be treated in the same way.

Use case 2: Inserting a new final demand contract for 1 resource X (see Figure 4-10)

Point of departure is the result of the previous use case. This implies that we have one planned demand contract for 40 X and one planned supply contract also for 40 X. The user inserts a new (final) demand contract for 1 piece of X [new]. This demand contract asks the RM if he is able to supply 1 piece of X at moment T [plan (1,X,T)]. The resource manager asks the resource X to give a list of all the possibilities how this demand can be satisfied [getCapacityUsers()]. The result is a list with one planned supply contract and one contract potential. Here, we will only consider the first option. The RM ask the planned supply contract of X to create a new supply contract for 1 resource X [createPlannedContract(1,X)]. A new supply contract is now created. The old planned supply contract cancels the reservation for 1 X [cancel (1,X)]. The RM asks the old planned supply contract for its cash flow [getCashFlow()]. Then the RM asks to cancel the old planned supply contract for 1 X [cancel(1,X)]. Again the RM asks the supply contract for its cash flow [getCashFlow()]. (NB: the difference between these two cash flows is the first opportunity effect of this order acceptance decision.) The same procedure is repeated for the old demand contract. Here a second opportunity effect (cancellation of the demand contract) is determined. The RM calculates the balance of these effects, and returns the value to the user. The user asks the demand contract for the incremental effect by means of the method [getCashFlowGrossBalance(plannedSC2)]. This value together with the opportunity effect determines the cash flow net balance of this order acceptance decision.

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Note that if the user is not satisfied with the cash flow net balance, he does not accept the new demand. All actions of the use case are rolled back.



Figure 4-9: Use case diagram for planning 40 X



Figure 4-10: Use case diagram for accepting an order for 1 X

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## 4.5 CONCLUSIONS

In this chapter an object model has been described that can be used for operations management decision support. Two research questions have been discussed:

- Can existing data models be used for the Hierarchical Cash Flow Model? And if not:
- □ What extensions have to be made in order to make the support of operations management decisions with *ex ante* accounting information possible?

First of all, the REA model and the 'Grundrechnung' only give a static description concerning accounting data storage. The object model presented combines static and behavioural aspects in one model. The REA model and the 'Grundrechnung' can only be compared for the static part. Furthermore, both the REA model and 'Grundrechnung' relate to *ex post* data<sup>19</sup>. Similarity between the object model and the two mentioned can only be found for the *ex post* part.

When the object models presented in this chapter are compared with the REA model, the conclusion can be drawn that the object models presented are REA compliant. The classes [Resource], [Activity], and [Agent], can be fully compared with the entities Resource, Event, and Agent of the REA model. However, the REA model explicitly recognises the following three events: sales event, purchase event, and cash disbursement. In the object model presented these events are incorporated by means of the dual relationship between contract and resource. The REA model is thus extended with the contract functionality and the possibility to relate the effect of a decision-alternative to the plans of the organisation.

The object model can be compared with the basic principles of recording of the 'Grundrechnung'. The object model complies with these rules. The first three rules are implemented by means of the contract. The first rule relates to the heterogeneous summarising of financial elements. All accounting information is recorded in contracts. Each contract has one subject. This implies that the basic accounting data is not summarised. The second rule relates to allocation and apportioning of accounting data. Since, all accounting data is recorded according the way the data arises (interaction

<sup>&</sup>lt;sup>19</sup> As we have seen in Chapter 1 'Grundrechnung' registers the replacement value of material. This can be considered as *ex ante* data.

between the organisation and its markets) accounting data is not allocated nor apportioned. The third rule is more or less specific for the way accounting data has to be stored for the logic of Einzelkosten und Deckungsbeitragsrechnung. For our purposes we do not need cost hierarchies. However, since accounting data is recorded in contracts for specific resources, and the resources are the lowest level in the cost hierarchies mentioned, the object model complies with the third rule. The final rule: 'characterisation with all attributes of interest and importance' is rather abstract for making a fair comparison. For our purpose the data is characterised with all attributes of interest.

In this chapter the ideas of the existing models from the literature have been used to construct an object model that is able to supply relevant information for the HCFM. The contracts ensure that resource transition can be converted to a cash transition. Contract potentials ensure the objective implementation of incremental costs and revenues. The hierarchy necessary to determine the opportunity costs by the HCFM is implemented by the reservation logic and the type of commitment (status) of contracts and activities. The recipes ensure that external demand is traced to the consumption of resources, and eventually to the acquisition of resources.

Literature concerning information systems for production and inventory control make a distinction between state-dependent data and state-independent data (Bertrand *et al.* 1990). *State-independent data* is defined as 'data indirectly supportive to the recording and planning of orders and materials'. *State-dependent data* relates to 'the recording and planning of orders and materials'. In our model resources, agents, recipes, and contract potentials are state-independent data. Contracts and activities are state-dependent data.

A limited prototype has been built to validate the logical structure of the static object model. The object model presented is the result after adaptions made based on this prototype.

The object model only deals with the fundamental problems underlying the incorporation of *ex ante* accounting information into standard software. When a real life application is built, additional effort must be undertaken to streamline the object models. For example, for overview purposes an explicit link could be necessary between realised contracts and agreements per supplier. Since fundamental problems are not expected, this is not discussed further.

The question may arise if the detailed registration of (accounting) data, as prescribed by the model is feasible. Weber and Weissenberger (1997) indicate that the maintenance of the *purpose neutral database* of Riebel and Sinzig could be very extensive. However, they do not give any empirical evidence to this effect. We argue that most of the data required is already present in most of the ERP systems. Therefore, these data must be registered for other purposes as well. This makes it more feasible than one would assess in the first place.

The model is intended as a part of an ERP system. For this reason, we have assumed that some important functionality to support the model is present. For instance, the functionality to maintain the registration of resources (new resources, engineering changes, etc.), functionality to maintain the registration of contracts (new contract, order entry, customer data, supplier data, etc.), advanced scheduling functionality, etc. is available and can be used for the functionality described here. Furthermore, we have given a workable solution for our model to deal with capacity and materials in an identical way. However, when the model is implemented in an ERP system this should be executed by a more advanced scheduling and planning tools.

## Rationale



# Chapter 5

## **Rationale of the information system design**

## 5.1 INTRODUCTION

In this chapter a rationale is given of the information system design described in Chapter 3 and 4. The purpose of this rationale is to demonstrate that the information system design presented, defines a system, that if implemented, would satisfy the collection of system stakeholders' need statements (Dolan *et al.* 1998). As explained in Chapter 1, the stakeholders' need statement is primarily focussed on functional requirements with the user as the most important stakeholder. Therefore, we have chosen to focus on users in the rationale. The rationale is based on two operations management decisions: 'setting the Master Production Schedule (MPS)' and 'order acceptance' (see also Verdaasdonk and Wouters 1998b). The reasons for choosing these decisions are twofold. Firstly, these decisions are commonly supported in ERP systems, which are our target systems. Secondly, there exists a hierarchy between the decisions 'setting the MPS' and 'order acceptance' which allows us to describe the hierarchy needed for the Hierarchical Cash Flow Model. For each decision we describe a possible implementation of the HCFM in a

realistic information system setting. However, the implementation of the HCFM is not straightforward. We show that some serious complexities arise when the generic concept of the Hierarchical Cash Flow Model (HCFM) is applied to decisions, modelled in present information systems. Therefore, the complexities and the solutions to solve these complexities also have a central place in this chapter.

Section 5.2 deals with the decision 'setting the MPS'. In that section we describe how the HCFM is applied to the MPS. In this section we explain the complexities encountered and we propose solutions to solve these complexities. The complexities are caused by the way the decision is modelled in present information systems. As a consequence, the object model presented in Chapter 4 is extended to support the decision. Section 5.3 deals with the decision 'order acceptance'. The HCFM is also applied to this decision. The order acceptance decision did not lead to serious complexities. Only a small extension of the object model is proposed. In Section 5.4 a numerical example is elaborated to clarify the complexities encountered and we show that the HCFM is still able to supply the relevant information, with the proposed solution. Finally, in Section 5.5 conclusions are drawn from this application of the HCFM in an information system setting.

## 5.2 SETTING THE MASTER PRODUCTION SCHEDULE (MPS)

In the operations management literature many articles exists about the MRP II concept and the role of the MPS, e.g., Taal and Wortmann (1997) and Wortmann *et al.* (1996). Such concepts can be used in real life complex situations and have been included in information systems. These concepts have been taken as a reference point. However, financial trade-offs are generally not included in these concepts. As a consequence, information systems generally only provide decision support on non-financial parameters such as occupation rate, lead times, and capacity absorption.

By means of production control, supply of resources is tuned with the forecasted demand for these resources. For many organisations this is a complex process. In order to control this process, models are used. A model is a representation of the reality and reduces the complexity of the production control problem by decomposition, aggregation and omission (Giesberts 1993; Bertrand *et al.* 1990). Decomposition is the process of dividing the production control problem into sub-problems. For each sub-problem a production control function is defined. The production control functions can be structured hierarchically, which means that decisions of a function on a higher level are constraints

for functions on lower levels. The production control problem can be decomposed into parameter setting, volume co-ordination, mix co-ordination, and operations co-ordination, as in Figure 5-1. Parameter setting is concerned with the determination of logistic norms for batch sizes, safety stock norms, throughput time norms, work content norms, utilisation norms in such a way that the required market performance and the production cost budget as specified by the top management are satisfied. Volume and mix co-ordination have already been defined in Chapter 2. To recall, the objective of the volume co-ordination function is to absorb medium-term fluctuations in the agreed upon sales output; the objective of mix co-ordination is to obtain the required service level and possibly the required delivery times of separate end products. The objective of the operations coordination function is to realise the planned production quantities specified by mix coordination. For more information about this topic see Giesberts (1993).



Figure 5-1: Decomposition of the production control problem (Giesberts 1993)

Omission and / or aggregation are used to further reduce the complexity of the decisionmaking process. Omission of an element of the primary process means that the element is ignored in the primary process model. An element can be ignored when the element is considered irrelevant for the decision, e.g., when the element not critical and does not influence the outcome of the plan. Aggregation of two or more elements of the primary process means that these elements are replaced by one aggregated element in the primary process model.

The function of the MPS is to take care of 'volume co-ordination' and 'mix co-ordination'. The principles of omission and / or aggregation are used. This means that the decision

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function only relates to a limited set of products and work centres and / or aggregated products and work centres. Included in the MPS are items / work centres that are critical, for example, because of limited capacity or long supply times. Aggregation can occur if products or work centres are combined which have a certain similarity. Examples of this are family items (e.g., bicycle instead of all specific types of bikes) or resources combined in one work centre (e.g., work centre drilling, instead of all specific drilling machines). When deciding on a volume and mix of products (MPS), capacity shortage problems are also assessed and where needed feasible short-term capacity adjustments are planned.

The HCFM should be able to calculate the cash flow gross balance of a MPS scenario. However, the application of the HCFM for the MPS decision encounters some serious complexities, which are caused by aggregation and / or omission: sales prices per product (MPS item) and purchase prices (or material value) per MPS item are in some cases not available. This implies that the cash transition resulting from the resource transition cannot be determined. For instance, for planning purposes, several related items with the same characteristics are combined into one MPS item. This item, which is not a real item, does not have a sales price. Therefore, the cash transition resulting from the sales of this item (defined in the MPS) cannot be determined. Or as result of efficiency in planning, specific non-critical items are not considered in the MPS. This implies that the resource transition and therefore also the cash transition is not considered in the MPS. The problems encountered and the solutions found are discussed in the next subsection.

# 5.2.1 PROBLEMS WHEN APPLYING THE HCFM FOR EVALUATING MPS SCENARIO'S

The HCFM determines the cash flow net balance of a MPS scenario by considering the cash outflow resulting from purchase of resources specified in the MPS and the cash inflow resulting from the sales of resources specified in the MPS. However, due to modelling of the MPS decision in information systems, this calculation method could leads to 1) overestimating the cash flow net balance, since possibly a part of the outgoing cash flow is ignored (omission of resources) or 2) underestimating the cash flow net balance, since possibly a part of the incoming cash flow is ignored. Moreover, due to aggregation fictitious resources are introduced that do not have real cash flow effects with the outside world at all. In total, we have encountered eight problems when applying the HCFM for the decision setting the MPS due to omission and aggregation. Next we discuss the solutions for these problems. These solutions are constructed in such that we still can use resource transition and cash transition as a basis to assess a MPS scenario.

Chapter 5

To explain the problems encountered and the solutions found we start with the definition of:

- □ Material value.
- □ Contribution margin.

We need these concepts to discuss the generic solutions found for the problems caused by omission and aggregation.

The material value of an item is calculated by rolling up the material value of all its components, see Equation  $5-1^{20}$ .

$$M_{0,p} = \sum_{C} M_{0,c}$$
Equation 5-1

 $\begin{array}{rcl} M_{0, \mathrm{p}} & : & \mathrm{Material\ value\ of\ a\ real\ (0)\ parent\ item\ p.} \\ \mathrm{C} & : & \mathrm{Component\ items\ of\ the\ parent\ item\ p.} \\ M_{0, \mathrm{c}} & : & \mathrm{Material\ value\ of\ a\ real\ (0)\ component\ item\ c.} \end{array}$ 

This contribution margin of an item can now be calculated as:

$$C_{0,p} = S_{0,p} - M_{0,p}$$
 Equation 5-2

 $C_{0,p}$ :Contribution margin of a real (0) sales item p. $S_{0,p}$ :Sales price of a real (0) sales item p. $M_{0,p}$ :Material value of a real (0) parent item p.

Due to omission of elements from the primary process in the primary process model, four problems can occur. These problems are described next, together with the found solutions.

 $<sup>^{20}</sup>$  The notation of material values, sales prices and contribution margins includes the numbers 0, 1 and 2. These numbers refer a specific type of item. The number 0 refers to a real item, the number 1 refers to an MPS item, the number 2 refers to a MPS family item.

## Problem 1

A sales item is not included in the model. Instead, only one component of that sales item is included. This means that the demand for the end item is projected to the component. Since the component does not have a sales price, a part of the cash inflow would not be considered. Therefore, the financial evaluation of the MPS cannot be performed. For this reason the component gets a fictitious sales price:  $S_{1,c}$ . This sales price is calculated by the material value of the item considered plus the contribution margin of its parent (See Equation 5-3). If the component has more then one excluded parent the weighted average of the contribution margin of these parents are used. The weights are determined by the disaggregation percentages. This percentage can be considered as the mix percentage. It is a forecast of the allocation of the demand for the MPS family item to the real items.

$$S_{1,c} = M_{0,c} + \sum_{p} (r_p \times C_{0,p})$$
 Equation 5-3

$S_{1,c}$	:	Sales price of a MPS (1) sales item c.
$M_{0,c}$	:	Material value of the real (0) item c.
Р	:	Parent items of the component considered.
r <sub>p</sub>	:	Disaggregation percentage of parent p.
$C_{0,p}$	:	Contribution margin of a real (0) parent item p.

## Problem 2

An end item is not included in the MPS model. Instead *several* components are included in the model (more than one). This problem cannot be solved the same way as the previous problem, since here the contribution margin of the parent now has to be divided over several components. Since such a division can never be done objectively, we suggest including the parent item in the MPS model. Since this is not necessary from an operations management perspective, the lead-time and the capacity requirements to work centres can be considered zero.

#### **Problem 3**

An end item is not included in the MPS model, neither are its components. This means that a part of the cash inflow of the organisation, together with the cash outflow caused by these excluded items are ignored. This problem cannot be solved without including these items in the MPS. This may not be needed from an operations management point of view (if the items are not critical for capacity or material reasons). However, if the quantities of these items differ between MPS scenarios, these items should be forecasted and planned nevertheless to be able to compare the MPS scenarios financially.

#### Problem 4

A purchase item (component) is omitted. Therefore, the material value of its parent is incomplete and thus the contribution margin of the MPS sales item would be incorrect. The sales price of the sales item must be adjusted. The new sales price (see Equation 5-4) equals the original contribution margin of the real parent plus the material value of the MPS parent. This sales price is denoted as  $S_{1,p}$ . Of course, the material value can be calculated by the roll up of the material value of the items that are considered.

$$S_{1,p} = M_{1,p} + C_{0,p}$$
 Equation 5-4

 $S_{1,p}$  : Sales price of the MPS (1) item p.  $M_{1,p}$  : Material value of the MPS (1) item p.  $C_{0,p}$  : Contribution margin of the real (0) item p.

Due to the mechanism of aggregation, three additional problems can occur. The problems are described below, together with the chosen solutions.

#### **Problem 5**

Due to similarity of items (component and parents), the separate items are combined into one MPS family item. Since this family item is not a real item, the MPS item does not have a material value or sales price. The sales price problem is discussed under point 6. The material value (see Equation 5-5) can be calculated as the weighted average of the material value of the separate items that are included in the family. This material value is called Material Value 2 ( $M_{2,p}$ ).

$$M_{2,p} = \sum_{I} (r_i \times M_{0,i})$$
 Equation 5-5

 $M_{2,p}$ : Material value of a MPS family (2) item p.

I : Items considered.

 $r_i$  : Disaggregation percentage of item i.

 $M_{0,i}$  : Material value of a real (0) item i.

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Of course, the material value of a parent item can now be calculated as the roll up of the material values of the components.

#### Problem 6

A family MPS also does not have a sales price. A sales price can be calculated as the material value of the MPS family item considered plus the weighted average of the contribution margin of the items included in this family item (see Equation 5-6). Again, the weights are determined by the disaggregation percentages of the items considered. This sales price is called Sales Price 2 ( $S_{2,p}$ ).

$$S_{2,p} = M_{2,p} + \sum_{I} (r_i \times C_{0,i})$$
 Equation 5-6

 $S_{2,p}$  : Sales price of a MPS family (2) item p.

 $M_{2,p}$ : Material value of a MPS family (2) item p.

I : Items considered.

 $r_i$  : Disaggregation percentage of item i.

 $C_{0,i}$  : Contribution margin of a real (0) sales item i.

## Problem 7

Due to similarity of resources, the separate resources are combined into work centres. For this reason, one does not have the availability of additional expenditures due to short-term capacity expansion. Due to the great similarity of type of work in one work centre, the assumption is made that the expenditures due to short-term capacity expansion do not differ within work centres. The expenditures are based on an average rate over all separate resources within one work centre.

Besides problems occurred by omission and aggregation, the following additional problems can occur (and, of course, in the MPS model all kinds of combinatory problems can occur):

#### Problem 8

In a specific MPS scenario to the end of the time period considered, stock is build up. Since stock is not sold (of course) there does not occur any incoming cash flow. This means that a MPS scenario that purposely plans a stock increase will always score worse than one that does not. This problem is resolved by including the reason that stock is build up. This reason usually is a specific demand. This demand including the sales prices should therefore be included in the financial evaluation. In this way is assumed that the stock is sold. If the items do not have a demand, then this stock is not valued.

When the problems have been solved, the procedures stated in the decision trees of Chapter 3 can be executed. The cash flow net balance resulting from the HCFM expresses the financial result of a MPS scenario. We have showed that the procedure in operations management to evaluate a MPS scenario does not consider all resource transitions. For this reason the resulting cash transitions would also be incomplete. This could lead to overestimating or underestimating the cash flow net balance resulting from this decision. When have compensated this effect by eliminating the cash transition not considered at the purchase side also at the sales side.

Each resource included in the MPS decision now has a purchase price and / or a selling price. However, some of these prices are only an approximation of the real prices that will be realised on the purchase and sales markets. The error made in the estimation of these prices equals the error made by making the forecast and estimation the disaggregation percentages, since these percentages influence the prices calculated. The total result of the decision-alternative: the cash flow net balance is relative to *not* executing the MPS.

The problems discerned, and the solutions given put some additional requirements on the object model. Next, these are discussed.

## 5.2.2 CONSEQUENCES FOR THE OBJECT MODEL

This subsection describes the consequences for the object model of the financial evaluations of 'setting the MPS' on the object model. The translation of the decision 'setting the MPS' in terms of the HCFM has encountered some problems. These problems have been solved. Here, the relationship with the object models is discussed.

The decision 'setting the MPS' requires specific resources. These resources have specific behaviour that present resources do not have. For instance, MPS resources (a family item) can be asked to disaggregate its forecast to its real resources (separate items). For this reason, the class [MPSResource] is introduced, which is a subclass of the class [Resource]. The [MPSResource] has an association relationship with its superclass. This relationship specifies the possible relation with the real resources. When the calculation is finished and a MPS scenario is chosen, the scenario is copied to the real resources.

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The methods of calculating sales prices, purchase prices, and contribution margins are incorporated in the class [PriceCalculator]. This class has an association relationship with the class [Resource]. When calculated, the prices are recorded in the model in newly created instances of the class [Quantity]. These instances are related via the instance of the class [QuantityPer] to specific instances of the class [Contract] that represent contract potentials, and the resource instance cash.



Figure 5-2: Object models for MPS functionality

Figure 5-2 gives the object classes introduced. Note that the core of the model stays intact. New functionality is completely incorporated by introducing new classes and re-use (inheritance relation between [Resource] and [MPSResource]). This is completely according to the philosophy of object-orientation.

## 5.3 ORDER ACCEPTANCE

In this section the order acceptance decision is considered in the hierarchy with the MPS decision. Wouters (1997) discusses this link between order acceptance and MPS. Here the main points of that paper are summarised and compared with the HCFM. Moreover, the explicit link to the MPS is discussed. Finally, the consequences of the decision 'order acceptance' on the object model are examined.

The MPS, as discussed above, has been determined on basis of financial trade-offs, amongst other considerations. When order acceptance decisions are made next, also based on financial considerations, this could be straightforward: accept only those orders that are consistent with the MPS. Order acceptance, then is just a matter of executing the MPS and therefore no new financial evaluation is required. However, it is likely that actual conditions during order acceptance will differ from the assumptions that have been used

when making financial trade-offs in the MPS decision. Sales prices, purchase prices, capacity requirements, capacity availability, timing and quantity of demand, etc. could be different than expected and it may not be wise to follow the MPS decision without allowing any exceptions. Exceptions would be not accepting something planned in the MPS, or accepting something not planned in the MPS. In other words, we propose to consider the order acceptance decision in the hierarchy of the MPS. If differences occur with the plan, incremental modifications of production plans are proposed, based on financial evaluations, rather than a complete plan regeneration with each decision. See also Winter (1996) who discusses this principle of incremental modification.

Wouters (1997) distinguishes between two possibilities when accepting orders:

- 1. The order is included in the MPS.
- 2. The order is not included in the MPS.

The trade-off that is being made in both situations is the cash flow gross balance of accepting versus the opportunity cash flow balance of not accepting.

When the order is included in the MPS, the financial consequences of accepting the order is determined by the incremental effect of the order (cash flow gross balance). Not accepting the order implies that the planned reservation should be cancelled. This results in an opportunity effect (opportunity cash flow balance). This effect depends on what is done with these resources for which the reservation has been cancelled:

- 1.1. The resources for which the reservation is cancelled cannot be reserved for other destinations. Therefore, the opportunity effect is zero.
- 1.2. The resources for which the reservation is cancelled are being used for other destinations (maybe some unplanned production for alternative customer demand that has been rejected when setting the MPS). This option results in an opportunity effect. The opportunity effect equals the cash transition resulting from this potential sale and potential purchase of additional resources.
- 1.3. The cancellation of the reservation of the resources results in the cancellation of planned future resource expansion, or in the reduction of contracted resources. This option leads to reduction of future expenditures regarding the purchase of resources, or an increase of future cash inflows resulting from the sale of the resource considered.

The opportunity effect (opportunity cash flow balance) can now be compared with the incremental effect (cash flow gross balance).

When the order has not been included in the MPS, the financial result of not accepting would equal zero. The financial result of accepting would depend on how the demand is satisfied:

- 2.1. The demand is (completely) satisfied with resources that do not have reservations. This option does not lead to additional cash outflows. Therefore, the opportunity effect for this decision equals zero; the incremental effect equals the total cash inflow resulting from the demand (order).
- 2.2. The demand is satisfied with resources that were reserved for other demand, which is cancelled. The opportunity effect of this decision is the missed cash inflow of the demand that is cancelled (only when resources are scarce, otherwise option 2.1 applies) The incremental effect of the decision constitutes of the cash inflow resulting from this demand minus the cash outflow resulting from needed purchases.
- 2.3. The demand is satisfied by expanding resources needed or the cancellation of planned resource reduction. In the first situation, the opportunity effect equals zero, in the second situation the opportunity effect equals the missed reduction in cash outflow, or the missed cash inflow due to the sale of the resource. The incremental effect equals the cash inflow resulting from the demand (order) minus the cash outflow resulting from the purchase of resources needed to satisfy the demand.

The incremental effect (cash flow gross balance, which equals zero in this situation) can now be compared with the opportunity effect (opportunity cash flow balance).

In the HCFM, these different consequences when accepting orders can be dealt with in generic form. For instance, the HCFM does not make a distinction between types of resources. The HCFM does not require an explicit distinction between 'included in the MPS' and 'not included in the MPS' in its calculation. Whether or not an order has been foreseen in the MPS, fulfilling demand always results in cancellation of activities / contracts upstream and downstream the planned resource flow. This cancellation results in an opportunity effect. Both situations (foreseen and not foreseen in the MPS) thus lead to an opportunity effect. This opportunity effect is then compared with the incremental effect. Note that when the order was foreseen in the MPS, order acceptance is just carrying out the plan (i.e. the MPS). The opportunity effect thus equals the incremental effect.

## 5.3.1 PROBLEMS WHEN EVALUATING ORDERS

The HCFM explicitly discusses that conditions are likely to change after a new plan has been made or an existing plan has been adapted incrementally. In this way, the acknowledgement is made that there is always uncertainty about future conditions. Consequently, it may not be possible to calculate the opportunity costs of order acceptance decisions and an alternative approach would be to shift from exact rules to algorithms that offer best approximations. This is also discussed in the literature, which has been summarised in Chapter 2, Section 3.1. In that literature, order acceptance is discussed is discussed under uncertainty and in isolation from other planning decisions. In the HCFM we fully acknowledges that there is uncertainty, but the order acceptance decision is placed in a framework of earlier, more aggregate decisions. As a result, the order acceptance decision can build on much more information than what is available when described in isolation. This planning information is used to assess the opportunity costs and capacity costs associated with an order. At the same time, we suggest to give the decision-maker information that can help to assess the accuracy / certainty of order acceptance calculations.

## 5.3.2 CONSEQUENCES FOR THE OBJECT MODEL

The decision 'order acceptance' explained above, does not have great impact on the object model defined. All requirements, except one, are already incorporated in the model. This requirement is related to the knowledge of rejected demand of the MPS due to, e.g., capacity restrictions. The demand that could not be incorporated in the MPS should be recorded. This demand can be incorporated in the model as a contract potential.

## 5.4 ILLUSTRATION

Consider a company that produces a product  $(E_n)$  in three variants:  $E_1$ ,  $E_2$  and  $E_3$ . The production situation is given in Figure 5-3. Product  $E_1$  consists of the components  $S_1$  and  $Y_1$ ,  $E_2$  consists of  $S_2$  and  $Y_2$ , etc. Consequently,  $S_1$  consist of  $R_1$ , etc. The resource consumption in the work centres equals 4 hours in work centre A, 3 hours in work centre B, and 3 hours in work centre C.



**Figure 5-3: Production situation** 

In Table 5-1 relevant production data is given.

**Table 5-1: Production data** 

			Lead	time	
Resource	Order quantity	Purchase	Activity 1	Activity 2	Activity 3
E <sub>n</sub>	10				1
Sj	15		1		
Y <sub>j</sub>	25			1	
R <sub>i</sub>	20	1			
X <sub>i</sub>	15	1			

 $E_1$ ,  $E_2$ , and  $E_3$  are usually sold against 90, 120, 180 EURO respectively. The customers are supposed to pay 1 period after delivery. Purchase prices are given in Table 5-2. The purchases have to be paid 1 period after delivery.

**Table 5-2: Purchase prices** 

Resource	<b>R</b> <sub>1</sub>	<b>R</b> <sub>2</sub>	<b>R</b> <sub>3</sub>	$\mathbf{X}_1$	$X_2$	X <sub>3</sub>
Price (in EURO)	10	12.5	20	5	10	15

Per period, the resources A, B, and C are available 300, 360 and 180 hours respectively. The capacity of work centre C can be expanded temporarily, only in period 3 by means of working overtime. The maximum number of hours that can be worked in overtime equals 60 hours. The reaction time equals zero. The capacity expansion is paid in the same period the expansion is realised. The purchase price of on hour of overtime equals 10 EURO.

For the decision 'setting the MPS' the company has combined the items  $(E_1, E_2, and E_3)$  into the MPS family item E, the items  $S_1$ ,  $S_2$ , and  $S_3$  into the MPS family item S and the items  $R_1$ ,  $R_2$ , and  $R_3$  into the MPS family item R. The other items are not considered in this decision. Work centres A and C are considered critical, and are thus included in the MPS. The stock on hand of both MPS resource R and S equals 30 pieces.

The total demand for MPS item E is forecasted and the result of that is shown in Table 5-3.

Table 5-3:	Demand	forecast
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Period	1	2	3	4	5	6	7	8
	30	40	60	80	90	60	60	60

This forecast is translated to a MPS demand. By doing so it becomes clear that not all demand can be fulfilled. The results for each item are displayed in Table 5-4.

Table 5-4: MPS result

MPS Resource E	0	1	2	3	4	5	6	7	8
Independent demand		30	40	60	80	90	60	60	60
MPS		30	30	60	80	60	60	60	60
Projected available	0	0	0 (-10)	0	0	0 (-30)	0	0	0

Projected available	0	0	0 (-10)	0	0	0 (-30)	0	0	0
MPS Resource S									
Dependent demand	30	30	60	80	60	60	60	60	
MPS	-	30	75	75	60	60	60	60	

10 10

10

10

10

15

0 0

MPS Resource R								
Dependent demand	30	75	75	60	60	60	60	
MPS	-	80	80	60	60	60	60	
Projected available	0	5	10	10	10	10	10	

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Projected available

The negative numbers in Table 5-4 represent rejected demand, due to capacity shortage. In Table 5-5 the capacity consumption of the work centres is displayed. A distinction has been made between consumption of regular capacity and consumption of additionally bought capacity.

Work centre C	0	1	2	3	4	5	6	7	8
Dependent demand	90	90	180	240	180	180	180	180	
Demand regular	90	90	180	180	180	180	180	180	
Demand expansion				60					

Table 5-5: Capacity consumption on the MPS work centres

Work centre A								
Dependent demand	120	300	300	240	240	240	240	
Demand regular	120	300	300	240	240	240	240	
Demand expansion								

The disaggregation percentage (based on historic data) to the real items  $E_1$ ,  $E_2$ , and  $E_3$  is 60%, 30%, and 10%. As a result the material value of MPS resource R can be calculated as (see also Equation 5-5):

 $0.60 \times 10 + 0.30 \times 12.5 + 0.10 \times 20 = 11.75$  Euro

This material value is also the material value of the MPS resources E and R.

The calculation of the sales price of MPS resource E requires the material value of the real items  $E_1$ ,  $E_2$ , and  $E_3$ . These values can be calculated with Equation 5-1. This results in:

$$E_{1} = M_{0, R1} + M_{0, X1} = 10.00 + 5.00 = 15.00 \text{ EURO.}$$

$$E_{2} = M_{0, R2} + M_{0, X2} = 12.50 + 10.00 = 22.50 \text{ EURO.}$$

$$E_{3} = M_{0, R3} + M_{0, X3} = 20.00 + 15.00 = 35.00 \text{ EURO.}$$

The sales price of MPS item E can be calculated as the material value of MPS item E plus the weighted contribution margin of the real items (see also Equation 5-6):

$$11.75 + 0.60 \times (90 - 15) + 0.30 \times (120 - 22.5) + 0.10 \times (180 - 35) = 100.50 \text{ Euro.}$$

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Related to the object model, first of all, the MPS resources have to be included. For these resources, again the recipes and contract potentials have to be defined. The demand that is planned to be realised is incorporated in the model by means of planned demand contracts. The demand that has been rejected is incorporated by means of instances of the class contract (contract potentials). All contracts and activities are planned.

The cash flow net balance of the MPS is determined by the take-relationship of the newly inserted demand contracts and the give-relationship of the newly inserted supply contract. This total effect equals:

Incremental effect			
Cash inflow (A)		Cash outflow (B)	Cash flow gross balance
	44.220	Resource R:	
		- 4.700	
		Resource work centre C:	
		- 600	38.920
Opportunity effect			
			Opportunity cash flow balance
			0
Total			Cash flow net balance
			38.920

Suppose an order arrives for product  $E_1$ , 20 pieces, at a price of 90 EURO. When the procedures depicted in the decision trees of Chapter 3 are completed the result is a cash flow net balance of zero. Since this order corresponds completely with the expectations defined in the MPS the opportunity cash flow balance equals the cash flow gross balance. The alternative is not accepting the order. This implies that the forecasted planned demand contract has to be cancelled (which results in the opportunity effect). Since the reservation of resources is cancelled, the rejected demand contracts can be incorporated. This results in a positive cash flow gross balance. Since the orders rejected do not deviate from the accepted orders, again the total cash flow net balance equals zero.

Suppose an order arrives for  $E_1$ , 20 pieces, at a price of 85 EURO. This price is below the level assumed in the MPS. The financial evaluation, when completing the decision diagrams results in an opportunity cash flow balance that exceeds the cash flow gross balance with 100 EURO.

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Next, the consequences of not accepting the order should be determined. Not accepting the order would result in the possibility of accepting prior rejected demand. This possibility has a total financial result of zero. In other words it would be better not accept the order, and introduce the rejected order.

## 5.5 CONCLUSIONS

In this chapter a rationale has been given for the information system design described in Chapter 3 and 4. The purpose of this rationale is to demonstrate that the information system design presented, defines a system, that if implemented, would satisfy the collection of system stakeholders' need statements (Dolan *et al.* 1998). As explained in Chapter 1, the stakeholders' need statement is primarily focussed on functional requirements with the user as the most important stakeholder. Therefore, we have chosen to focus on users in the rationale. We have chosen to use two operations management decisions in this rationale: 'setting the MPS' and 'order acceptance'. The reason for choosing these two decisions are 1) these two operations management decisions are often implemented in present ERP systems, and 2) these two decision can be described in hierarchy to each other.

We have shown that these two decisions can be supplied with relevant accounting information based on the concepts used in the HCFM. Moreover, we have illustrated that the object model is able to supply and store relevant data, needed by the HCFM. Therefore, we argue that with the elaboration of these decisions we have made a reasonable case that the HCFM and the object model fulfil the needs for the stakeholders discerned.

We have concluded, that the object model did not incorporate all data needed to support the decision 'setting the MPS'. The object data that has not been included in the model relate to the MPS resources, methods to calculate sales and purchase prices for MPS resources, and demand that could not be satisfied when making the MPS scenario. These extensions do not change the basics of the model.

During the elaboration of the rationale we were confronted with complexities exposed by integrating planning concepts from operations management with planning concepts from the management accounting. The solutions found to resolve these complexities result in three additional theoretical contributions to the literature.

The first theoretical contribution to the literature is the possibility to deal with incomplete resource transition patterns, when assessing a MPS scenario. We have argued that the modelling of the MPS decision (that leads to incomplete resource transition patterns) makes overestimating or underestimating of the cash transition likely. We have proposed situational dependent calculation techniques for calculating cash transition patterns. These techniques are specified in Equation 5-3 till Equation 5-6.

The second theoretical contribution to the literature is the proposal to expand the traditional criteria for selecting MPS items with criteria that are required for financial evaluations of planning decisions. Traditionally, an item is included in the MPS if the item critical from a materials or capacity standpoint. However, we propose to include an item in the MPS if the item does not have an acceptable profit margin (meaning: there are special considerations to phase out or phase in the item), or if quantities of the item are different between MPS scenarios.

The third theoretical contribution to the literature is the recording of the accounting criteria used and accounting assumptions made during an evaluation of a MPS scenario. These criteria and assumptions are needed to be able to assess the order acceptance decisions later. Present systems already record non-accounting criteria such as reservations for specific customers, reservations for specific products, etc. We argue to expand these criteria with the accounting criteria.

# **Chapter 6**

# **Conclusions and further research directions**

## 6.1 THE RESEARCH OBJECTIVE RECONSIDERED

The objective of this thesis, as defined in Chapter 1, is to obtain knowledge about the incorporation of *ex ante* accounting information to support operations management decisions in information systems. We have focussed on short-term and medium-term operations management decisions. The reason for this is that present operations management information systems are aimed at supporting these types of decisions. We have shown that operations management is not satisfied with their information systems regarding the functionality to support decisions with *ex ante* accounting information. We have identified three main problem areas why present systems lack this functionality:

- 1. Accounting theories for decision support are difficult to implement in information systems.
- 2. There are discussions in the accounting literature about which accounting information to use for decision support.
- 3. Present data structures are inappropriate.

The first problem area relates to the difficulties encountered when trying to translate the concepts of the accounting technique to support operations management decisions (the relevant cost technique) to information systems. The relevant costs of a decisionalternative consist of the incremental costs and the opportunity costs. The incremental costs are those that differ between alternatives. Opportunity costs are the benefits foregone as a result of choosing one course of action rather than another. The definitions of the components of the relevant costs imply that these costs are situational dependent. The knowledge how to determine the relevant costs can be applied by humans. However, in the literature this knowledge is not formalised in such a way that this knowledge can be implemented in information systems. There are many examples in the literature concerning the formal application of a relevant cost technique for a decision problem, e.g., in the operations research literature. In this literature, usually, this problem is solved by means of a predefinition of relevant cost regarding a decision. However, predefinition of costs cannot be used as a generic solution to incorporate accounting information into information systems. First of all predefinition could lead to enormous amounts of costs decision-alternative combinations, which can only be used for that specific decision. Since the same data can be used in multiple combinations, maintainability becomes difficult. Moreover, predefinition of costs results in a rather static view on relevance of costs, whereas we have argued that relevancy is a very dynamic concept. Therefore, we argue to define a generic technique based on procedures that can dynamically determine the relevant effects of a decision-alternative, and converts these effects to financial consequences.

The second problem area relates to the conceptual discussion in accounting literature to the accounting information to use for decision support. Short-term accounting information (incremental cost plus known opportunity costs) sometimes directs companies to decisionalternatives that are in contradiction with the directions companies would choose based on longer-term accounting information. How can an organisation ever achieve the objectives in the long run, when short-term information points in another direction? This confusion usually leads to discussions in the literature about what type of accounting information to use for short-term decision-making (full cost or incremental costs). Related to information systems, this results in the conditional question: If the other problem areas mentioned are resolved regarding the question why present systems lack accounting for operation management decisions, what type of information should be generated by the system?

The final problem area relates to the registration methods of accounting data in most of the present information systems. The most common technique (double entry bookkeeping) blocks the use of accounting data for operations management decision support, since this technique does not incorporate ex ante accounting data. Therefore, we need other data models to serve our purpose. However, one of the main pitfalls in the design of accounting data models is that the data models limit itself too one application domain only (and therefore exclude others). Research in accounting data modelling has resulted in two alternative models: the REA model and the 'Grundrechnung'. These models claim to store accounting data objectively, meaning that they do not exclude any accounting application domain. However, the models relate to *ex post* functionality only, and not to the *ex ante* area meant in this thesis. Since we want to avoid the main pitfall in the design of accounting data models, the research effort should be aimed at the extension of the models in the literature. This should enable our model to supply relevant data for operations management decisions (ex ante) and relevant data for ex post purposes. Since realised ex ante data becomes ex post data it would be convenient that the registration technique to store *ex ante* data equals the registration technique to store *ex post* data.

Therefore, we have formulated the research questions as:

- 1. What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?
- 2. Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?
- 3. What are the implications of the accounting technique for the known accounting data models?

Next we discuss the answers to the research questions in relation to the current state in literature.

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# What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?

The functionality to support operations management decisions with *ex ante* accounting information requires a different view on the registration of accounting data. In most of the present systems the variability of costs is considered to be a characteristic of the cost driver. However, these costs associated with the cost driver could consist of apportioned cost as in Activity-Based Costing. This makes definitions regarding short-term controllability of cost rather confuse. The variability of cost should be an attribute of the decision – cost driver combination. However, it would take a lot of effort to predefine all variabilities for all decision – cost driver combinations beforehand. Based on Theeuwes and Adriaansen (1994) the contract concept has been introduced in the object model. We have shown that the contract concept can be used for information systems to record the variability and avoidability of cash flows (costs). With the help of the 'contract' concept clear definitions can be given concerning the controllability of cash flows. (Final) Supply contracts define the resources, which a company is able to use without additional cash outflows. Contract potentials express the ability to expand the resources and thus result in additional cash flows.

The framework of Theeuwes and Adriaansen (1994) only refers to the incremental effect of a decision. We have extended this management accounting framework with the hierarchical planning concept derived from the field of operations management. The integration of this concept allows us to extend the framework to include the opportunity effect of decisions.

The determination of the effects of a decision-alternative is described in procedures that trace the effect of an alternative on resource flows. We do not calculate with intermediate cost values regarding the use of resources. We only value those resource flows that are involved in transactions with suppliers / buyers. This strict separation of the resource flow and the valuation is consistent with the ideas of Riebel (1994), regarding the consequences of decisions. However, Riebel only refers to the incremental effect of the resources flow and does not consider the opportunity effect. Therefore, we have extended the ideas of Riebel (1994) by including opportunity effects in our model. The opportunity effect is determined by tracing the physical effect of the decision-alternative on future resources flows.

We therefore conclude that information systems that aim at providing operations management decisions with *ex ante* accounting information should primarily be based upon the physical flows (resource flows) influenced by decisions. The physical flow can be measured objectively, and is therefore best suited for expressing the effect of a decision. Financial flows can be derived from the physical flows and just serve as a unified measure to express the economic effect.

In the information system design, concepts from operations management literature have been integrated with management accounting concepts. The operations management concept of hierarchical planning is joined with accounting concepts to serve as a means to determine the opportunity effect of a decision-alternative. With the help of the hierarchical concepts, information can be given to the decision-maker concerning the context in which the decision is made. This context information is related to missed or created opportunities and thus gives information concerning the opportunity costs of a decision, even if the alternatives to the decision are not known simultaneously.

# Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?

We have argued in Chapter 3 (Section 1) that there is a conceptual discussion in the accounting literature which accounting information to use for short-term and medium-term decisions. Accounting information for short-term and medium-term decisions is different opposed to accounting information for longer-term decisions. For longer-term decisions more costs are considered to be relevant than for short-term and medium-term decisions. However, some authors argue that such a strict separation of different decision may not be realistic since long-term and short-term decisions interact. The accumulation of several short-term decisions may have a long-term impact that is not in line with long-term preferences. Present accounting techniques do not recognise this interaction explicitly. We have presented an accounting technique that uses hierarchical planning concepts to obtain a broader scope when making short-term and medium-term decisions. These hierarchical planning is used to structure long-term and shorter-term decisions.

In our model, called the Hierarchical Cash Flow Model (HCFM) we relate shorter-term decisions to longer-term plans. Longer-term plans record the direction the organisation wants to go with its decisions. For each shorter-term decision-alternative we determine its

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effect on the plan. This effect, eventually expressed in financial values, should provide the decision-maker information by which the decision-maker is able to project an individual decision in a much broader perspective. By doing so, the decision-maker is able to make a choice based on more information than just the incremental effect.

## What are the implications of the accounting technique for the known accounting data models?

In the literature a lot of attention has been paid to the modelling of accounting data. Two main streams have been discussed in this thesis: a German school and the American School. Both schools have the same objective. This objective is to enlarge the application domain of accounting data that is stored in information systems. The model of the German school is called 'Grundrechnung'. This method consists of 4 basic principles in recording accounting data. The REA model is an ER – model that can serve as a conceptual tool for modelling accounting phenomena. However, all these models are related to *ex post* accounting data. So there is a lack in literature concerning the *ex ante* accounting data and functionality.

In the first chapter of this thesis we have argued that one of the criticisms of present systems has been a too narrow focus on one application domain, which precludes other applications. We want to avoid that the information system design presented gets the criticism of only concentrating on the field of management accounting. Therefore, a close junction between the object model described in this thesis and existing models to record data for multiple purposes is very important. McCarthy (1982) has demonstrated with the REA model that by capturing the essential characteristics of a business event, multiple classification schemes can be supported, including traditional information (e.g., financial statements that adhere to Generally Accepted Accounting Principles: GAAP). Since our object model complies with the REA model it is able to provide the functionality mentioned and one main barrier is removed from getting the model accepted in information systems.

The REA model only contains state-dependent data. Our object model incorporates both state-dependent data and state-independent date. Examples of state-independent data in our model are the contract potentials and recipes. This data allows us to make projections of the resource flow in the future.

Regarding the state-dependent data, the object model presented complies with the REA model. However, we have allowed some exceptions of the model. We do not consider explicitly the following three events in our model: the sales event, the purchase event, and the cash disbursement event. In our model a sales event is represented as a relation between two objects of the classes contract and resource. In other words, in our model the sales event is represented as an association relation between two objects and not as an object itself. The same is true for purchase event and cash disbursement. The object model extends the REA model with contracts. As discussed above, contracts allows us to measure variability of cash flows regarding a decision.

The *ex ante* functionality is included in the model by means of recipes, planned activities, contract potentials, planned contracts, and reservations. All of these concepts are extensions of present accounting data modelling in the literature.

#### 6.2 THE RESEARCH METHODOLY RECONSIDERED

The research objective has been pursued by the development of an information system design that is able to supply relevant *ex ante* accounting information for operations management decisions. The information system design has been developed according to the methodology of Dolan *et al.* (1998). This methodology consists of three phases. In the first phase the stakeholders of the standard software system are involved to retrieve the requirements. In the second phase the requirements are used to build the architecture design. In the final phase a rationale is given which demonstrates that the architecture design, if implemented would satisfy the requirements of the stakeholders.

The requirement statement is restricted to functional requirements (stakeholder: user). The technical requirements have been guarded by professional ERP systems developers, but have not been made explicit in this research project (stakeholder: architect, software developer, and maintainer). The customer has not been involved as a stakeholder in this project. The reason for this is that the information system design is mainly in a conceptual phase. This makes it very premature to involve the customer as a stakeholder. In total five requirements have been defined for the system. These requirements are named 1) objectivity of accounting data, 2) resource consumption, 3) resource transition, 4) cash transition, and 5) contextual information. These requirements are fulfilled with the information system design.

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The information system design consists of two parts. In the first part the generic accounting technique, called the Hierarchical Cash Flow Model, has been defined. The technique is defined in such a way that it can be incorporated in information systems. The technique gives a solution to two of the three problem areas mentioned above, which concern difficulties in implementing accounting theory into information systems and the conceptual discussion in accounting literature regarding accounting information to supply for short-term decisions. In the second part of the design, the relevant accounting phenomena are captured in object models. This part of the design gives solution to the third problem area that relates to inappropriateness of present accounting data models. Next we discuss how the requirements have been fulfilled by means of the information system design.

#### **Requirement 1: Objectivity of accounting data**

Objectivity of accounting data ensures that accounting data is not stored for one purpose (application) only and delimits the use of this data for other purposes. Examples of subjective data are accounting artefacts such as depreciation or product costs. We have chosen to model cash flows only. Cash flows with outside partners are considered to be the origin of all accounting information. This implies that all accounting information can be derived from the cash flow based data. Moreover, we have excluded any classification of the cash flow data to periods or common cost objects (cost centres, products, etc.). Cash flows are recorded against the contracts that have been made up between the organisation and its partners. Note that we did not exclude the possibility to perform the allocation or apportioning of accounting the one discussed in this thesis) separate from data registration. The objective data should only be characterised with relevant data that ensures that data-manipulation can be performed. Examples of such data manipulations are reservation for our purpose, individual cash flows for auditing purposes, or the economic lifetime for financial accounting purposes.

Moreover, in our application domain, the use of *ex ante* accounting information for operations management decisions, we have only used cash flows to assess decision-alternatives on a financial basis. We did not use consumption based cost techniques that value the use of resources.

#### **Requirement 2: Resource consumption**

The requirement of resource consumption is meant to ensure that we are able to determine the efforts needed to fulfil (an increase in) the demand for resources. In our information system design the demand for resources can be fulfilled by means of activities or supply contracts. Activities in their turn are able to generate a demand for resources (input resources), which also leads to resource consumption. We do not value this resource consumption, but we use consumption only as a means to trace demand to purchases.

We have included *ex ante* functionality in the information system design by including recipes and planned activities. Recipes are normative assumptions how many input resources are needed to obtain a specific amount of output recourses. These recipes are useful to predict the effect of an increase of demand for resources on the internal demand for resources. Planned activities can also be considered as recipes. The only difference is that planned activities are scheduled to be carried out at a specific moment in time in the future.

#### **Requirement 3: Resource transition**

Resource transition is the physical flow between the organisation and its markets. We have modelled this flow in our design by means of resources and contracts. Resources can only be purchased and sold by means of a contract. When the resource transition has been realised and the organisation or partners want to generate additional resource transitions, the model assumes that new contracts are drawn up. In this way scarcity of resources is modelled in the information system design.

*Ex ante* functionality is obtained by means of contract potentials and planned contracts. Contract potentials specify the conditions under which possible resource flows are carried out in the future. However, the moment when the resource flow is due is not specified. This characteristic discerns contract potentials from planned contracts. Planned contracts represent possible resource flows that are scheduled to be carried out at a specific moment in time in the future.

Resource transition at the 'customer side' of the organisation is converted by means of the requirement resource consumption to the resource transition at the 'suppliers side'. In other words, by means of the requirements resource consumption and resource transition, the physical effect of a decision can be determined.

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#### **Requirement 4: Cash transition**

A contract closely couples the resource transition with the cash transition. In our information system design cash transition is modelled as a counterpart of each resource transition. Cash transitions are specified in the give-relationship of the supply contracts, and the take-relationship of demand contracts. It is clear that the *ex ante* cash transitions are modelled in contract potentials and planned contracts.

#### **Requirement 5: Context information**

The context information refers to the plans organisations have with their resources, and possibilities to obtain the resources in order to fulfil their goals. Plans are recorded in the model by means of planned contracts and planned activities. Reservation is used to match planned demand with planned supply of resources. A decision-alternative may changes these plans. The reservation logic is now used to determine the potentials that have been created and / or the potentials that have been blocked by the decision-alternative.

In the relative simple setting of the rationale of the information system design we have shown that we are able to retrieve the relevant information for the operations management decisions 'setting the MPS' and 'order acceptance'. This rationale shows that the information system design is able to supply the relevant information based on the five requirements defined. In other words, the design is able to fulfil the requirements defined.

#### 6.3 LIMITATIONS OF THE INFORMATION SYSTEM DESIGN

Although not included in the objective of the research project, one of the most important limitations of the information system design is that the information system design lacks real-life implementation and empirical testing. In this project two operations management decisions have been elaborated in detail to make a rationale of the information system design. This step has resulted in the possibility to apply the model 'on paper' for complex operations management decisions. The rationale has been aimed to the possibility to check the consistency of the model and has served as a first test of applicability. However, it remains unclear if the concepts can be used in more complex and realistic settings of operations management decision-making. The model requires explicit planning decisions at different levels and requires a detailed registration of plans and actual events. Is such planning and registration feasible? One could think that the applications. A clear conceptual answer cannot be given at this point. However, one should take into account

that the model is designed for operations management decisions with a time horizon of about one year maximum. In this domain planning is widespread. Furthermore, the model is aimed at the financial evaluation of decisions, but how important do managers consider such an evaluation to improve operations management?

In the rationale it became clear that due to modelling aspects of the operations management decisions, the initial object model lacked data and needed some elaboration. When applying the design presented to other operations management decisions it could well be that this problem occurs again. This should then lead to extensions of the model.

The usage of information systems technology for decision support presumes an *ex ante* perfect knowledge of a sequence of events. This criterion cannot be met for all decisions. Therefore, the model presented here can only be used for standardised, repetitive decisions. We did not investigate whether the concepts could also be used in less formalised environments, such as an engineer-to-order situation.

The models have been based on the assumption that integrated systems are used. For instance, in our object model we had to convert a piece of machinery into capacity hours. We used our generic concept of activities for this purpose. However, in an integrated system setting, planning and scheduling tools should provide more advanced solutions for this problem. Furthermore, much of the data discussed here is also available (and required) for other purposes in the organisation. In other words, the costs of registering the required data should be justified by several applications, not just the applications discussed here.

The generality of the HCFM enables a decision-maker to start-up activities and enter supply contracts regardless the type of resource involved. For instance, the acceptance of a small order could lead in theory to the purchase of an (expensive) piece of machinery. It seems logic to draw rules that specify which activities and contracts are not allowed to be influenced by the decision-maker. We did not determine such rules.

One of the main disadvantages of general ledger based accounting information systems is its limited potential in expanding the data provision to a broader accounting application domain than just the financial accounting domain. As a result, other models to store accounting data have been developed which are able to have a broader application domain. However, the application domain of these models is also restricted (*ex post* only). The object model presented in this thesis has expanded the models to the *ex ante* application

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domain. One of the reason for expanding the current models has been the desire to take into account the *ex post* functionality as well. The assumption has been that when the object model complies with the known models the object model is also able to fulfil their application domain as well. However, we have not investigated if the application domain central in these prior studies can be fulfilled.

#### 6.4 **RECOMMENDATIONS FOR FUTURE RESEARCH**

Mattessich (1995) considers accounting as an applied science. In his philosophy accounting theory should consist of a set of conditional means – end relationships. Or in other words accounting theory should be considered as a three dimensional framework which professionals could use to help determine which accounting tools, standards, or techniques to use given the objectives they pursue and the conditions that are applicable. This implies that research in accounting should be aimed at constructing this three dimensional framework.

In the current research project the usefulness of *ex ante* accounting information has been assumed. In the delimitation of the research design, the research has been restricted to managers who want to know the cash flow balance consequences. However, a fundamental research into the reasons why and when managers want to use ex ante accounting information has never been executed. In terms of Mattessich this implies that the conditions (when) managers want to use the information has not been carried out. In future research this area should be given attention. Here, at the end of this project when the question rises how to move on, this initial assumption becomes relevant again. Wouters and Verdaasdonk (1998) give a first framework when managers are interested in using exante accounting information. This framework states that use of ex ante accounting information is perceived to be useful when alternative courses of actions are possible in operations management decisions and / or courses of actions have various effects and these are complex to integrate. The hypothesis then is that the *ex ante* accounting information is then used to reduce managers' uncertainty about which course of action to choose and / or to persuade others to choose a particular course of action. However, this framework needs additional empirical testing. The results from such empirical research should then give a strong basis to define in which situation managers are willing to use the information system design presented in this thesis.

A second condition of the means – end relationship proposed in the current research project is related to the use of longer-term plans to determine the opportunity effect of lower level decisions. In the current research project an empirical test when longer-term plans can be used for this purpose has not been performed. In the current project the assumption has been that the higher level plan is useful. Usefulness would occur in situations that are relatively stable within the time frame of the plans. To test the benefits of using the information system developed, empirical research should be performed to determine the prerequisites for higher level plans to serve as a proxy for determining the opportunity effect.

In the current research project we have built a limited prototype to test if the static object model are feasible technically. Here we suggest to built a full prototype in which also the dynamic behaviour (decision support functionality) is incorporated. The aim of the prototype is to test the information system design technically. Additional academic research questions regarding this track are not foreseen. With the help of this prototype the integration with ERP systems should be investigated. Here, an important issue relates to the possibility to perform the necessary functionality from the financial accounting application domain. Within the application domain itself complexities are foreseen with the dependency of the recipe structure. It is possible that due to the dependency of resources (specified by the recipes), too many recalculations have to be performed. A related issue concerns the performance of the information system. In the rationale described in Chapter 5, we encountered that a relatively simple setting could already result in the registration of much data. This could result in bad (slow) performance of the application. This could lead to modifications in the object model.

- Abernethy, M.A. and A.M. Lillis (1995). The impact of manufacturing flexibility on management control system and design. *Accounting, Organisations and Society*, 20 (4), 241 – 258.
- Anderson, S.W. (1995a). A framework for assessing cost management system changes: the case of activity-based costing implementing at General Motors, 1986 – 1993. *Journal of Management Accounting Research*, 7, 1 – 51.
- Anderson, S.W. (1995b). Measuring the impact of product mix heterogeneity on manufacturing overhead cost. *The Accounting Review*, 70 (3), 363 – 387.
- Anthony, R.N. (1988). *The management control function*. Boston, MA: Harvard Business School Press.
- Atkinson, A.A., Balakrishnan, R., Booth, P., Cote, J.M., Groot, T., Malmi, T., Roberts, H., Uliana, E., and A. Wu (1997). New directions in management accounting research. *Journal of Management Accounting Research*, 9, 79 – 108.
- Baker, K.R. (1993). Requirements planning. In Graves, S.C., Rinnooy Kan, A.H.G., and P.H. Zipkin (Eds.), Logistics of production and inventory: handbooks in operations research and management science (pp. 571 – 627). Amsterdam [etc.]: Elsevier Science Publishers.
- Bakke, N.A. and R. Hellberg (1991). Relevance lost? A critical discussion of different cost accounting principles in connection with decision-making for both short and longterm production scheduling. *International Journal of Production Economics*, 24, 1-18.
- Balachandran, B.V. and B.N Srinidhi (1988). A stable cost application scheme for service center usage. *Journal of Business Finance & Accounting*, 15 (1), 87 99.
- Balachandran, B.V. and B.N. Srinidhi (1990). A note on cost allocation, opportunity costs and optimal utilisation. *Journal of Business Finance & Accounting*, 17 (4), 579 – 584.
- Balakrishnan, R. and K. Sivaramakrishnan (1996). Is assigning capacity costs to individual products necessary for capacity planning? Accounting Horizons, 10 (3), 1-11.

- Banker, R.D. and J.S. Hughes (1994). Product costing and pricing. *The Accounting Review*, 69 (3), 479 494.
- Banker, R.D. and H.H. Johnston (1993). An empirical study of cost drivers in the U.S. airline industry. *The Accounting Review*, 68 (3), 576 601.
- Banker, R.D., Potter, G., and R.G. Schroeder (1995). An empirical analysis of manufacturing overhead cost drivers. *Journal of Accounting and Economics*, 19 (1), 115 – 138.
- Belkaoui, A.R. (1992). Accounting Theory (3rd edition). London [etc.]: Academic Press.
- Bertrand, J.W.M., Wortmann, J.C., and J. Wijngaard (1990). *Production control, a structural and design oriented approach*. Amsterdam [etc.]: Elsevier Science Publishers.
- Bitran, G.R. and A.C. Hax (1977). On the design of hierarchical production planning systems. *Decision Sciences*, 8, 28 55.
- Bitran, G.R. and D. Tirupati (1993). Hierarchical planning. In S.C. Graves, A.H.G. Rinnooy Kan & P.H. Zipkin (Eds.), Logistics of production and inventory: handbooks in operations research and management sciences (pp. 523 – 568). Amsterdam [etc.]: Elsevier Science Publishers.
- Böer, G. (1996). Management accounting beyond the year 2000. *Journal of Cost Management*, Winter, 46 49.
- Booch, G. (1994). The Benjamin / Cummings series in object-oriented software engineering. Redwood City, CA [etc.]: Benjamin / Cummings Publication Company.
- Borthick, A.F. and H.P. Roth (1997). Faster access to more information for better decisions. *Journal of Cost Management*, Winter, 25 30.
- Brown, C. (1984). Confidence in causal reasoning and evidence search for performance evaluation, In S. Moriarity & E. Joyce (Eds.), *Decision making and accounting: current research* (pp. 1 – 18). Norman, OK: University of Oklahoma.
- Bruns, W.J. and S.M. McKinnon (1993). Information and managers: a field study. *Journal* of Management Accounting Research, Fall, 84 108.
- Chapman, C.S. (1997). Reflections on a contingent view of accounting. *Accounting Organisations and Society*, 22 (2), 189 205.

- Chase, R.B. and N.J. Aquilano (1995). *Production and operations management, manufacturing and services* (7<sup>th</sup> edition). Chicago, ILL [etc.]: Irwin.
- Chen, P.P. (1976). The entity-relationship model toward a unified view of data. ACM *Transactions on Database Systems*, March, 9 36.
- Chenhall, R.H. and Morris, D. (1986). The impact of structure, environment, and interdependence on the perceived usefulness of management accounting systems. *The Accounting Review*, 61 (1), 16 35.
- Chenhall, R.H. and Morris, D. (1995). Organic decision and communication processes and management accounting systems in entrepreneurial and conservative business organisations. *Omega*, 23 (5), 485 – 497.
- Chia, Y.M. (1995). Decentralisation, management accounting systems (MAS) information characteristics and their interaction effect on managerial performance: a Singapore study. *Journal of Business Finance & Accounting*, 22 (6), 811 – 830.
- Chong, V.K. (1996). Management accounting systems, task uncertainty and managerial performance: a research note. *Accounting, Organisations and Society*, 21 (5), 415 421.
- Colantoni, C.S., Manes, R.P., and A. Whinston (1971). A unified approach to the theory of accounting and information systems. *The Accounting Review*, January, 90 102.
- Cooper, R. (1990). Explaining the logic of ABC. *Management Accounting (U.K.)*, November, 58 60.
- Corbey, M.H. (1991). Measurable economic consequences of investments in flexible capacity. *International Journal of Production Economics*, 23, 47 57.
- Corbey, M.H. (1994). On the availability of relevant costs information in operations management. *International Journal of Production Economics*, 35, 121 129.
- Corbey, M.H. (1995). Logistiek management en management accounting, Ph.D. thesis, Eindhoven University of Technology ['Operations management and management accounting' – in Dutch].
- Corbey, M.H. and P.G. Tullemans (1991). Economische beslisondersteuning bij volumeflexibiliteit. *Bedrijfskunde*, 63 (3), 289 – 302 ['Financial decision support for the volume flexibility decision' – in Dutch].

- Corbey, M.H. and R.A. Jansen (1993). The economic lot size and relevant costs. *International Journal of Production Economics*, 30-31, 519 530.
- Date, C.J. (1995). An introduction to database systems (6<sup>th</sup> edition). Reading, MA [etc.]: Addison Wesley.
- Dewan, S. and H. Mendelson (1990). User delay costs and internal pricing for a service facility. *Management Science*, 36 (12), 1502 – 1517.
- Dirks, P. (1994). MIS investments for operations management: relevant costs and revenues. *International Journal of Production Economics*, 35, 137 148.
- Dolan, T., Weterings, R., and J.C. Wortmann (1998). Stakeholders in software system family architectures. *Paper presented at the second international workshop on development and evolution of software architectures for product families*, Las Palmas de Gran Canaria, Spain.
- Dunn, C.L. and W.E. McCarthy (1997). The REA accounting model: intellectual heritage and prospects for progress. *Journal of Information Systems*, 11 (1), 31 51.
- Dupoch, N. and M. Gupta (1994). Economic effects of production changes: accounting implications. *Journal of Management Accounting Research*, 6, 1 – 23.
- Everest, G.C. and R. Weber (1977). A relational approach to accounting models. *The Accounting Review*, April, 340 359.
- Fisher, C. (1996). The impact of perceived environmental uncertainty and individual differences on management accounting requirements: a research note. Accounting Organisation an Society, 21 (4), 361 – 369.
- Foster, G. and M. Gupta (1990). Manufacturing overhead cost driver analysis. *Journal of Accounting and Economics*, 14, 309 – 337.
- Foster, G. and S.M. Young (1997). Frontiers of management accounting research. *Journal* of Management Accounting Research, 9, 63 77.
- Fowler, M. (1997). *Analysis patterns: reusable object models*. Menlo Park, CA [etc.]: Addison Wesley.
- Fowler, M. and K. Scott (1997). UML distilled, applying the standard object modelling language. Reading, MA [etc.]: Addison Wesley.

- Fransoo, J.C., Sridharan, V., and J.W.M. Bertrand (1995). A hierarchical approach for capacity co-ordination in multiple products singe machine production systems with stationary stochastic demands. *European Journal of Operational Research*, 86 (1), 57 – 72.
- Fry, T., Steele, D.C., and B.A. Saladin (1995). The role of management accounting in the development of a manufacturing strategy. *International Journal of Operations and Production Management*, 15 (12), 21 – 31.
- Gacek, C., Abd-Allah, B., Clark, B., and B. Boehm (1995). On the definition of software system architecture. *Paper presented at the ICSE 17 software architecture workshop*.
- Geerts, G.L. (1997). The timeless way of building accounting information systems: the activity pattern. *Paper presented at the OOPSLA 97 conference*, Atlanta, Georgia.
- Geerts, G.L. and W.E. McCarthy (1997). Using object templates from the REA accounting model to engineer business processes and tasks. *Paper presented at the 20<sup>th</sup> annual congress of the European Accounting Association*, Graz, Austria.
- Giesberts, P.M.J. (1993). *Master planning, dealing with flexibility*. Ph.D. thesis, Eindhoven University of Technology.
- Gietzman, M.B. and G.E. Mohanan (1996). Absorption versus direct costing: the relevance of opportunity costs in the management of congested stochastic production systems. *Management Accounting Research*, 7, 409 – 429.
- Gietzman, M.B. and A.J. Ostaszweski (1996). Optimal disbursement of a sunk resource and decentralised cost allocation. *Accounting and Business Research*, 27 (1), 17– 40.
- Goetz, B.E. (1949). *Management planning and control: a managerial approach to industrial accounting*. New York [etc.]: McGraw-Hill.
- Gordon, L.A. and V.K. Narayanan (1984). Management accounting systems, perceived environmental uncertainty and organisation structure: an empirical investigation. *Accounting, Organisations and Society*, 9 (1), 33 47.
- Gosse, D.I. (1993). Cost accounting's role in computer integrated manufacturing: an empirical field study. *Journal of Management Accounting Research*, 5, 159 179.

- Grabski, S.V. and R.J. Marsh (1994). Integrating accounting and manufacturing information systems: an ABC and REA-based approach. *Journal of Information Systems*, 8 (2), 61 80.
- Greenwood, T.G. and J.M. Reeve (1992). Activity-based cost management for continuous improvement: a process design framework. *Journal of Cost Management*, Winter, 22 40.
- Gul, F.A. (1991). The effects of management accounting systems and environmental uncertainty on small business managers' performance. Accounting and Business Research, 22 (85), 57 – 61.
- Gul, F.A. and Y.M. Chia (1994). The effects of management accounting systems, perceived environmental uncertainty and decentralisation on managerial performance: a test of three-way interaction. Accounting, Organisations and Society, 8 (2/3), 287 – 305.
- Haseman, W.D. and A.B. Whinston (1976). Design of a multidimensional accounting system. *The Accounting Review*, January, 65 79.
- Haseman, W.D. and A.B. Whinston (1977). *Introduction to data management*. Homewood, ILL [etc.]: Irwin.
- Hax, A.C. and H.C. Meal (1975). Hierarchical integration of production planning and scheduling, In M.A. Geisler (Ed.), *Studies in the management science, Vol 1: Logistics* (pp. 53 – 69). New York [etc.]: Elsevier Science Publishers.
- Hollander, A.S., Dena, E.L., and J.O. Cherrington (1996). Accounting information technology, and business solutions (2<sup>nd</sup> edition). Chicago, ILL [etc.]: Irwin.
- Hopwood, A.G. (1980). The organisational and behavioural aspects of budgeting and control. In Arnold, J., Carlsberg, B., and R. Scapens (Eds.), *Topics in Management Accounting* (pp. 221 – 240). Oxford: Philip Allen.
- Ijiri, Y. (1975). Theory of accounting measurement. American Accounting Association.
- Israelsen, P. (1994). ABC and variability accounting: differences and potential benefits of integration. *The European Accounting Review*, 3 (1), 15 48.
- Israelsen, P. and J.M. Reeve (1998). Profit reporting and analysis in complex market and manufacturing environments. *Journal of Cost Management*, 12 (4), 16 32.

- Jacobson, I. and M. Christerson (1992). *Object-oriented software engineering: a use case driven approach.* Wokingham [etc.]: Addison-Wesley.
- Jazayeri, M. and T. Hopper (1997). Management accounting within world class manufacturing: a case study. Paper presented at the 3<sup>rd</sup> international conference of Manufacturing Accounting Research, Edinburgh, United Kingdom.
- Johnson, H.T. and R..S. Kaplan (1987). *Relevance lost: the rise and fall of management accounting*, Boston, MA: Harvard Business School Press.
- Jönsson, S. and A. Grönlund (1988). Life with a sub-contractor: new technology and management accounting. *Accounting, Organisations and Society*, 13 (5), 512 532.
- Kaplan, S.E. and J.T. Mackay (1992). An examination of the association between organisational design factors and the use of accounting information for managerial performance evaluation. *Journal of Management Accounting Research*, 4, 116– 130.
- Kaplan, R.S., Shank, J.K., Horngren, C.T., Böer, G., Ferrara, W.L., and M.A. Robinson (1990). Contribution margin analysis: no longer relevant / Strategic cost management: the new paradigm. *Journal of Management Accounting Research*, 2, 1-32.
- Karmarkar, U.S., Lederer, P.J., and J.L. Zimmerman (1990). Choosing manufacturing production control and cost accounting systems. In R.S. Kaplan (Ed.), *Measures for Manufacturing Excellence* (pp. 353 – 396). Boston, MA: Harvard Business School Press.
- Kate, H.A., ten (1995). *Order acceptance and production control.* Ph.D. thesis, Rijksuniversiteit Groningen.
- Lee, H.L. and S. Nahmias (1993). Single-product, single-location models. In Graves, S.C., Rinnooy Kan, A.H.G., and P.H. Zipkin (Eds.), *Logistics of production and inventory: handbooks in operations research and management science* (pp. 3 – 55). Amsterdam [etc.]: Elsevier Science Publishers.
- Lieberman, A.Z. and A.B. Whinston (1975). A structuring of an events-accounting information system. *The Accounting Review*, April, 246 258.

- Mattessich, R. (1995). Conditional-normative accounting methodology: incorporating value judgements and means-end relations of an applied science. *Accounting, Organisations and Society*, 20 (4), 259 284.
- McCarthy, W.E. (1979). An entity-relationship view of accounting models. *The Accounting Review*, July, 667 686.
- McCarthy, W.E. (1980). Construction and use of integrated accounting systems with entity-relationship modelling. In P. Chen (Ed.), *Entity relationship approach to systems analysis and design* (pp. 625 637). New York [etc.]: North Holland Publishing Company.
- McCarthy, W.E. (1982). The REA accounting model: a generalised framework for accounting systems in a shared data environment. *The Accounting Review*, July, 554 578.
- McCarthy, W.E. (1995). The REA accounting model framework. *Paper presented at the OOPSLA 95 conference*, Austin, Texas.
- McCarthy, W.E. (1996). The evolution of enterprise information systems from sticks and jars past journals and ledgers toward inter-organisational webs of business objects and beyond. *Paper presented at the OOPSLA 96 conference*, San Jose, CA.
- Meal, H.C. (1984). Putting production decisions where they belong. *Harvard Business Review*, 62 (2), 102 – 111.
- Mia, L. (1993). The role of MAS information in organisations: an empirical study. *British* Accounting Review, 25, 269 285.
- Mia, L. and R.H. Chenhall (1994). The usefulness of management accounting systems, functional differentiation and management effectiveness. Accounting, Organisations and Society, 19 (1), 1 – 13.
- Miller, B.L. and A.G. Buckman (1987). Cost allocation and opportunity costs. *Management Science*, 33 (5), 626 – 639.
- Murthy, U.S. and C.E. Wiggins jr. (1993). Object-oriented modelling approaches for designing accounting information systems. *Journal of Information Systems*, 7 (2), 97 – 111.

- O'Brian, J. and K. Sivaramakrishan (1996). Co-ordinating order processing and production scheduling in order initiated production environments. *Journal of Management Accounting Research*, 8, 151 170.
- Ochuodho, S.J. (1992). Object-oriented database support for software project management environments: data-modelling issues. *Information and Software Technology*, 33 (1), 22 30.
- Patell, J.M. (1987). Adapting a cost accounting system to just-in-time manufacturing: the Hewlett-Packard personal office computer division, In W. Bruns & R.S. Kaplan (Eds.), Accounting and Management – field study perspectives (pp. 229 – 267). Cambridge, MA: Harvard Business School Press.
- Perera, S., Harrison, G., and M. Poole (1997). Customer-focussed manufacturing strategy and the use of operations-based non-financial performance measures: a research note. Accounting, Organisations and Society, 22 (6), 557 – 572.
- Riebel, P. (1959). Das Rechnen mit Einzelkosten und Deckungsbeiträgen. Zeitschrift für handelswissenschaftliche Forschung – Neue Folge, 11, 231 – 239 ['Calculating with Einzelkosten und Deckungsbeiträgen' – in German].
- Riebel, P. (1994). Core features of the 'Einzelkosten- und Deckungsbeitragsrechnung. *The European Accounting Review*, 3 (3), 515 543.
- Riebel, P. and W. Sinzig (1981). Zur Realisierung der Einzelkosten- und Deckungsbeitragsrechnung mit einer relationalen Datenbank, *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung*, 33 (6), 457 – 489 ['Towards the implementation of the Einzelkosten- und Deckungsbeitragsrechnung in a relational database' – in German].
- Riebel, P., Sinzig, W., and M. Heesch (1992). Fortschritte bei der Realisierung der Einzelkostenrechnung met dem SAP-System. *Controlling*, März / April, 100 – 105 ['Progress in the realisation of the Einzelkostenrechnung in the SAP-system' – in German].
- Rumbaugh, J., Blaha, M., Premerlani, W., Eddy, F., and W. Lorensen (1991). *Objectoriented modelling and design*. Englewood Cliffs, NJ: Prentice Hall.
- Sakagami, M (1995). Introducing an object-oriented model into accounting. Osaka City University Business Review, 6, 11 25.

- Scapens, R.W., Turley, S., Burn, J., Lewis, L., Joseph, N., and A. Southwoth (1996). *External* reporting and management decisions. London: Chartered Institute of Management Accountants.
- Schmalenbach, E. (1948). Pretiale Wirtschaftslenkung, Bd 2: Pretiale Lenkung des Betriebes. Bremen-Horn [etc.]: Industrie– und Handelsverlag ['Prices in a planned economy, Part 2: Price policy in organisations' – in German].
- Schmalenbach, E. (1956). *Kostenrechnung und Preispolitik*. (7<sup>th</sup> edition). Cologne: Opladen ['Cost calculations and price politics' in German].
- Schneeweiss, C. (1995). Hierarchical structures in organisations: a conceptual framework. *European Journal of Operational Research*, 86 (1), 4 31.
- Shank, J.K. (1997). Cost management solutions. The cost revolution: customer value enhancement through SCM. Keynote address at the 9<sup>th</sup> Annual Cost Management Cost Con '97, Manufacturing Institute, New York.
- Shank, J.K. and V. Govindarajan (1989). Strategic cost analyses: the evolution from managerial to strategic accounting. Homewood, ILL [etc.]: Irwin.
- Shields, M.D. (1995). An empirical analysis of firms' implementation experiences with activity-based costing. *Journal of Management Accounting Research*, 7, 148 – 166.
- Shields, M.D. (1997). Research in management accounting by North Americans in the 1990s. *Journal of Management Accounting Research*, 9, 1 59.
- Silver, E.A., Pyke, D.F., and R. Peterson (1998). *Inventory management and production planning and scheduling* (3<sup>rd</sup> edition). New York [etc.]: John Wiley & Sons.
- Sinzig, W. (1983). *Datenbank-orientiertes Rechnungswesen*. Berlin: Springer-Verlag ['Database oriented accounting' in German].
- Sinzig, W. (1994). Relative identifiable cost / contribution accounting: basic principles and methods of implementation. *International Journal of Production Economics*, 36, 65 – 73.
- Sorter, G.H. (1969). An events approach to basic accounting theory. *The Accounting Review*, January, 12 19.
- Stidham jr., S. (1992). Pricing and capacity decisions for a service facility: stability and multiple local optima. *Management Science*, 38 (8), 1121 – 1139.

- Sullivan, A.C. and K.V. Smith (1993). What is really happening to cost management systems in U.S. manufacturing? *Review of Business Studies*, 2 (1), 51 68.
- Swenson, D. (1995). The benefits of activity-based cost management to the manufacturing industry. *Journal of Management Accounting Research*, 7, 167 180.
- Taal, M. and J.C. Wortmann (1997). Integrating MRP and finite capacity planning. *Production Planning & Control*, 8 (3), 245 – 254.
- Taylor, D.A. (1995). Business engineering with object technology. New York [etc.]: John Wiley & Sons.
- Theeuwes, J.A.M. and J.K.M. Adriaansen (1994). Towards an integrated accounting framework for manufacturing improvement. *International Journal of Production Economics*, 36, 85 96.
- Theeuwes, J.A.M. and A.D. de Vos (1991). Winstgevendheid van flexibiliteit. *Tijdschrift* voor Inkoop & Logistiek, 6 (3), 36 40 ['Profitability of flexibility' in Dutch].
- Thomas, L.J. and J.O. McClain (1993). An overview of production planning. In Graves, S.C., Rinnooy Kan, A.H.G., and P.H. Zipkin (Eds.), *Logistics of production and inventory: handbooks in operations research and management science* (pp. 333 – 370). Amsterdam [etc.]: Elsevier Science Publishers.
- Veeken, H.J.M., van der (1988). Kosteninterpretatie bij logistieke beslissingen. Bedrijfskunde, 61 (1), 20 – 30 ['The interpretation of costs for operations management decisions' – in Dutch].
- Veltman, H. and K. van Donselaar (1993). Serriegroottebepaling als capaciteit een dominante factor is. *Bedrijfskunde*, 65 (3), 270 – 279 ['Lot size determination when capacity plays a dominant role' – in Dutch].
- Verdaasdonk, P.J.A. (1998). Defining an object model to analyse cash flow changes of operations management decisions. *Paper presented at the first European Conference on Accounting Information systems*, Antwerp, Belgium.
- Verdaasdonk, P.J.A. and M.J.F. Wouters (1998a). A generic financial model to support operations management decisions. *Paper presented at the 2<sup>nd</sup> conference on Hierarchical Organisational Planning (HOPII)*, Mannheim, Germany.

- Verdaasdonk, P.J.A. and M.J.F. Wouters (1998b). Defining an information structure to analyse resource spending changes of operations management decisions. Accepted for publication in *Production Planning & Control*.
- Weber, J. and B. E. Weissenberger (1997). Relative Einzelkosten- und Deckungsbeitragsrechnung: a critical evaluation of Riebel's approach. *Management Accounting Research*, 8, 277 – 298.
- Weber, R. (1986). Data models research in accounting: an evaluation of wholesale distribution software. *The Accounting Review*, July, 498 518.
- Weston, R. (1998). PeopleSoft climbs ERP ladder, http://www.news.com/news/item/0,4,22629,00.htlm.
- Whang, S. (1989). Cost allocation revisited: an optimality result. *Management Science*, 35 (10), 1264 – 1273.
- Winter, R. (1996). Continuous abstraction hierarchies in hierarchical production planning. *Revue des Systèmes de Décision / Journal of Decision Systems*, 5 (1, 2), 11 – 34.
- Wortmann, J.C., Euwe, M.J., Taal, M., and V.C.W. Wiers (1996). A review of capacity planning techniques within standard software packages. *Production Planning & Control*, 7 (2), 117 – 128.
- Wouters, M.J.F. (1993a). Relevant costs or full costs: explaining why managers use cost allocations for short-term decisions. Ph.D. thesis, Antwerp [etc.]: Maklu Uitgevers.
- Wouters, M.J.F. (1993b). The use of cost information by managers when making short-term decisions. *European Accounting Review*, 2 (2), 432 436.
- Wouters, M.J.F. (1994). Decision orientation of activity-based costing. *International Journal of Production Economics*, 36, 75 84.
- Wouters, M.J.F. (1997). Relevant cost information for order acceptance decisions. *Production Planning & Control*, 8 (1), 2 – 9.
- Wouters, M.J.F. and P.J.A. Verdaasdonk (1997). Waarom is bedrijfseconomisch onderzoek belangrijk binnen Technische Bedrijfskunde? *VLO-magazine*, 2, 26 28 [Why is management accounting research important within Industrial Engineering and Management Science? in Dutch].

- Wouters, M.J.F. and P.J.A. Verdaasdonk (1998). The relevance of ex ante management accounting information for operations management decisions: a theoretical model and empirical results. *Paper presented at the 21<sup>st</sup> annual conference of the European Accounting Association*, Antwerp, Belgium.
- Young, S.M. and F.H. Selto (1993). Explaining cross-sectional workgroup performance differences in a JIT facility: a critical appraisal of a field-based study. *Journal of Management Accounting Research*, 5, 300 – 326.
- Yu, S.C. (1976). The structure of accounting theory. The University Presses of Florida.
- Zimmerman, J.L. (1997). Accounting for decision-making and control (2<sup>nd</sup> edition). Chicago, ILL [etc.]: Irwin.

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## Appendix A UML notation convention



Subclass A

Subclass B



## Samenvatting (summary in Dutch)

De doelstelling van het onderzoek beschreven in dit proefschrift is het verkrijgen van kennis op welke wijze *ex ante* financiële informatie voor het ondersteunen van operations management beslissingen kan worden geïmplementeerd in informatiesystemen. Wij richten ons op korte – en middellange termijn beslissingen. Literatuur onderzoek leert ons dat de huidige informatiesystemen geen *ex ante* financiële informatie geven voor het ondersteunen van de genoemde soort beslissingen. Wij hebben drie probleemvelden geïdentificeerd waarom het de huidige systemen aan deze functionaliteit ontbreekt:

- 1. Accounting theorieën voor het ondersteunen van beslissingen zijn moeilijk te implementeren in informatiesystemen.
- 2. Er bestaat een discussie in the accounting literatuur ten aanzien welke informatie moet worden gebruikt voor beslisondersteuning.
- 3. Huidige data structuren zijn ongeschikt.

Het eerste probleemveld betreft moeilijkheden om de relevante kosten techniek operationeel te maken voor implementatie in informatiesystemen. De relevante kosten voor een beslissing bestaan uit de incrementele kosten plus de opportuniteitskosten. De incrementele kosten zijn die kosten die verschillen tussen alternatieven. Opportuniteitskosten zijn de gemiste financiële voordelen tengevolge van het niet gekozen (of gemiste) alternatief. Uit de definities blijkt dat de genoemde kosten situatie afhankelijk zijn. De kennis om deze kosten te achterhalen kan 'eenvoudig' worden toegepast door een beslisser. Echter, deze kennis is niet op een zodanig wijze geformaliseerd in de literatuur dat deze kan worden toegepast voor de implementatie in een informatiesysteem.

Het tweede probleemveld betreft de conceptuele discussie in the accounting literatuur ten aanzien van het soort informatie te gebruiken voor beslisondersteuning. Korte termijn financiële informatie (incrementele kosten en de bekende opportuniteitskosten) geven soms andere adviezen dan de adviezen verkregen uit langere termijn financiële informatie. Bijvoorbeeld, stel dat de integrale kostprijs van een component boven de inkoopprijs van hetzelfde product ligt. Dit betekent dat je het product op de langere termijn moet inkopen. Echter de korte termijn relevante kosten kunnen onder deze inkoopprijs liggen, wat weer betekent dat het beter is om dit product zelf te produceren. Hoe kan een organisatie nu ooit de langere termijn doelstellingen halen, indien de kortere termijn informatie haar de andere richting opstuurt? Deze verwarring leidt meestal tot discussies in de literatuur ten aanzien wat voor financiële informatie je nu moet gebruiken voor deze korte termijn beslissingen (integrale kosten of incrementele kosten).

Het derde probleemveld betreft de registratie technieken van accounting data in de huidige systemen. De meest gangbare techniek om financiële data op te slaan (het dubbel boekhoudsysteem) blokkeert het gebruik van financiële data voor het ondersteunen van operations management beslissingen omdat deze techniek niet gericht is op het opslaan van *ex ante* data. Om deze reden is een ander data model nodig. Echter de belangrijkste valkuil tijdens het ontwerpen van financiële data registratie systemen is de te beperkte blik op het toepassingsgebied. Vaak wordt één toepassing als uitgangspunt genomen, en worden hiermee andere financiële toepassingen van dezelfde data geblokkeerd. Het is dus belangrijk aansluiting te zoeken bij bestaande modellen die ofwel deze *ex ante* data reeds registreren, ofwel makkelijk zijn uit te breiden met de benodigde data. De belangrijkste alternatieve modellen voor het opslaan van financiële data zijn het Resource – Event – Agent (REA) model en de 'Grundrechnung'. Deze modellen claimen financiële data objectief op te slaan. Dit betekent dat de data niet wordt opgeslagen voor één specifiek doel, maar voor een reeks van doelen in het financiële domein. Analyse van de modellen leert, dat zij voornamelijk gericht zijn op *ex post* (registratie) functionaliteit.

Op basis van de genoemde probleemvelden, kunnen de volgende onderzoeksvragen worden geformuleerd:

- 1. Wat zijn de formele procedures om het gedrag van kosten te beschrijven zodanig dat een informatiesysteem de incrementele en de opportuniteitskosten voor een gegeven beslissingsalternatief kan bepalen?
- 2. Welke financiële techniek kunnen we gebruiken in een informatiesysteem voor het evalueren van operations management beslissingen, zodanig dat korte termijn beslissinggen in overeenstemming worden gebracht met het langere termijn beleid?
- 3. Wat zijn de implicaties voor de bedoelde accounting techniek voor de bestaande accounting data modellen?

De doelstelling van het onderzoek is gehaald door middel van het ontwerp van een informatiesysteem gericht op het genereren van relevante *ex ante* financiële informatie voor operations management beslissingen. De methodologie voor het ontwerpen van het systeem bestaat uit drie fases. In de eerste fase zijn de eisen van de belanghebbenden van het te ontwikkelen informatiesysteem achterhaald. In de tweede fase zijn deze eisen vertaald naar een informatiesysteem ontwerp. In de laatste fase wordt aangetoond dat het

ontwerp van het informatiesysteem, indien dat zou worden geïmplementeerd voldoet aan de eisen van de belanghebbenden. De methodologie onderkent vier groepen belanghebbenden: 1) de gebruiker, 2) de klant, 3) de architect en de software ontwikkelaar, en 4) de onderhouder van het systeem. In dit onderzoek zijn de eisen tot functionele eisen (gebruiker als belanghebbende). De technische eisen zijn bewaakt door professionele ERP systeem ontwerpers en ontwikkelaars (architect, ontwikkelaar, en onderhouder als belanghebbenden). Deze behoeften worden niet expliciet gemaakt in dit proefschrift. Een potentiële klant is niet betrokken bij het traject, omdat het ontwerpproces zich voornamelijk in een conceptuele fase heeft afgespeeld. Dit maakte het erg voorbarig de potentiële klant bij het proces te betrekken. De eisen zijn achterhaald door middel van het uitwerken van financiële informatie voor het ondersteunen van een vijftal operations management beslissingen welke kunnen worden ondersteund in een informatiesysteem. Deze beslissingen zijn: 1) 'vaststellen van een hoofd productie programma', 2) 'order acceptatie', 3) 'vaststellen van seriegroottes', 4) 'capaciteitsuitbreiding', en 5) 'vaststellen van veiligheidsvoorraden'. De uitwerking van deze beslissingen heeft geleid tot een vijftal eisen. Deze eisen zullen hieronder verder worden toegelicht. De eisen zijn: 1) objectiviteit van financiële data, 2) resource consumptie, 3) resource transitie, 4) geld transitie, en 5) contextuele informatie. Deze eisen zijn geïmplementeerd in het informatiesysteem ontwerp.

Het ontwerp van het informatiesysteem bestaat uit een tweetal delen. Het eerste deel betreft de financiële techniek voor het ondersteunen van operations management beslissingen; het Hiërarchische Geldstroom Model (HGM). Het HGM bestaat uit een set van procedures die erop is gericht het effect van een beslissingsalternatief te achterhalen gebaseerd op objectieve parameters. Dit betekent dat het HGM niet rekent met tussentijdse waarderingen van het gebruik van resources. Het HGM waardeert alleen de transacties tussen de organisatie en haar klanten / toeleverancier. Het HGM beantwoordt de eerste en de tweede onderzoeksvraag. Het HGM maakt een strikt onderscheid tussen het fysieke effect van een beslissing (de resource stroom) en het monetaire effect van een beslissing (de geldstroom). De resource stroom wordt achterhaald door middel van de eisen resource consumptie en resource transitie. Resource consumptie verwijst naar het gebruik van resources; resource transitie verwijst naar de verkoop en inkoop transacties tussen de onderneming en haar markten. Geldstromen worden bepaald aan de hand van de resource transities. Deze mogelijkheid wordt geboden door het concept 'contract'. Het concept 'contract' maakt het mogelijk in het HGM om variabiliteit en vermijdbaarheid in geldstromen te modelleren.

Samenvatting (summary in Dutch)

We hebben hiërarchische planning concepten uit de operations management literatuur in het model ingebracht. Deze introductie van deze concepten zorgt voor een uitbreiding op bestaande accounting literatuur. Het resultaat van dit concept in het model is tweeledig. Ten eerste maakt hiërarchische planning een operationeel gebruik van opportuniteitskosten in een informatiesysteem mogelijk. In het HGM wordt een beslissing gerelateerd aan de impact op het hogere hiërarchische plan. De financiële vertaling van dit effect bedraagt de opportuniteitskosten voor dit alternatief. Ten tweede wordt het hiërarchische concept tegelijkertijd gebruikt om informatie te geven omtrent de langere termijn doelstelling van de organisatie ten aanzien van het gebruik van de resources. De opportuniteitskosten dienen nu dus tevens als doelstelling waaraan het alternatief minimaal moet voldoen. Het hiërarchische concept implementeert de eis van contextuele informatie.

Het tweede deel van het ontwerp van het informatiesysteem is het object model. Het object model incorporeert de data en procedures nodig voor het uitvoeren van het HGM. Het object model bouwt voort op bestaande modellen zoals het REA model en de 'Grundrechnung'. Het object model is gebaseerd op contracten, activiteiten, resources, en reserveringen. Financiële informatie is uitsluitend gerelateerd aan contracten. Dit betekent dat financiële informatie niet wordt gealloceeerd aan zogenaamde kosten objecten. Hierdoor voldoen we aan de eis van objectiviteit van accounting data. We hebben gekozen om voort te bouwen op bestaande modellen, om de belangrijkste valkuil te vermijden tijdens het ontwikkelen van informatiesystemen ten behoeve van het accounting applicatie domein. Zoals vermeld betreft deze valkuil een focus op uitsluitend het eigen gebied, waardoor andere accounting gebieden worden uitgesloten. Door nu bestaande modellen, welke zich hebben bewezen op het *ex post* applicatie gebied uit te breiden vermijden wij deze valkuil.

Het HGM en het object model zijn vervolgens toegepast voor een tweetal beslissingen: 'het vaststellen van het hoofd productie programma', en 'order acceptatie' zoals deze worden geïmplementeerd in een informatiesysteem. De toepassing is bedoeld om aan te tonen dat het informatiesysteem ontwerp voldoet aan de vooraf opgestelde eisen. We laten zien dat het HGM werkt voor deze beslissingen in een informatiesysteem. Echter het toepassen van het HGM leverde additionele moeilijkheden op die worden veroorzaakt door de wijze waarop de genoemde beslissingen worden gemodelleerd in huidige informatiesystemen. Wij geven oplossingen voor de gesignaleerde problemen, en laten zien dat het HGM kan werken met deze oplossingen.

## Summary

The objective of this thesis is to obtain knowledge about the incorporation of *ex ante* accounting information to support operations management decisions in information systems. We focus on short-term and medium-term operations management decisions. Prior research and literature review show that present information systems lack the ability to generate *ex ante* accounting information for operations management decisions. We have identified three reasons why present information systems lack this functionality:

- 1. Accounting theories for decision support are difficult to implement in information systems.
- 2. There are discussions in the accounting literature about which accounting information to use for decision support.
- 3. Present data structures are inappropriate.

The first problem area relates to the difficulties encountered when trying to translate the concepts of the accounting technique to support operations management decisions (the relevant cost technique) to information systems. The relevant costs of a decision-alternative consist of the incremental costs and the opportunity costs. The incremental costs are those that differ between alternatives. Opportunity costs are the benefits foregone as a result of choosing one course of action rather than another. The definitions of the components of the relevant costs imply that these costs are situational dependent. The knowledge how to determine the relevant costs can be applied by humans. However, in the literature this knowledge is not formalised in such a way that this knowledge can be implemented in information systems.

The second problem area relates to the conceptual discussion in accounting literature to the accounting information to use for decision support. Short-term accounting information (incremental cost plus known opportunity costs) sometimes directs companies to decisionalternatives that are in contradiction to the directions companies would choose based on longer-term accounting information. Imagine, for example, that the full costs of making a component are above the purchase price of the same component, suggesting that in the long run the component could better be purchased outside. However, short-term relevant costs could very well be below the purchase price, because many costs are unavoidable in the short-run. How can organisation ever achieve the objectives in the long run, when short-term information points in another direction? This confusion usually leads to discussions in the literature about what type of accounting information to use for shortterm decision-making (full cost or incremental costs).

The final problem area relates to the registration methods of accounting data in most of the present information systems. The most common technique (double entry bookkeeping) blocks the use of accounting data for operations management decision support, since this technique does not incorporate *ex ante* accounting data. Therefore, we need other data models to serve our purpose. However, one of the main pitfalls in the design of accounting data models is that the data models limit itself too one application domain only (and therefore exclude others). Therefore, it is important to have a close junction with existing data models in order to obtain a larger application domain for the data. Literature provides two alternative models: the REA model and the 'Grundrechnung'. These models claim to store accounting data objectively, meaning that they do not exclude any accounting application domain. However, the models relate to *ex post* functionality only, and not to the *ex ante* area meant in this thesis. Since we want to avoid the main pitfall in the design of accounting data models in the iterature.

Based on the problems described above, we have formulated the following research questions:

- 1. What are the formal procedures to describe cost behaviour in such a way that an information system can determine incremental costs and opportunity costs for a given decision-alternative?
- 2. Which accounting technique can be used in information systems for the evaluations of operations management decisions in order to bring short-term decisions in congruence with long-term policy?
- 3. What are the implications of the accounting technique for the known accounting data models?

The research objective has been pursued by the development of an information system design that is able to supply relevant *ex ante* accounting information for operations management decisions. The methodology of developing the information system design consists of three phases. In the first phase the stakeholders of the information system are involved to retrieve the requirements for such as system. In the second phase the requirements are used to build the architecture design. In the final phase a rationale is given which demonstrates that the architecture design, if implemented would satisfy the

requirements of the stakeholders. In the methodology four groups of stakeholders are discerned: 1) the user, 2) the customer, 3), the architect and the software developer, and 4) the maintainer of the system. In this thesis, the requirement statement has been restricted to functional requirements (user as stakeholder). The technical requirements have been guarded by professional ERP systems developers, but have not been made explicit in this research project (architect, software developer, and maintainer as stakeholders). The customer has not been involved as a stakeholder in this project. The reason for this is that the information system design is mainly in a conceptual phase. This makes it very premature to involve the customer as a stakeholder. The requirements have been based on the analyses how and which ex ante accounting information can be used for five operations management decisions. These decision are: 1) 'setting the Master Production Schedule', 2) 'order acceptance', 3) 'determining lot sizes', 4) 'capacity expansion', and 5) 'determining safety stock levels'. Based on these decisions, in total five requirements have been defined for the system. These requirements, which are explained next are named 1) objectivity of accounting data, 2) resource consumption, 3) resource transition, 4) cash transition, and 5) contextual information. These requirements are fulfilled by the information system design.

The information system design consists of two parts. The first part is the generic accounting technique to support operations management decisions. This technique is called the Hierarchical Cash Flow Model (HCFM). The HCFM consists of a set of procedures that is aimed at retrieving the effect of a decision-alternative based on objective parameters. The HCFM does not calculate with intermediate cost values regarding the use of resources. The HCFM only values the transactions with (external) customers and suppliers. The model gives answer to the first and second research question, described above. The HCFM makes a strict separation between the analyses of the effects on the resource flow and the analyses of the effect on the cash flow. The resource flow is analysed by means of the concepts resource consumption and resource transition. Resource consumption refers to the usage of resources; resource transition refers to the purchase and sales transactions between the organisation and its markets. Cash flows are retrieved by converting resource transition into cash transition. This possibility is created by making use of the contract concept. The contract concept enables the HCFM to model variability and avoidability of cash flows.

We have introduced the operations management concept of hierarchical planning into our accounting model. Therefore, the HCFM extends the cash flow models known from

Summary

accounting literature with this hierarchical concept. The result of this introduction is twofold. Firstly, the hierarchical concept enables the operational use of the opportunity cost concept in information systems. A higher hierarchical plan is used for a particular decision-alternative to determine the benefit forgone in this plan when executing the decision-alternative. Secondly, at the same time, the hierarchical concept is used to provide accounting information for shorter-term decisions that is in congruence with longer-term policy. The opportunity costs of the plan serve as a financial target for shorterterm decisions. In this way shorter-term decisions can be made in congruence with longerterm policy, but at the discretion of the decision-maker. The hierarchical concept implements the requirement of contextual information.

The second part of the information system design is the object model. The object model incorporates the data and procedures needed by the HCFM. The object model extends prior research effort into accounting data models, which has resulted in the Resource – Event – Agent (REA) model and the 'Grundrechnung'. The object model is based on contracts, activities, resources, and reservations. Accounting information is only related to contracts. This implies that we do not allocate or apportion accounting data, and therefore, fulfil the requirement of objectivity of accounting data. We have chosen to extend these prior models to avoid the main pitfall in the development of information systems for the accounting application domain. As mentioned above, this pitfall is a narrow focus on just one application domain, which causes the exclusion of other domains. By extending the prior models, the application domain of these models in maintained, which automatically leads to a multiple purpose focus of the accounting data.

The HCFM is applied for two operations management decisions 'setting the Master Production Schedule (MPS)' and 'order acceptance' in an information system setting. We use this elaboration as a rationale to illustrate that the information system design is able to fulfil the stakeholders' needs. However, the implementation of the HCFM is not straightforward. Modelling choices when implementing the decisions 'setting the MPS' and 'order acceptance' on non-financial grounds in present ERP systems lead to complexities when implementing the HCFM. We give solutions for these complexities, and then show that the HCFM is able to retrieve the accounting information needed to support these two decisions.
## **Curriculum Vitae**

Peter Verdaasdonk was born on November 23<sup>rd</sup>, 1970, in Breda, the Netherlands. In 1989, he received his VWO diploma from the Mencia de Mendoza Lyceum in Breda. In that same year he started his study Industrial Engineering and Management Science at the Eindhoven University of Technology. He graduated from the master's program in 1994. In 1994, he started his Ph.D. work at the same university as a member of the department 'Accounting, Finance, and Marketing' of the faculty of Technology Management. During the project he has been working with Machinefabriek Meijn BV, Oostzaan, the Netherlands and Baan Company NV, Ede, the Netherlands. This thesis concludes the Ph.D. project.

In 1999 Peter will continue his work at Eindhoven University of Technology on a parttime basis. Furthermore, he continues his work into accounting information for (operations) management as a private business consultant.

## Stellingen

behorende bij het proefschrift

# Accounting information

## for

## operations management decisions

van

Peter Verdaasdonk

De stelling van Johnson en Kaplan (1987) dat financial accounting management accounting domineert in de huidige informatie systemen, zou moeten worden genuanceerd naar de stelling dat *ex post* accounting informatie *ex ante* accounting informatie domineert.

Dit proefschrift; Hoofdstuk 1.

Π

Het ontbreken van *ex ante* financiële informatie voor het ondersteunen van operations management beslissingen in geautomatiseerde informatie systemen wordt ondermeer veroorzaakt door het ontbreken van een registratie techniek voor relevante data.

Dit proefschrift; Hoofdstuk 1.

#### Ш

De introductie van hiërarchische planning in management informatie systemen bevordert een operationeel gebruik van het begrip opportuniteitskosten.

Dit proefschrift; Hoofdstuk 3.

#### IV

De implementatie van functionaliteit in *ex ante* financiële informatie in geautomatiseerde informatie systemen kan worden gerealiseerd door de fysieke stromen als uitgangspunt te nemen, in plaats van de financiële stromen.

Dit proefschrift; Hoofdstuk 3.

#### V

Huidige accounting data modellen zoals de 'Grundrechnung' and het Resource – Event – Agent (REA) model alleen, volstaan niet voor het verstrekken van *ex ante* financiële informatie voor het ondersteunen van operations management beslissingen.

Dit proefschrift; Hoofdstuk 4.

Het in twijfel trekken van het doel van een doel neutrale database is zonder twijfel

gerechtvaardigd.

VI

Verstrekking van een vergoeding aan de werknemer ter grootte van de huidige kosten voor de werkgever voor de 'auto van de zaak' reduceert files ten gevolge van het woon werkverkeer.

Het wetsvoorstel van staatssecretaris Vermeend om bepaalde vermogende Nederlanders woonachting België alsnog fiscaal te belasten is een typisch voorbeeld van de wet van het afnemend grensnut.

Het gemiddelde AiO traject zal worden bespoedigd indien het AiO salaris in omgekeerde volgorde zou worden uitbetaald.

IX

De alternatieve straf welke in ons rechtssysteem kan worden opgelegd, is een belediging voor hen die deze 'straf' als hun dagelijkse broodwinning uitvoeren.

Х

De ware rijkdom van iemands ideeën wordt vaak pas duidelijk wanneer men zelf deze ideeën heeft toegepast.

Wanneer de Nederlandse hypotheken vanaf 1976 in ECU's waren afgesloten, dan zou de gemiddelde hypotheekschuld per 1 januari 1999 in euro's lager zijn geweest, dan volgens de procedure die nu wordt gevolgd.

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