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Flexible Budgeting in an Activity-Based Costing Framework: From Conceptual Modeling to Prototypical Implementation

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Christoph Fraller, BSc

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Kurzfassung

Im Rahmen der IT-gestützten Unternehmenssteuerung wird die konzeptionelle Modellierung zunehmend angewendet um ein fundiertes Verständnis von ökonomischen Ansätzen zu ermöglichen, wodurch nachfolgende Implementierungsprozesse erleichtert werden. Die vorliegende Arbeit befasst sich mit der konzeptionellen Modellierung und prototypischen Implementierung eines Activity-Based Costing (ABC) Ansatzes, der zu flexiblen Budgetierungszwecken verwendet wird. Bisherige Forschungsarbeiten beschränken sich ausschließlich auf die ökonomischen Aspekte dieses Ansatzes. Daher besteht eine Diskrepanz zwischen Wirtschaftswissenschaften und konzeptioneller Modellierung hinsichtlich der flexiblen Budgetierung in einem ABC Rahmen, welche bis dato in der vorhandenen Literatur nicht hinreichend behandelt wurde. Aufgrund dieser Unzulänglichkeit widmet sich die vorliegende Arbeit der Entwicklung eines konzeptionellen Modells, indem die ontologischen Eigenschaften eines kapazitäts-basierten ABC Ansatzes in Bezug auf flexible Budgetierungszwecke dargestellt werden. Die Forschungsmethode dieser Arbeit basiert auf einer design-wissenschaftlichen Methodik, bei der das konzeptionelle Modell als primäres Forschungsartefakt entwickelt wird. Darüber hinaus wird eine prototypische Implementierung im Rahmen einer beobachtenden Fallstudie durchgeführt und in weiterer Folge zur Validierung des konzeptionellen Modells eingesetzt. Diese Fallstudie basiert auf einem erstellten Datensatz eines fiktiven Unternehmens. Nachdem die praktische Anwendbarkeit des konzeptionellen Modells anhand der prototypischen Implementierung demonstriert wurde, wird die Fallstudie mit der Demonstration eines Anwendungsfalles abgeschlossen. Das primäre Ergebnis dieser Arbeit entspricht einem konzeptionellen Modell eines kapazitätsbasierten ABC Ansatzes, welches als Erweiterung des REA-Modells mit Hilfe der OntoUML entwickelt wurde. Zusammenfassend demonstriert diese Arbeit die gesamte Vorgehensweise von der konzeptionellen Modellierung bis hin zur prototypischen Implementierung bezüglich flexibler Budgetierung in einem ABC Rahmen.

Abstract

In IT-based management control, conceptual modeling of economic approaches is frequently applied in order to facilitate further implementation processes and understandings. More specifically, this thesis focuses on conceptual modeling and prototypical implementation of an Activity-Based Costing (ABC) system, which is appropriate for flexible budgeting purposes. Previous research has failed to address the discrepancy between economic sciences and conceptual modeling in terms of flexible budgeting within an ABC framework. To overcome this limitation, we propose a conceptual model that captures the ontological peculiarities of a capacity-based ABC system for flexible budgeting. The research approach of this thesis is based on a design science research methodology, in which the conceptual model is designed as the main artifact. Moreover, the prototypical implementation is carried out in the course of an observational case study, and, consequently, it is used for validating the conceptual model. This case study is based on a constructed data set of a fictitious company for which the prototypical implementation is conducted. After the practical applicability of the conceptual model has been demonstrated through the prototypical implementation, the case study is concluded with an observational evaluation of the prototypical implementation based on a use case demonstration. The primary outcome of this thesis corresponds to a conceptual model of a capacity-based ABC system that has been developed as an extension of the well-founded REA accounting model by means of the OntoUML. In conclusion, this thesis demonstrates the entire proceedings from conceptual modeling to prototypical implementation regarding flexible budgeting in an ABC framework.

Contents

CHAPTER 1

Introduction

1.1 Motivation

Historically, the roots of conceptual modeling can be traced back to the semantic model proposed by Abrial [1] as well as to the Entity-Relationship (ER) model proposed by Chen [2]. Both models were developed using the techniques applied in database engineering, one of the subfields of computer science. As a result of Abrial's and Chen's work, what followed has been a series of ER conferences [3] on conceptual modeling.

At present, one of the main concerns in IT-based management control is the conceptual modeling of those concepts that are subject to the domains of accounting, finance, and controlling. Once the various peculiarities of a certain domain-specific approach within a conceptual model are detected, usually, the next stage is the building and implementation of a fully integrated Management Information System (MIS). The problem that arises at this stage is twofold: on the one hand, we have those people who are not domain experts and who, therefore struggle to master the complexity of such economic approaches. On the other hand, we have people who are established domain experts, but who are mostly unfamiliar with software engineering techniques. This is because they usually have a background of economic sciences only, which has nothing at all to do with software engineering. In practice, this often leads to misunderstandings between the involved stakeholders, especially if they view one and the same project from different perspectives or levels of understanding. So, these problems typically occur during the implementation processes of a MIS. In fact, any misunderstandings regarding the requirements engineering stage may lead to incomplete, unclear, inconsistent, and false requirements. Broadly speaking, misunderstandings concerning the implementation of a complex MIS can cause incredible damage.

According to Robinson et al. [4], the intent of conceptual modeling is to take a sufficiently large part of a real world problem domain and work it into a solution-independent model without software-specific characteristics. Therefore, a conceptual model provides a reasonably effective instrument of communication between all involved stakeholders. It thus minimizes the likelihood of unnecessary misunderstandings and subsequent problems during requirements engineering.

1.2 Problem Statement

Flexible budgeting is an essential part of management control. However, Activity-Based Costing (ABC) is a method used in management accounting to compute product costs. In this thesis flexible budgeting is discussed within an ABC framework, so that both methods are addressed.

Frequently, simple ABC approaches fail when they are used for flexible budgeting purposes. This happens mainly when the budgeted operating expenses are solely adjusted to the anticipated activity levels. In the case of shrinking markets, this only works when the budgeted operating expenses and the anticipated activity levels are decreasing to the same extent. It does not work when the activity levels are falling faster than the operating expenses are being reduced, as this is often the case in practice. Hence, these simple ABC approaches tend to fail and lead to so called 'death spirals' [5]. So, it is crucial to solve any issue that may arise from simple ABC approaches prior to using flexible budgeting. A proper solution is provided then only when more sophisticated ABC approaches are being used that incorporate the capacity of the activity levels of certain businesses. Therefore, the economic part of this paper is focusing on flexible budgeting that incorporates the capacity-based ABC approach introduced by Kaplan [6], which further distinguishes between committed and flexible resources.

Although this capacity-based ABC approach is well described in literature, there is a discrepancy between economic sciences and conceptual modeling. From a model engineering perspective, scientific elaborations are not fully conceptualized what concerns the conceptual modeling of the above approach. Since economic literature regularly uses oversimplified examples for demonstration purposes, for the purpose of this thesis some additions are going to be made in order to establish a solid foundation to enable the further processes and understandings of conceptual modeling and prototypical implementation. Even if some obstacles are identified, none of the existing literature provides a solution to the identified shortcomings of Table 1.1. In the first place, an ABC system for flexible budgeting is designed on the basis of the capacity-based ABC approach with committed and flexible resources of Kaplan [6]. Thus, the identified shortcomings are taken into account and possible requirements for conceptual modeling are identified and formulated. Once these requirements have been derived, the next stage is concerned to conceptual modeling of an ontological representation of the designed ABC system. The major objective of this thesis is to provide a conceptual model that grasps the ontological peculiarities of that designed ABC system and therefore provides a solution for the aforementioned deficiencies.

#	**Main concern**	**Shortcomings**
1	Resource typification	The typification of resources is not fully conceptualized with regard to conceptual modeling of a capacity-based ABC system. In particular, a standardized resource typification in terms of enabling information systems integration has not been discussed yet.
2	Integration of general ledger accounts	In literature, the integration of general ledger accounts has not been adequately addressed according to conceptual modeling of an ABC framework for flexible budgeting. The distinction of direct and overhead expenses is unclear. Furthermore, it is not clarified how expenses are categorized by their underlying resource types.
3	Allocation of resources	The allocation of resources has not been discussed in a suitable manner. This includes the mapping of expenses from resources to activities and subsequently from activities to cost objects.
4	Inclusion of key components for flexible budgeting	The inclusion of key components for flexible budgeting is not entirely clarified in order to provide a comprehensive foundation for conceptual modeling and prototypical implementation. Flexible budgeting key components include operating expenses, production volumes, activity levels, and planning periods.
5	Mapping of data pools	With regard to conceptual modeling, the mapping of data pools, such as cost and activity pools, has not been sufficiently addressed by existing literature.

Table 1.1: Identified shortcomings

The conceptual model is developed using the foundational Ontology-Driven Unified Modeling Language (OntoUML) proposed by Guizzardi [7]. The OntoUML can be briefly described as an extension of the Unified Modeling Language (UML)[1], that integrates ontological meta-properties by making them accessible in UML class diagrams through the utilization of stereotypes. Furthermore, the conceptual model in this paper is discussed as being built on top of the well-founded REA accounting model (cf. Figure 4.4), which has been introduced by McCarthy [8] and translated into the OntoUML by Fischer-Pauzenberger and Schwaiger [9]. It covers the fundamental characteristics of the accounting domain. Although the REA accounting model serves as a good starting point, it needs to be specifically adapted to flexible budgeting in an ABC framework.

In addition, a prototypical implementation that is based on the conceptual model to be developed is performed. Thus, it is used for the validation of the conceptual model within an observational case study demonstration. Another important point of the prototypical implementation is the manifestation of the benefits of having an explicit conceptual model for the implementation process.

[1] https://www.omg.org/spec/UML/

1.3 Aim of the Work

The primary research objective in this thesis is a conceptual model of an ABC system characterized by Kaplan's capacity-based ABC approach with flexible and committed resources. It will be developed as an extension of the REA accounting model and based on flexible budgeting. For conceptual modeling the OntoUML will be utilized.

As proof of concept, a prototypical implementation based on the conceptual model is performed in the course of an observational case study. Therefore, an ER diagram is created and in the following process converted into a PostgreSQL[2] database. For demonstration purposes a web-based application with a Graphical User Interface (GUI) is implemented using RShiny[3]. Furthermore, UML activity diagrams are created for capturing the calculation procedures of the capacity-based ABC system.

In summary, the expected conclusion of this thesis is influenced by four different research artifacts:

1. **Capacity-based ABC system** for flexible budgeting established on the capacity-based ABC approach with flexible and committed resources of Kaplan [6]
2. **Requirements identification** based on ontological peculiarities of the capacity-based ABC system with regard to conceptual modeling
3. **Conceptual model** of the capacity-based ABC system for flexible budgeting based on previously identified requirements
4. **Prototypical implementation** consisting out of an ER diagram, UML activity diagrams, and a database implementation that is accessible via a web-based application

Another focal point of this thesis is the constructed sample data set introduced in Section 2.2. It is used for identification and illumination of the different operating principles among the three ABC approaches proposed by Kaplan [6]: simple ABC, capacity-based ABC with committed expenses, and capacity-based ABC with flexible and committed resources. Moreover, the emergence of a death spiral in the simple ABC approach will be demonstrated. As a part of the case study demonstration, the data set is used for the observational evaluation of the prototypical implementation and implicitly used for validation of the conceptual model.

The overall goal of this paper is to deliver a contribution to the conceptual modeling of a capacity-based ABC system for flexible budgeting within the area of IT-based management control.

[2]https://www.postgresql.org/
[3]https://shiny.rstudio.com/

1.4 Methodological Approach

The methodological approach corresponds to the paper of Hevner et al. [10] on design science in information systems research. The research in information science is characterized by two paradigms. On the one hand, there is the behavioral science paradigm, and on the other hand, there is the design science paradigm. With regard to the behavioral science paradigm, the focus is on developing and verifying theories that explain, or predict, human as well as organizational behavior. And the design science paradigm is intended to be used for extending the boundaries of human as well as organizational capabilities via the creation of new and innovative artifacts. The different aspects of both paradigms have to be considered for achieving the expected research objectives of this paper. Firstly, the design science paradigm is concerned with the creation of innovative artifacts such as development of the conceptual model in this thesis. Secondly, the behavioral science paradigm is addressed when an observational case study demonstration is performed for evaluating the conceptual model. Figure 1.1 represents the research framework adapted to the extent of this thesis.

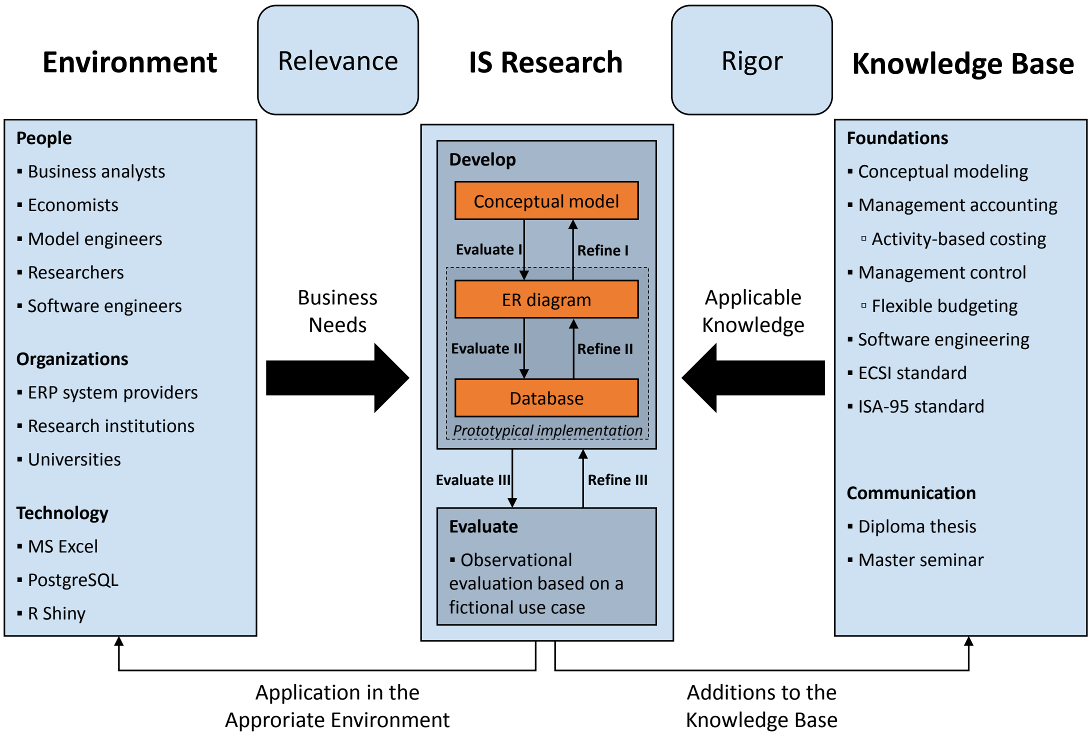


Figure 1.1: Research framework based on the design science framework [10]

Hevner et al. [10] stated seven design-science research guidelines according to the design science in information systems research. Subsequently, these guidelines are described with reference to this work.

Guideline 1: Design as an Artifact The main artifact of this thesis is the conceptual model of a capacity-based ABC system with regard to flexible budgeting.

Guideline 2: Problem Relevance As mentioned in Section 1.2, there is a discrepancy between economic literature and conceptual modeling regarding viable flexible budgeting approaches in an ABC framework. In order to enable the implementation of such approaches into a software application, such as a MIS, these differences must be balanced.

Guideline 3: Design Evaluation The research framework of Figure 1.1 illustrates the evaluation process that consists of three different evaluation stages. It is important to mention that each stage of this evaluation process contains a feedback loop. The first stage is concerned with the validation of the conceptual model and the ER diagram. The second stage of evaluation is conducted within the prototypical implementation, whereby the implemented database is evaluated against the ER diagram. And the third stage of the evaluation process corresponds to the observational evaluation of the prototypical implementation based on a fictional use case. Furthermore, the conceptual model is evaluated based on a qualitative analysis in order to proof whether or not the identified shortcomings of this paper have been clarified.

Guideline 4: Research Contributions The primary research contribution of this thesis is a conceptual model that is developed as an extension of the well-founded REA accounting model. It is based on flexible budgeting using a capacity-based ABC system with flexible and committed resources.

Guideline 5: Research Rigor The methodological approach of this thesis corresponds to a rigorous scientific research methodology. First, a systematic review of the existing literature related to this topic is performed, then the problems are formulated, and after that the capacity-based ABC system is designed. Next, the requirements are derived and then the conceptual model is developed based on these requirements. The evaluation is based on an observational case study demonstration. Thereby, the conceptual model is applied in the course of a prototypical implementation. After the evaluation is completed, the results of this paper are discussed. Finally, a conclusion is drawn whether or not the anticipated extent and value of the contribution have been achieved in this thesis.

Guideline 6: Design as a Search Process Due to the fact that design science is inherently iterative, the search for the optimal design can be difficult in case of genuine information system problems. This search for an effective artifact requires the use of available means, such as standardized modeling languages and proven software engineering techniques, to accomplish the expected results that are in compliance with the principles of a particular problem domain. Hence, the conceptual model is in accordance with the syntactical and semantical specifications of the foundational OntoUML [7]. Furthermore, it is built upon the well-founded

REA accounting model of McCarthy [8]. Figure 1.2 represents the applied search process as part of this thesis.

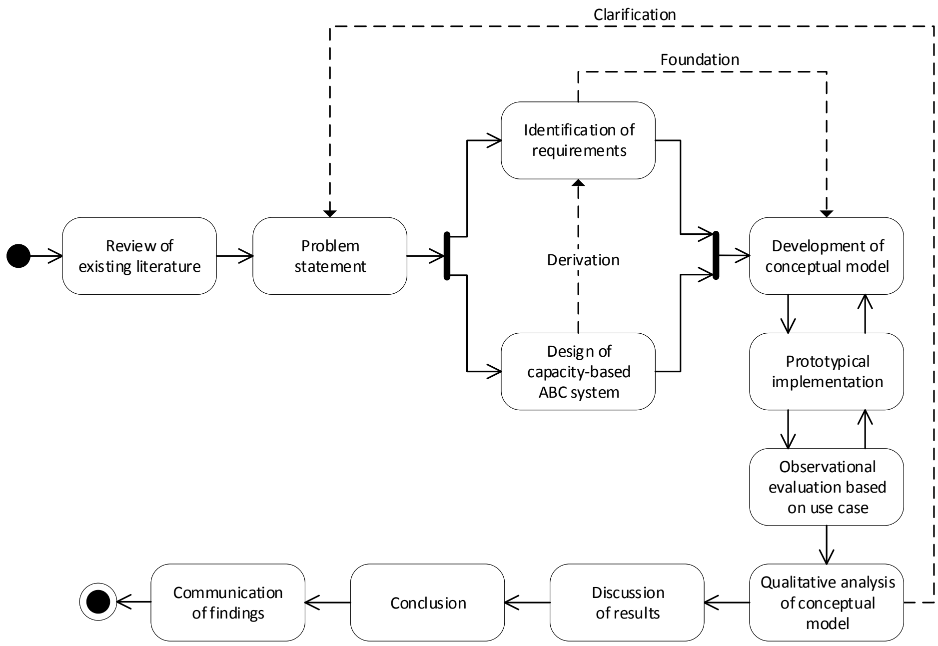


Figure 1.2: Design science search process of this thesis

Guideline 7: Communication of Research The findings of this diploma thesis are communicated in two ways. On the one hand, there is the written part of this thesis. On the other hand, there is that part of the thesis that is intended for the presentation of the results that will take place during the 'Seminar for Master Students' at the Vienna University of Technology. The audience of this seminar is mainly composed of students of Business Informatics. Thus, it is ensured that the findings of this thesis are presented to an technology-oriented and management-oriented audience.

1.5 Structure of the Work

This thesis is composed of further six chapters. Due to practical considerations, there is no strict separation of theoretical background and practical parts among the different chapters. Thus, all chapters of this paper include both theoretical and practical paragraphs.

In Chapter 2 and Chapter 3, the design of the capacity-based ABC system is discussed. Thereby, the requirements concerning its ontological peculiarities are identified and formulated in order to facilitate further proceedings of conceptual modeling. For illustrative purposes, the fictitious data set of the case study is applied.

Chapter 2 is concerned with the design of an ABC framework, which forms the first part of developing the capacity-based ABC system. Thus, the theoretical foundations of ABC are addressed and investigated in regard to the purposes of this thesis.

Chapter 3 is engaged with the second part regarding the development of the capacity-based ABC system, in which the incorporation of flexible budgeting is addressed. Furthermore, the arise of a death spiral in a simple ABC system is demonstrated.

Chapter 4 is concerned with the conceptual modeling of the designed capacity-based ABC system by using the OntoUML. Thereby, the previously identified requirements regarding the ontology of this system are taken into account. Since the conceptual model is developed as an extension of the REA accounting model, this chapter discusses related work concerning the REA and OntoREA accounting model.

The purpose of Chapter 5 is twofold: On the one hand, it deals with the prototypical implementation of the designed capacity-based ABC system in the course of a case study. On the other hand, this chapter addresses the evaluation of the conceptual model.

Related work is introduced in Chapter 6 with focus on different product costing systems and recent research in ODCM techniques.

Chapter 7 provides a summary of the main points of this thesis. Furthermore, it includes a critical discussion of the findings of this paper as well as a comparison with related work.

CHAPTER 2

Design of ABC Framework

2.1 Introduction to ABC

Activity-Based Costing (ABC) can be traced back to an empirical study of Miller and Vollmann [11] published in 1985. This study pointed out that the proportion of overhead expenses in the US industry had been steadily increased from 1855 to 1975. Findings of their work revealed that when competition was increased, the focus of managers shifted away from the efficient use of direct labor and machines to the need of more accurate information about the costs of outputs[1]. Traditional cost systems were primarily used for financial reporting but they were not able to provide cost information of outputs in a way that is appropriate for decision-making. Due to inadequacies when using cost information of traditional systems for decision-making, ABC has been emerged in the mid-1980s through contributions of Kaplan, Johnson, and Cooper [12] [13].

ABC systems enable overhead expenses to be assigned, first to activities and processes, and then to outputs. While traditional systems measure costs using volume-driven allocation bases, such as direct labor or machine hours, to assign operational expenses to outputs. It is obvious that not all of the resource demands by the outputs are proportional to the volume of units produced. As a result, traditional systems do not measure the costs of resources used accurately. Cooper and Kaplan [14] introduced an important distinction between activity-based measurement of resources used and traditional financial measurement of resources supplied. The underlying concepts of this distinction are shown in the following equation [6]:

$$\begin{array}{c}\text{Costs of Resources}\\ \text{Supplied}\end{array} = \begin{array}{c}\text{Costs of Resources}\\ \text{Used}\end{array} + \begin{array}{c}\text{Costs of Unused}\\ \text{Capacity}\end{array} \tag{2.1}$$

[1] The term 'outputs' is referring to cost objects e.g., products, services, and customers.

Periodic financial statements measure the costs of resources supplied to enable activities, which are specified at the left-hand-side of Equation 2.1. Whereas the expenses charged to products of ABC systems measure the costs of resources used by activities, which are referred to the first term of the right-hand-side at Equation 2.1. The difference between these measurements represents the costs of unused capacity, or in other words, the portion of costs of resources supplied is de facto not used for operational activities [6].

According to Kaplan [15] the development of cost and performance measurement systems can be described by four sequential stages (cf. Figure 2.1). Traditional cost systems with focus on financial reporting standards are corresponding to Stage II systems at this classification. Stage III systems are typically consisting out of a traditional system for financial reporting, one or more ABC systems for an accurate measurement of costs, and an operational feedback system for performance management. Typically, all systems of Stage III are built as stand-alone systems that are linked by sharing of databases. However, a fully integrated Management Information System (MIS) is usually located at Stage IV of the 'Four-Stage Model of Cost System Design', which has been introduced by Kaplan and Cooper [16].

	Stage I Systems *Broken*	**Stage II Systems** *Financial Reporting–Driven*	**Stage III Systems** *Specialized*	**Stage IV Systems** *Integrated*
Data Quality	• Many errors • Large variances	• No surprises • Meets audit standards	• Shared data-bases • Stand-alone systems • Informal linkages	• Fully linked databases and systems
External Financial Reporting	• Inadequate	• Tailored to financial reporting needs	• Stage II system maintained	• Financial reporting systems
Product/ Customer Costs	• Inadequate	• Inaccurate • Hidden costs and profits	• Several stand-alone ABC systems	• Integrated ABM systems
Operational and Strategic Control	• Inadequate	• Limited feedback • Delayed feedback	• Several stand-alone performance measurement systems	• Operational and strategic performance measurement systems

Figure 2.1: Four-Stage Model of Cost System Design [16]

The main objective of this thesis is to provide a conceptual model of an ABC system for flexible budgeting that is characterized by Kaplan's capacity-based ABC approach.

The basic idea behind this conceptual model is to facilitate the understanding and implementation of such an ABC system no matter whether it is used for building a stand-alone system (Stage III) or integration into an existing MIS (Stage IV). With respect to literature, the development process of an ABC system is described by four sequential steps [16]:

1. **Identification of Activities**
   Initially, when developing an ABC system the important activities of an organization must be identified. The identification of activities comes along with the construction of an activity dictionary that includes all major activities performed in an organization. The number of identified activities depends on the purpose of the model as well as on the size and complexity of the organization. As a rule of thumb, activities that use less than 5% of individual's time or resource's capacity can be ignored. This will help avoiding the inclusion of too much activities that can be both expensive and confusing.

2. **Determination of Activity Expenses**
   Typically, organizations spend money on resources that are required for performing operational activities. ABC systems assign resource expenses to activities based on resource cost drivers. Therefore, the expenses of general ledger accounts need to be aggregated according to their resource types first.

3. **Identification of Cost Objects**
   The aim of this step is to answer the question, why an organization is performing activities. Obviously, organizations need activities to design, build, and deliver products and services to their customers. Even if this step is quite simple, practitioners often skip it when focusing solely on the process efficiency. However, it is essential to check whether those activities or processes are worth doing at all.

4. **Selection of Activity Cost Drivers**
   The selection of an activity cost driver usually is based on a subjective trade-off between accuracy and cost of measurement. Table 2.1 exhibits the distinction of different types of activity cost drivers within existing literature.

Activity Cost Driver Type	**Measurement**	**Accuracy**	**Costs**	**Example**
Transaction	Number of activity runs performed	+	+	Setups
Duration	Amount of time required	++	++	Setup hours
Intensity	Direct charge of resources used	+++	+++	Actual cost per setup

Table 2.1: Different types of activity cost drivers based on [16]

The development of an ABC system for flexible budgeting, which is established on the capacity-based ABC approach with committed and flexible resources of Kaplan [6], is investigated in the upcoming sections of Chapter 2 and Chapter 3. Furthermore, the constructed data set of the case study is introduced during development of the ABC system, and it is consequently used to illustrate the workings of that system. Simultaneously, the ontological peculiarities of the ABC system to be developed are identified and thus the requirements for conceptual modeling are derived.

2.2 Identification of Activities

The first stage of developing an ABC system is taken by the identification of activities. The theoretical background of this stage has already been briefly addressed in Section 2.1. Since activities are the core of ABC, the identification of them is crucial for developing an efficient ABC system. Further details regarding the identification of activities are provided through scientific elaborations of Kaplan [16].

As mentioned previously, a fictitious sample data set has been constructed for the case study demonstration of this thesis. Furthermore, it is utilized for illustration purposes during the investigations of flexible budgeting in an ABC framework. The data set is composed of production data from the Slot Car Manufacturing Ltd. which is a company for the production of slot cars. There are five required activities in the Slot Car Manufacturing Ltd. concerning the production of slot cars (cf. Table 2.2). For the sake of simplicity, these activities are considered as elementary, which means there are no superordinate or subordinate activities. An activity includes the following attributes: *Activity ID*, *Name* and *Description*. In addition, there is an attribute *Index i* that is required for specification of formulas later in this chapter.

Activities			
Activity ID	***Name***	***Description***	***Index i***
10	Staging	Provide materials according to picking list	1
20	Setting up	Setting up of the manufacturing machines	2
30	Machining	Production of the Drive Unit	3
40	Assembling	Assemble Drive Unit, Front Unit, Undercarriage	4
50	Inspection	Quality inspection of the finished good	5

Table 2.2: Activities of the Slot Car Manufacturing Ltd.

Since the conceptual model to be developed is an extension of the REA accounting model, the requirements identification is taken into account the existing REA accounting model. The Requirement 1.1 is identified regarding the involvement of activities because the REA accounting model does not include activities at all. As the conceptual model focuses on the ontological peculiarities of a system, attributes that are less relevant such as *Name* and *Description* can be neglected.

Requirement 1.1 The conceptual model shall be able to the depict activities with an unique identifier attribute.

2.3 Resource Typification

The DIN EN-62264 (ISO IEC-62264), which is also called Enterprise Control System Integration (ECSI) standard, provides a profound solution to a standardized resource typification. It focuses on the seamless integration of management and productive systems within certain businesses. To facilitate its readability through a content-related separation, the ECSI standard has been divided into different parts. Within this paper, only the first two parts of this standard are addressed. The first part [17] is concerned with models and terminology, and the second part [18] is related to objects and their attributes in terms of enterprise-control system integration.

Resource Types

With regard to the definition of resources types, the ECSI provides a profound description of common resource types by means of object models. These models give prevailing information about the different resource types and their application in the business process segment. Furthermore, the particular attention is on the attributes of those resources. For the purposes of this thesis, the resource typification can be almost directly derived from the ECSI standard [18]:

Material (MAT) resources include raw materials, finished goods, consumables, and intermediate materials.

Personnel (PERS) resources typically include all resources that are related to human capital.

Equipment (TECH) resources may correspond to areas, production units, work cells, or storage zones. Physical pieces of equipment are represented as physical assets, which can be production machines, conveyors, sensors, and so on. In this thesis, all physical assets are associated to the equipment (TECH) resource type.

As illustrated in Table 2.3, the resources of the Slot Car Manufacturing Ltd. have been typified in conformity with the ECSI standard [18]. The attribute *Index j* is used for the description of formulas within this paper and is therefore not relevant for conceptual modeling. In terms of providing a conceptual model that captures the ontology of an underlying system, it is reasonable to focus merely on the ontological peculiarities of that system. In order to provide a solution-independent conceptual model that focuses on the ontology of a system without taking into account company-related characteristics, the miscellaneous (MISC) resource type is not considered explicitly in the conceptual model. However, it is taken into account later when building the prototypical implementation. Although the REA accounting model already includes an element for the depiction of economic resources, it needs to be extended in order to ensure a resource typification in conformity with the ECSI standard. With respect to aforementioned considerations, the Requirement 2.1 is identified and formulated.

Requirement 2.1 The conceptual model shall include a resource typification in conformity with the Enterprise Control System Integration (ECSI) standard (MAT/PERS/TECH).

Resources		
Resource Type	***Name***	***Index j***
MAT	Material	1
PERS	Personnel	2
TECH	Equipment	3
MISC	Miscellaneous	4

Table 2.3: Resources of the Slot Car Manufacturing Ltd.

Finished Goods

The Slot Car Manufacturing Ltd. produces two kinds of finished goods (cf. Table 2.4). A finished good includes the attributes: *Finished Good ID*, *Name*, and *Index k*. As mentioned before, the index attribute is solely utilized for specifying the indices of formulas. Consequently, such index attributes are not considered for conceptual modeling. Furthermore, the attribute *Name* is neglected because it does not provide essential information in terms of ontology-driven conceptual modeling. In order to ensure that the finished goods are covered by the resource typification of the conceptual model, the Requirement 2.2 is derived.

Requirement 2.2 The resource typification of the conceptual model must consider the mapping of finished goods with an unique identifier attribute.

Finished Goods		
Finished Good ID	***Name***	***Index k***
120	Slot Car X1	1
140	Slot Car Z2	2

Table 2.4: Finished goods of the Slot Car Manufacturing Ltd.

Bill of Material (BOM)

In principle, each finished good is composed of subcomponents such as raw or intermediate materials, which are required for the manufacturing process. According to the ECSI standard [17], a Bill of Material (BOM) is defined as a list that contains all required material resources and their quantities for the manufacturing of a certain finished good. Those material resources (MAT) can be raw materials, intermediate materials, assembly parts, components, and consumables. Typically, a BOM does not contain any information about where the materials are used or when they are needed. The BOM of the Slot Car Manufacturing Ltd. is illustrated in Table 2.5. It contains a breakdown of the required raw materials for each finished good. Thereby, the BOM involves the following attributes: *Finished Good ID*, *Item Level*, *Material ID*, *Name*, *Quantity*, *Unit*, and *Unit Cost*.

Bill of Material (BOM)						
Finished Good ID	***Item Level***	***Material ID***	***Name***	***Quantity***	***Unit***	***Unit Cost (UC_k)***
120	0	120-1000	Slot Car X1	1.00	PC	$300.00
	1	120-1100	Body X-Series	1.00	PC	$162.00
	2	120-1110	Front Unit Blue	1.00	PC	$70.00
	2	120-1120	Drive Unit X1	1.00	PC	$92.00
	3	120-1121	Motor E500	1.00	PC	$85.50
	3	100-1001	Hexagon Screw	0.25	KG	$4.00
	3	100-1002	Hexagon Nut	0.65	KG	$4.00
	3	100-1003	Washer	0.10	KG	$4.00
	3	100-1004	Adhesives	0.25	L	$10.00
	1	120-1200	Undercarriage X-Series	1.00	PC	$138.00
140	0	140-1000	Slot Car Z2	1.00	PC	$520.00
	1	140-1100	Body Z-Series	1.00	PC	$303.00
	2	140-1110	Front Unit Red	1.00	PC	$100.00
	2	140-1120	Drive Unit Z2	1.00	PC	$203.00
	3	140-1121	Motor E700	1.00	PC	$196.50
	3	100-1001	Hexagon Screw	0.25	KG	$4.00
	3	100-1002	Hexagon Nut	0.65	KG	$4.00
	3	100-1003	Washer	0.10	KG	$4.00
	3	100-1004	Adhesives	0.25	L	$10.00
	1	140-1200	Undercarriage Z-Series	1.00	PC	$217.00

Table 2.5: Bill of material (BOM) of the Slot Car Manufacturing Ltd.

In many cases, a BOM includes recursive relationships among listed material resources as in case of this data set. For expressing these recursive relationships of the BOM that is shown in Table 2.5, the attribute *Item Level* is utilized. Figure 2.2 shows a visual representation of such recursive structure for the finished good with *Finished Good ID* of '120'. The unit costs are solely predetermined for basic materials without subcomponents. In contrast, when a material resource is composed of subcomponents its unit costs are computed using the unit costs of its subcomponents. Obviously, the quantities must be taken into account at this procedure.

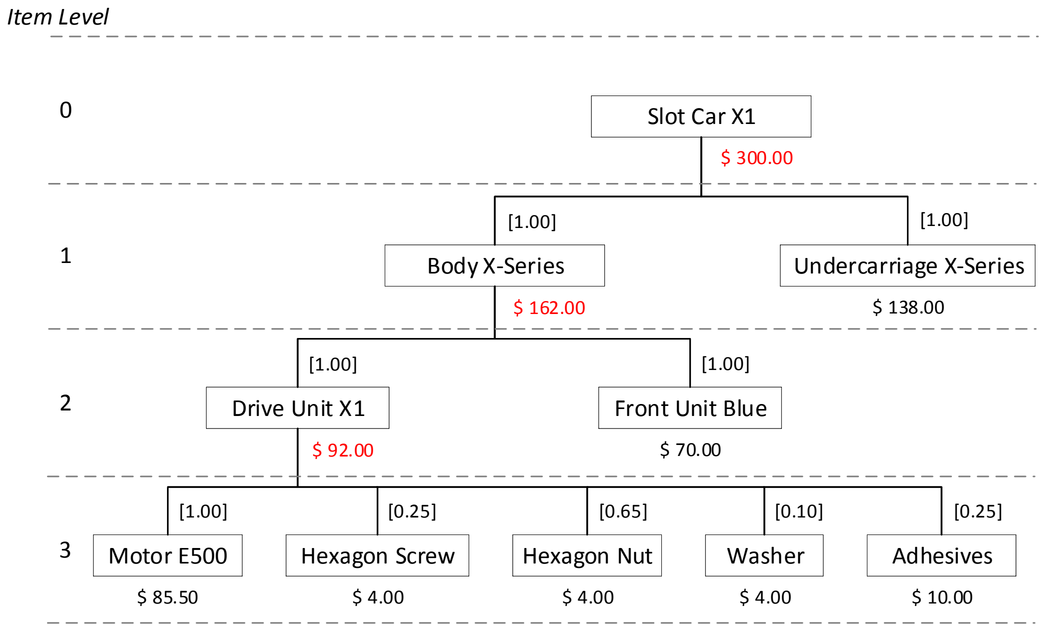


Figure 2.2: Representation of the recursive relationships in a Bill of Material (BOM)

With respect to a comprehensive resource typification, the essential characteristics of a BOM must be considered too. Therefore, the following requirements are derived for conceptual modeling:

Requirement 2.3 The resource typification of the conceptual model must allow a distinction between finished goods and raw materials. In case of raw materials, an additional attribute for the unit costs must be considered.

Requirement 2.4 The resource typification of the conceptual model shall ensure the correct integration of the Bill of Material (BOM) associated with the required quantities of the material resources.

Requirement 2.5 The recursive relationships among raw materials shall be visible in the conceptual model.

Routing (Working Plan)

The ECSI standard [17] defines domains such as corporate, operation, and management by means of hierarchical models. They are referring to functional hierarchy, role-based equipment hierarchy, and equipment hierarchy of the physical assets. Different levels are used for describing the functional hierarchy in which the routing (working plan) belongs to the third level. Subsequently, those different levels of the functional hierarchy are described according to their functions and times frames based on the definition of the ECSI standard [17]:

Level 0 defines the utilized physical processes.

Level 1 defines the activities for measuring and adjusting of physical processes. Typically, this level is associated with working in a time frame of seconds and faster.

Level 2 defines the activities for monitoring and steering of physical processes. The time frame of this level corresponds to hours, minutes, seconds, and faster.

Level 3 defines the activities of a routing (working plan) for the manufacturing of products. It involves activities for maintaining of the records as well as for the coordination of processes. Therefore, this level works in a time frame of days, shifts, hours, minutes, and seconds.

Level 4 defines the activities of corporate management for a manufacturing company. It comprises the preparation of a plan and the determination of an inventory. Furthermore, it ensures that required materials are available on time at the right place within manufacturing. This level is usually working in a time frame of months, weeks, and days.

The routing of the Slot Car Manufacturing Ltd. is illustrated in Table 2.6. It is composed of the following attributes: *Finished Good ID*, *Activity ID*, *Activity Name*, *Std. Prod. Coef. PERS*, and *Std. Prod. Coef. TECH*. The standard production coefficients (Std. Prod. Coef.) of the capacity resources (PERS & TECH) are used for determining the required proportion of capacity resources when performing a certain activity once. Since the routing (working plan) addresses the determination of capacity resources, it must be considered for resource typification as well. Consequently, the Requirement 2.6 is identified and formulated.

Requirement 2.6 The resource typification of the conceptual model shall ensure the correct inclusion of the routing (working plan) regarding the standard production coefficients of capacity resources (PERS & TECH).

Routing (Working Plan)				
Finished Good ID	***Activity ID***	***Activity Name***	***Std. Prod. Coef. PERS*** ($SPC^{PERS}{}_{k,i}$)	***Std. Prod. Coef. TECH*** ($SPC^{TECH}{}_{k,i}$)
120, 140	10	Staging	0.005	0.010
	20	Setting up	0.030	0.075
	30	Machining	0.080	0.275
	40	Assembling	0.275	0.090
	50	Inspection	0.110	0.050

Table 2.6: Routing (working plan) of the Slot Car Manufacturing Ltd.

2.4 Integration of General Ledger Accounts

Financial reporting systems are usually aggregating operating expenses according to their corresponding general ledger accounts. As a result, an ABC system must be able to process the expense data that are provided through financial reporting systems. Thus, the general ledger accounts of accounting systems have to be taken into account for the development of an ABC system.

Chart of Accounts (COA)

The Chart of Accounts (COA) serves as a foundation for the integration of general ledger accounts into accounting systems. By default, a COA contains general ledger accounts from the types of asset, liability, revenue, expense, or equity. With respect to the case study data set, the COA has been established on the basis of the Austrian uniform scheme of accounts [19]. Table 2.7 shows the COA of the Slot Car Manufacturing Ltd. that is comprised of the following attributes: *Account Type*, *Account ID*, and *Name*.

Chart of Accounts (COA)		
Account Type	***Account ID***	***Name***
Asset	040	Equipment (Anlagen und Maschinen)
	110	Materials (Bezogene Ressourcen)
	150	Finished goods (Fertige Erzeugnisse)
	200	Receivables (Lieferforderungen)
	250	Input VAT (Vorsteuer)
	270	Cash (Kassa)
	280	Bank (Bank)
Liability	330	Liabilities (Lieferverbindlichkeiten)
	350	VAT (Umsatzsteuer)
	352	Tax payable (Zahllast)
Revenue	400	Revenue account (Umsatzerloese)
	450	Inventory variation (Bestandsveraenderung)
Expense	510	Consumption materials (Materialaufwand)
	699	Discharge personnel (Personalaufwand)
	700	Depreciation (Abschreibung)
	709	Operating expenses (Betriebsaufwand)
	720	Maintenance costs (Instandhaltungskosten)
	798	Administrative expenses (Verwaltungsaufwand)
Equity	900	Equity (Eigenkapital)
	980	Opening balance sheet (Eroeffnungsbilanzkonto)
	985	Closing balance sheet (Schlussbilanzkonto)

Table 2.7: Chart of accounts (COA) of the Slot Car Manufacturing Ltd.

In regard to integration of ledger accounts, the REA accounting model needs to be extended. Therefore, the Requirement 3.1 is derived.

Requirement 3.1 The conceptual model shall ensure the integration of general ledger accounts based on the Austrian uniform scheme of accounts with an emphasis on the account type and the unique identifier.

Expense Accounts

In particular, the focus of this section is on the integration of expense accounts that are serving as a source when providing expense data to an ABC system. To ensure a clear distinction among expenses regarding further processing, the expense accounts must be refined by two additional attributes. On the one hand, an attribute for distinguishing between direct and overhead expenses is mandatory in order to obtain the overhead expenses for allocation process of the ABC system. And on the other hand, an attribute of the resource type is required, so that the aggregation of general ledger expenses according to their resource types is enabled.

The expense accounts of the Slot Car Manufacturing Ltd. are shown in Table 2.8 with the additional specified attributes: *Resource Type*, *Cost Type*, and *Index l*. Since the expense accounts require additional information than other general ledger accounts, the Requirement 3.2 is identified and formulated.

Requirement 3.2 The conceptual model shall ensure a proper mapping of expense accounts by considering additional attributes for cost and resource type.

Expense Accounts				
Account ID	***Name***	***Resource Type***	***Cost Type***	***Index l***
510	Consumption materials (Materialaufwand)	MAT	Direct	1
699	Discharge personnel (Personalaufwand)	PERS	Overhead	2
700	Depreciation (Abschreibung)	TECH	Overhead	3
709	Operating expenses (Betriebsaufwand)	TECH	Overhead	4
720	Maintenance costs (Instandhaltungskosten)	MISC	Overhead	5
798	Administrative expenses (Verwaltungsaufwand)	MISC	Overhead	6

Table 2.8: Expense accounts structured according resource and cost type

2.5 Allocation of Expenses

Traditional cost systems allocate overhead expenses to production cost centers using arbitrary allocation bases, such as direct labor hours or headcount. This often may result in an inaccurate allocation of overhead expenses. In contrast, ABC systems aggregate overhead expenses first by their resource type, and then they map the resource expenses to activities via resource cost drivers. Subsequently, the activity expenses are allocated to cost objects based on activity cost drivers. Figure 2.3 illustrates those different workings of traditional cost systems and ABC systems regarding the allocation of expenses [16]. With respect to the case study data set, the expense allocation of the Slot Car Manufacturing Ltd. is illustrated in Figure 2.4.

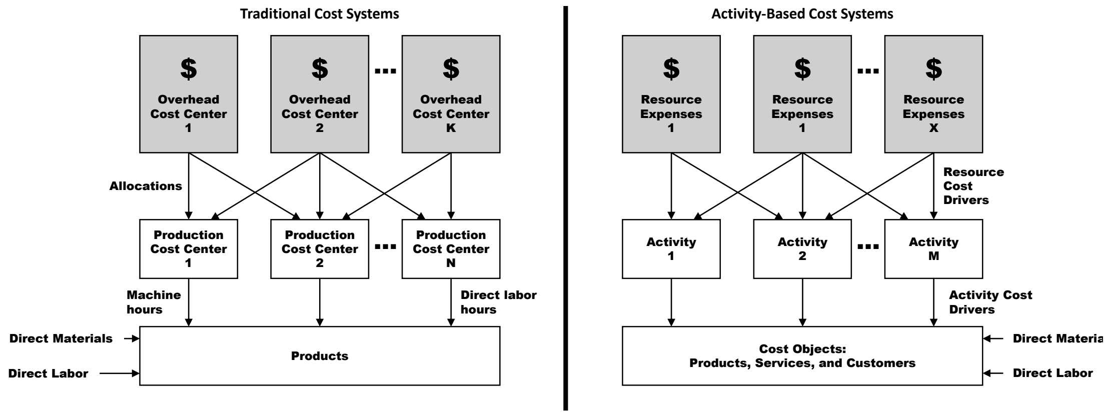


Figure 2.3: Different workings regarding the allocation of expenses adapted from [16]

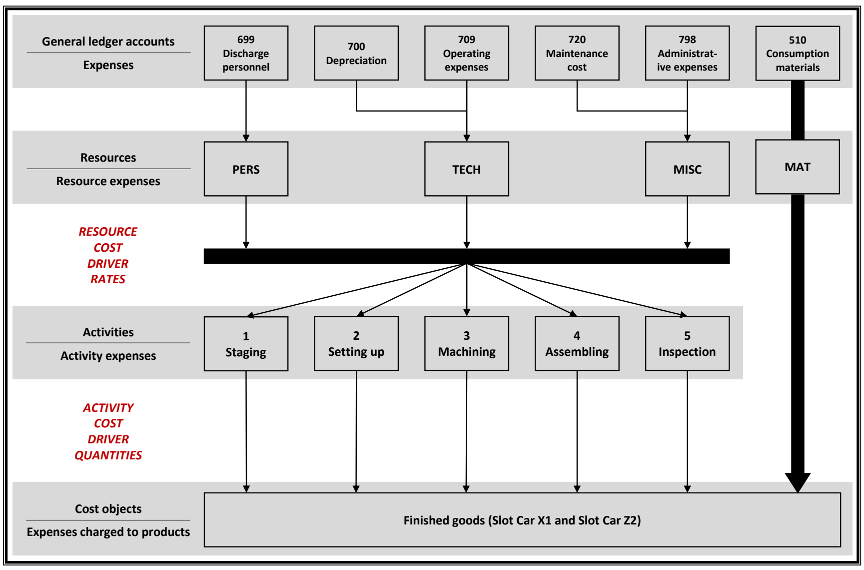


Figure 2.4: Allocation of expenses of the Slot Car Manufacturing Ltd.

Apparently, the selection of cost drivers is crucial for proper working of an ABC system. First, resource cost driver rates are used for the allocation of resource expenses to activities. Second, the allocation of activity expenses to cost objects is based on activity cost driver quantities. Within this section, the determination of both cost drivers is mainly discussed in terms of the case study example.

Resource Cost Driver Rates

Due to practical constraints, this paper does not engage with mechanics of the selection and estimation of resource cost drivers in every detail. In literature, these procedures are already reasonably well documented [16]. Even if the selection and estimation of resource cost drivers are absolutely crucial in practice, they are not that important for the purposes of this thesis. The reason for this is that the case study is based on a fictitious data set, which has been constructed solely for demonstration purposes.

The Slot Car Manufacturing Ltd. is using resource cost driver rates for the allocation of resource expenses to activities. For the capacity resources, these rates are calculated based on the standard production coefficients of the routing (working plan). Whereas the rate for other resources is computed by assigning an equal amount to each activity. Equation 2.2 illustrates the formulas that are applied for those calculations.

$$RCD_{\mathrm{i,j}} = \begin{cases} \sum_k SPC^{\mathrm{PERS}}{}_{\mathrm{k,i}}, & \text{if } j = 2. \\ \sum_k SPC^{\mathrm{TECH}}{}_{\mathrm{k,i}}, & \text{if } j = 3. \\ \frac{1}{n} = \frac{1}{5} = 0.20, & \text{otherwise.} \end{cases} \tag{2.2}$$

Of course the Equation 2.3 must hold for all indices j, to ensure, that all available resources have been assigned to activities.

$$\sum_i RCD_{\mathrm{i,j}} = 1.00 \tag{2.3}$$

Table 2.9 shows the resource cost drivers of the Slot Manufacturing Ltd. with the computed resource cost driver rates based on previous formulas. A resource cost driver is composed of the following attributes: *Activity ID*, *Activity Name*, *Resource Type*, and *Resource Cost Driver Rate*. The allocation of resource expenses to activities using resource cost drivers is an essential part of the ABC system. Consequently, the Requirement 1.2 is identified and formulated.

Requirement 1.2 The conceptual model shall enable the mediation between resources and activities using resource cost drivers. In case of resource cost drivers, the following attributes must be considered: resource type, cost driver quantity, and unique identifier of activities.

Resource Cost Drivers			
Activity ID	***Activity Name***	***Resource Type***	***Resource Cost Driver Rate ($RCD_{i,j}$)***
10	Staging	PERS	0.01
		TECH	0.02
		MISC	0.20
20	Setting up	PERS	0.06
		TECH	0.15
		MISC	0.20
30	Machining	PERS	0.16
		TECH	0.55
		MISC	0.20
40	Assembling	PERS	0.55
		TECH	0.18
		MISC	0.20
50	Inspection	PERS	0.22
		TECH	0.10
		MISC	0.20

Table 2.9: Resource cost driver rates of the Slot Car Manufacturing Ltd.

Activity Cost Driver Quantities

Activity cost drivers are corresponding to quantitative measures of outputs behind certain activities. Therefore, they are used for establishing a linkage between activities and cost objects. As already mentioned, the selection of activity cost drivers is a subjective trade-off between costs of measurement and accuracy [16].

The activity cost drivers of the Slot Car Manufacturing Ltd. are illustrated in Table 2.10. An activity cost driver includes the following attributes: *Finished Good ID*, *Activity ID*, *Activity Name*, *Activity Cost Driver*, and *Activity Cost Driver Quantity.* The determination of activity cost drivers is the final step when developing the ABC system. In regard to conceptual modeling, the Requirement 1.3 is derived.

Requirement 1.3 The conceptual model shall enable the mediation between finished goods and activities using activity cost drivers. In case of activity cost drivers, the following attributes must be considered: cost driver quantity, unique identifiers of finished goods and activities.

Activity Cost Drivers				
Finished Good ID	***Activity ID***	***Activity Name***	***Activity Cost Driver***	***Activity Cost Driver Quantity ($ACD_{k,i}$)***
120	10	Staging	Number of items	10.00
	20	Setting up	Setups	0.10
	30	Machining	Machine hours	3.00
	40	Assembling	Labor hours	4.00
	50	Inspection	Proportion of inspections	0.25
140	10	Staging	Number of items	10.00
	20	Setting up	Setups	0.25
	30	Machining	Machine hours	4.00
	40	Assembling	Labor hours	6.00
	50	Inspection	Proportion of inspections	1.00

Table 2.10: Activity cost drivers of the Slot Car Manufacturing Ltd.

CHAPTER 3

Incorporating Flexible Budgeting with ABC

3.1 Introduction to Flexible Budgeting

In standard costing, the expenses for an upcoming planning period are planned at the beginning (ex ante). After that the planned expenses are compared to the realized expenses, which are obtained at the end of that planning period (ex post). Thus, the cost planning and control are occurring at different times. Typically, the planned expenses are referred as 'budgeted expenses', and the realized expenses are referred as 'actual expenses'. In order to ensure that these expenses are comparable with each other, both are determined based on the actual activity levels. Budgeted expenses are usually determined using a cost function that incorporates the corresponding activity level. In terms of cost control, that function is evaluated at the actual activity level in order to ensure the comparability of budgeted and actual expenses [20].

Flexible budgeting has been emerged on the basis of standard costing by adding a differentiation between committed and flexible proportions of the budgeted expenses. Committed expenses are assumed as definitely assigned, which holds true in general at least for short-term periods. On the other hand, flexible expenses can be adjusted to occurring activity levels at any time of a planning period. The fundamental idea of flexible budgeting is an intensification of cost control [21]. So, the budgeted expenses are better adjustable to fluctuations of activity levels because they are divided into committed and flexible parts. Furthermore, the budgeted expenses are compared with the actual expenses in terms of cost control. Thereby, the detected variances of the cost control are analyzed based on three different causes [20]:

Execution cause
The process which leads up to realization of results is wrong. Corrective actions regarding the execution activity are taken for rectifying the process functionality.

Planning cause
At the end of a planning period, the budgeting turns out to be wrong. Adaptive measures according to planning activities are required in order to avoid such errors in upcoming planning periods.

Measurement cause
An incorrect measurement of actual expenses is the reason for this kind of cause. Adaptive actions regarding the control activities are required to ensure that actual expenses are measured correctly from now on.

Kaplan [6] investigated the basic principles for performing flexible budgeting within an Activity-Based Costing (ABC) framework. So, the following three ABC approaches have been proposed and discussed in terms of flexible budgeting: simple ABC, capacity-based ABC with committed expenses, and capacity-based ABC with flexible and committed resources. With regard to the findings of Kaplan's work, the main focus of this chapter is on extending the developed ABC system of Chapter 2 towards flexible budgeting. Therefore, the upcoming three sections of this chapter are intended to discuss rather general characteristics of flexible budgeting in an ABC framework without focusing on a specific ABC approach. Whereas the Section 3.5 is concerned with emphasizing the different operating principles among the three ABC approaches of Kaplan. Finally, in Section 3.6 an arising death spiral is demonstrated when using a simple ABC approach for flexible budgeting.

Since this chapter forms the second part of the development of a capacity-based ABC system for flexible budgeting, the requirements for conceptual modeling are derived in the same way as before. Similarly, the constructed data set of the case study is used to illustrate the development of the ABC system. As already mentioned earlier, the developed ABC system is established on a capacity-based ABC approach with committed and flexible resources. Therefore, the simple ABC as well as the capacity-based ABC approach with committed expenses are only addressed for comparative purposes but not considered for conceptual modeling.

Flexible budgeting is based on repetitive tasks that create transaction-based data for each planning period. As a result, the planning period is the root element of a certain flexible budgeting execution and therefore linked to all other components. In terms of conceptual modeling, the planning periods must be considered explicitly. Therefore, the Requirement 4.1 is derived.

Requirement 4.1 The conceptual model shall include the explicit mapping of planning periods with an unique identifier attribute.

3.2 Estimation of Parameters

A considerable amount of literature has already been published on cost planning. Most of these studies are distinguishing between two fundamental concepts of cost planning: On the one hand, there are the statistical cost planning methods that are requiring historical data of passed planning periods. On the other hand, there are analytical cost planning methods, where historical data of the past are not considered. In particular, statistical cost planning methods require historical data of expenses and volumes, as a starting point for their cost planning. As a rule of thumb, historical data of at least twelve months must exist in order to overcome seasonal fluctuations and to achieve reasonable results when using statistical methods. In contrast to statistical approaches, analytical cost planning methods are determining the expenses and volumes via technical-economical analyses. With regard to analytical approaches, the following methods are further differentiated: calculations, measurements, functional analysis, estimates, empirical values, and internal as well as external comparisons. Further information on cost planning and its methods is sufficiently provided by existing literature, such as books of Kilger et al. [21] or Schwaiger [20]. With respect to the case study data set of this thesis, an expert estimation is applied for estimating the parameters of flexible budgeting.

Production Volumes of Finished Goods

The production volumes of the Slot Car Manufacturing Ltd. are estimated in Table 3.1. Thereby, the following two parameters are determined for each finished good through an expert estimation: *Capacity Volume* and *Budgeted Volume*. The *Actual Volume* is realized at the end of a planning period. In regard to conceptual modeling, the Requirement 4.2 is identified and formulated.

Requirement 4.2 The conceptual model shall be able to depict the production volumes of finished goods with an emphasis on their unique identifiers and quantities.

Production Volumes of Finished Goods				
Planning Period ID	***Finished Good ID***	***Capacity Volume ($Q^{Cap}{}_k$)***	***Budgeted Volume ($Q^{Bud}{}_k$)***	***Actual Volume ($Q^{Act}{}_k$)***
0	120	500.00	480.00	450.00
	140	200.00	195.00	185.00

Table 3.1: Expert estimation of finished good quantities

Operating Expenses of General Ledger Accounts

The separation of the committed and flexible proportions of operating expenses is determined using factors of expense variability, which are called 'variators'. These factors are assuming the value 0.00 for entirely committed expenses, and they are set to 1.00 in case of solely flexible expenses. In practice, such variators usually adopt a value that is located between the aforementioned thresholds [21]. The estimated operating expenses of the Slot Car Manufacturing Ltd. with their corresponding variators are illustrated in Table 3.2. The parameters *Budgeted Expense* and *Variator* are both determined for each expense account of the general ledger through an expert estimation. Furthermore, the *Actual Expense* parameter is obtained at the end of a planning period from the financial reporting system. In regard to preceding considerations, the Requirement 4.3 for conceptual modeling is derived.

Requirement 4.3 The conceptual model shall ensure the correct mapping of operating expenses in correspondence with the expense accounts of the general ledger by considering the following attributes: unique identifier, amount of expense, and variator.

General Ledger Account Expenses						
Planning Period ID	***Cost Type***	***Account ID***	***Resource Type***	***Budgeted Expense*** ($E^{Bud}{}_{l,j}$)	***Variator*** ($V^{Led}{}_{l,j}$)	***Actual Expense*** ($E^{Act}{}_{l,j}$)
0	Direct	510	MAT	$245,400.00	1.00	$231,200.00
	Overhead	699	PERS	$320,000.00	0.30	$300,000.00
		700	TECH	$280,000.00	0.20	$275,000.00
		709	TECH	$55,000.00	0.20	$50,000.00
		720	MISC	$25,000.00	0.50	$15,000.00
		798	MISC	$80,000.00	0.50	$60,000.00
-	-	-	-	$760,000.00	-	$700,000.00

Table 3.2: Expert estimation of general ledger account expenses

3.3 Allocation to Cost Pools

Within this part, the cost allocation of Section 2.5 is implemented in terms of flexible budgeting. As a starting point, the general ledger expenses are aggregated by their resource types in order to obtain the resource expenses. Next, these resource expenses are allocated to the activities by using cost pools. Finally, the expenses of each activity are determined.

Resource Expenses

The first allocation stage of expenses according to cost pools is concerned with the aggregation of general ledger account expenses by their resource types. Therefore, the formulas of Equation 3.1 are used for computation. As a result of those calculations, the resources expenses are shown in Table 3.3.

$$RE^{\text{Bud}}{}_{\text{j}} = \sum_l E^{\text{Bud}}{}_{\text{l,j}}$$
$$RE^{\text{Act}}{}_{\text{j}} = \sum_l E^{\text{Act}}{}_{\text{l,j}} \tag{3.1}$$
$$V^{\text{Res}}{}_{\text{j}} = \frac{\sum_l E^{\text{Bud}}{}_{\text{l,j}} * V^{\text{Led}}{}_{\text{l,j}}}{\sum_l E^{\text{Bud}}{}_{\text{l,j}}}$$

Resource Expenses					
Planning Period ID	***Cost Type***	***Resource Type***	***Budgeted Resource Expense ($RE^{Bud}{}_j$)***	***Variator ($V^{Res}{}_j$)***	***Actual Resource Expense ($RE^{Act}{}_j$)***
0	Direct	MAT	$245,400.00	1.00	$231,200.00
	Overhead	PERS	$320,000.00	0.30	$300,000.00
		TECH	$335,000.00	0.20	$325,000.00
		MISC	$105,000.00	0.50	$75,000.00
-	-	-	$760,000.00	-	$700,000.00

Table 3.3: Computation of resource expenses

Activity Expenses

The second part of allocation to cost pools is related to the aggregation of resource expenses to activity expenses. In conformity with the cost allocation of Section 2.5, the resource cost driver rates of Table 2.9 are used for this procedure. The calculation of cost pool data is based on the formulas of Equation 3.2. Furthermore, the results of those calculations are presented in Table 3.4. Obviously, this step is trivial because the activity expenses are obtained through a simple aggregation of cost pool expenses according to their activities.

$$CPE^{\text{Bud}}{}_{\text{i,j}} = RE^{\text{Bud}}{}_{\text{j}} * RCD_{\text{i,j}}$$
$$CPE^{\text{Act}}{}_{\text{i,j}} = RE^{\text{Act}}{}_{\text{j}} * RCD_{\text{i,j}} \tag{3.2}$$
$$V^{\text{CP}}{}_{\text{i,j}} = V^{\text{Res}}{}_{\text{j}}$$

According to the developed capacity-based ABC system for flexible budgeting, there exist two kinds of data pools: cost pools and activity pools. Considering this property, the following requirements are identified in terms of conceptual modeling:

Requirement 5.1 The conceptual model shall include the explicit mapping of data pools with emphasis on the common attributes of cost and activity pools.

Requirement 5.2 The conceptual model must be able to depict the cost pools with focus on the attributes: resource type, variator, budgeted expense, and actual expense.

Cost Pools					
Planning Period ID	***Activity ID***	***Resource Type***	***Budgeted Cost Pool Expense ($CPE^{Bud}{}_{i,j}$)***	***Variator ($V^{CP}{}_{i,j}$)***	***Actual Cost Pool Expense ($CPE^{Act}{}_{i,j}$)***
0	10	PERS	$3,200.00	0.30	$3,000.00
		TECH	$6,700.00	0.20	$6,500.00
		MISC	$21,000.00	0.50	$15,000.00
	20	PERS	$19,200.00	0.30	$18,000.00
		TECH	$50,250.00	0.20	$48,750.00
		MISC	$21,000.00	0.50	$15,000.00
	30	PERS	$51,200.00	0.30	$48,000.00
		TECH	$184,250.00	0.20	$178,750.00
		MISC	$21,000.00	0.50	$15,000.00
	40	PERS	$176,000.00	0.30	$165,000.00
		TECH	$60,300.00	0.20	$58,500.00
		MISC	$21,000.00	0.50	$15,000.00
	50	PERS	$70,400.00	0.30	$66,000.00
		TECH	$33,500.00	0.20	$32,500.00
		MISC	$21,000.00	0.50	$15,000.00

Table 3.4: Allocation of resource expenses to cost pools

3.4 Computation of Activity Levels

The activity levels are computed based on the estimated production volumes of finished goods (cf. Table 3.1) and the activity cost drivers (cf. Table 2.10). Of course, the activity levels must be computed for each kind of volume, such as capacity volumes, budgeted volumes, and actual volumes. Equation 3.3 shows the computation of these activity levels by means of a mathematical expression. As a result, the computed activity levels are shown in Table 3.5.

$$
\begin{aligned}
AL^{\mathrm{Cap}}{}_{\mathrm{k,i}} &= Q^{\mathrm{Cap}}{}_{\mathrm{k}} * ACD_{\mathrm{k,i}} \\
AL^{\mathrm{Bud}}{}_{\mathrm{k,i}} &= Q^{\mathrm{Bud}}{}_{\mathrm{k}} * ACD_{\mathrm{k,i}} \\
AL^{\mathrm{Act}}{}_{\mathrm{k,i}} &= Q^{\mathrm{Act}}{}_{\mathrm{k}} * ACD_{\mathrm{k,i}}
\end{aligned} \tag{3.3}
$$

With respect to conceptual modeling, the Requirement 4.4 is derived regarding the mapping of activity levels.

Requirement 4.4 The conceptual model shall include the mapping of activity levels based on the extent of activity level and an unique identifier.

Activity Levels					
Planning Period ID	***Finished Good ID***	***Activity ID***	***Capacity Activity Level ($AL^{Cap}{}_{k,i}$)***	***Budgeted Activity Level ($AL^{Bud}{}_{k,i}$)***	***Actual Activity Level ($AL^{Act}{}_{k,i}$)***
0	120	10	5,000.00	4,800.00	4,500.00
		20	50.00	48.00	45.00
		30	1,500.00	1,440.00	1,350.00
		40	2,000.00	1,920.00	1,800.00
		50	125.00	120.00	112.50
	140	10	2,000.00	1,950.00	1,850.00
		20	50.00	48.75	46.25
		30	800.00	780.00	740.00
		40	1,200.00	1,170.00	1,110.00
		50	200.00	195.00	185.00

Table 3.5: Computation of activity levels

3.5 Allocation to Activity Pools

In this section, the different workings among the three ABC approaches of Kaplan [6] regarding flexible budgeting are discussed. As before, the data set of the case study is used for illustration purposes. Since the developed ABC system is characterized by the capacity-based ABC approach with committed and flexible resources only, the aspects of the other two approaches are not taken into account for conceptual modeling. However, these ABC approaches are also briefly addressed for comparative purposes.

Simple ABC

Within the simple ABC approach, the cost driver rates tend to fluctuate each period according to the fluctuations of anticipated activity levels. Typically, this may lead to so called 'death spirals' when the activity levels are falling faster than the operating expenses can be reduced [6]. Section 3.6 is concerned with demonstrating an arising death spiral in a simple ABC system, and how to overcome that issue by using capacity-based ABC systems. Equation 3.4 shows the applied formulas for the computation of activity expenses and activity levels. The activity expenses are computed by aggregating the cost pool expenses of Table 3.4. Analogically, the activity levels are computed by summing up the activity levels of Table 3.5 over the finished goods. In regard to the case study data set, the results of these calculations are shown in Table 3.6.

$$AE^{\text{Bud}}{}_{\text{i}} = \sum_j CPE^{\text{Bud}}{}_{\text{i,j}}$$

$$AE^{\text{Act}}{}_{\text{i}} = \sum_j CPE^{\text{Act}}{}_{\text{i,j}}$$

$$AL^{\text{Bud}}{}_{\text{i}} = \sum_k AL^{\text{Bud}}{}_{\text{k,i}} \tag{3.4}$$

$$AL^{\text{Bud}}{}_{\text{i}} = \sum_k AL^{\text{Act}}{}_{\text{k,i}}$$

Simple ABC: Activity Pools I					
Planning Period ID	***Activity ID***	***Budgeted Activity Expense ($AE^{Bud}{}_i$)***	***Actual Activity Expense ($AE^{Act}{}_i$)***	***Budgeted Activity Level ($AL^{Bud}{}_i$)***	***Actual Activity Level ($AL^{Bud}{}_i$)***
0	10	$30,900.00	$24,500.00	6,750.00	6,350.00
	20	$90,450.00	$81,750.00	96.75	91.25
	30	$256,450.00	$241,750.00	2,220.00	2,090.00
	40	$257,300.00	$238,500.00	3,090.00	2,910.00
	50	$124,900.00	$113,500.00	315.00	297.50
-	-	$760,000.00	$700,000.00	-	-

Table 3.6: Activity pools I of simple ABC

The next step is concerned with the calculation of cost driver rates, expenses charged to products, and some variances that are relevant for decision-making. For their calculation procedures, the previous calculated parameters of Table 3.4 are utilized. Equation 3.5 comprises the mathematical expressions of computations. The results regarding the case study data set are presented in Table 3.7.

$$CDR^{\text{Bud}}{}_{\text{i}} = \frac{AE^{\text{Bud}}{}_{\text{i}}}{AL^{\text{Bud}}{}_{\text{i}}}$$

$$CDR^{\text{Act}}{}_{\text{i}} = \frac{AE^{\text{Act}}{}_{\text{i}}}{AL^{\text{Act}}{}_{\text{i}}}$$

$$ECP_{\text{i}} = AL^{\text{Act}}{}_{\text{i}} * CDR^{\text{Bud}}{}_{\text{i}} \tag{3.5}$$

$$VV_{\text{i}} = (AL^{\text{Bud}}{}_{\text{i}} - AL^{\text{Act}}{}_{\text{i}}) * CDR^{\text{Bud}}{}_{\text{i}}$$

$$VV_{\text{i}} = AE^{\text{Act}}{}_{\text{i}} - AE^{\text{Bud}}{}_{\text{i}}$$

According to Kaplan, the budgeted cost driver rates that are calculated by means of a simple ABC approach are at best corresponding to a rough surrogate for the costs of resources used. The reason for this is that the budgeted cost driver rates include a proportion of the unused capacity costs of resources supplied, which is not beneficial for decision-making [6].

Simple ABC: Activity Pools II				
Budgeted Cost Driver Rate ($CDR^{Bud}{}_i$)	***Actual Cost Driver Rate ($CDR^{Act}{}_i$)***	***Expense Charged To Products (ECP_i)***	***Volume Variance (VV_i)***	***Spending Variance (SV_i)***
$4.58	$3.86	$29,068.89	$1,831.11	-$6,400.00
$934.88	$895.89	$85,308.14	$5,141.86	-$8,700.00
$115.52	$115.67	$241,432.66	$15,017.34	-$14,700.00
$83.27	$81.96	$242,311.65	$14,988.35	-$18,800.00
$396.51	$381.51	$117,961.11	$6,938.89	-$11,400.00
-	-	$716,082.45	$43,917.55	-$60,000.00

Table 3.7: Activity pools II of simple ABC

Capacity-Based ABC with Committed Expenses

The capacity-based ABC approach with committed expenses is able to overcome the limitations of simple ABC approaches by assuming the budgeted activity expenses as entirely committed. With regard to this assumption, additional information is required for such a commitment of resources. This information corresponds to the capacity of resources supplied [6]. In addition to calculations of Equation 3.4, the capacity activity levels are computed using the formula of Equation 3.6. The calculation results are stated in Table 3.8 and thus they serve as a foundation for capacity-based ABC.

$$AL^{\mathrm{Cap}}{}_{\mathrm{i}} = \sum_k AL^{\mathrm{Cap}}{}_{\mathrm{k,i}} \tag{3.6}$$

Capacity-Based ABC with Committed Expenses: Activity Pools I						
Planning Period ID	***Activity ID***	***Budgeted Activity Expense ($AE^{Bud}{}_i$)***	***Actual Activity Expense ($AE^{Act}{}_i$)***	***Capacity Activity Level ($AL^{Cap}{}_i$)***	***Budgeted Activity Level ($AL^{Bud}{}_i$)***	***Actual Activity Level ($AL^{Bud}{}_i$)***
0	10	$30,900.00	$24,500.00	7,000.00	6,750.00	6,350.00
	20	$90,450.00	$81,750.00	100.00	96.75	91.25
	30	$256,450.00	$241,750.00	2,300.00	2,220.00	2,090.00
	40	$257,300.00	$238,500.00	3,200.00	3,090.00	2,910.00
	50	$124,900.00	$113,500.00	325.00	315.00	297.50
-	-	$760,000.00	$700,000.00	-	-	-

Table 3.8: Activity pools I of capacity-based ABC with committed expenses

The second part of the calculations (cf. Equation 3.7) is concerned with capacity cost driver rates, expenses charged to products, budgeted unused capacities, and capacity utilization variances. In the following, the results of these calculations are shown in Table 3.9.

$$\begin{aligned}
&CDR^{\text{Cap}}{}_{\text{i}} = \frac{AE^{\text{Bud}}{}_{\text{i}}}{AL^{\text{Cap}}{}_{\text{i}}} \\
&ECP_{\text{i}} = AL^{\text{Act}}{}_{\text{i}} * CDR^{\text{Cap}}{}_{\text{i}} \\
&BUC_{\text{i}} = (AL^{\text{Cap}}{}_{\text{i}} - AL^{\text{Bud}}{}_{\text{i}}) * CDR^{\text{Cap}}{}_{\text{i}} \\
&CUV_{\text{i}} = (AL^{\text{Bud}}{}_{\text{i}} - AL^{\text{Act}}{}_{\text{i}}) * CDR^{\text{Cap}}{}_{\text{i}}
\end{aligned} \tag{3.7}$$

Capacity-Based ABC with Committed Expenses: Activity Pools II					
Capacity Cost Driver Rate ($CDR^{Cap}{}_i$)	***Budgeted Cost Driver Rate ($CDR^{Bud}{}_i$)***	***Budgeted Unused Capacity (BUC_i)***	***Capacity Utilization Variance (CUV_i)***	***Expense Charged To Products (ECP_i)***	***Spending Variance (SV_i)***
$4.41	$4.58	$1,103.57	$1,765.71	$28,030.71	-$6,400.00
$904.50	$934.88	$2,939.63	$4,974.75	$82,535.63	-$8,700.00
$111.50	$115.52	$8,920.00	$14,495.00	$233,035.00	-$14,700.00
$80.41	$83.27	$8,844.69	$14,473.13	$233,982.19	-$18,800.00
$384.31	$396.51	$3,843.08	$6,725.38	$114,331.54	-$11,400.00
-	-	$25,650.96	$42,433.97	$691,915.07	-$60,000.00

Table 3.9: Activity pools II of capacity-based ABC with committed expenses

The budgeted unused capacity represents the part of the resources supplied but not used that is known ex ante. Whereas the capacity utilization variance comprises the part of unused resources that is known when the actual activity levels are realized, so ex post. In other words: the budgeted unused capacity contains the expected part of unused capacity; while the capacity utilization variance comprises the unexpected part of the unused capacity. The major benefits of explicitly showing the unused capacities of resources supplied are situated in the opportunity that the supply of resources can be reduced or even additional businesses may be attracted. Even if this capacity-based ABC approach with committed expenses overcomes the limitations of simple ABC, it assumes that all expenses are incurred independently of the actual demand for performing activities during a period. In short, all expenses are viewed as entirely committed within this approach. From a practical perspective, this is often the case regarding physical resources that have already been acquired or personnel that get paid whether or not work is available. Typically, the assumption that operating expenses are entirely committed does not hold true for all resources of a certain business. Furthermore, it is not an inherent feature of ABC systems [6].

Capacity-Based ABC with Committed and Flexible Resources

In contrast to the aforementioned approaches, the capacity-based ABC approach with committed and flexible resources allows a portion of resources to be committed in advance as well as a separate portion of resources to be supplied as required. By this property, it overcomes the limitations of simple ABC and furthermore avoids this undesired behavior that resources have to be either entirely committed or flexible [6]. The committed and flexible parts of the budgeted expenses are calculated using the cost pool information of Table 3.4. For the calculation of cost driver rates, the activity levels of Table 3.8 are applied. Two different cost driver rates are calculated: On the one hand, there are the capacity cost driver rates, which are computed using committed expenses and capacity activity levels. And on the other hand, we have the budgeted cost driver rates, which are calculated using flexible expenses and actual activity levels. Equation 3.8 comprises the mathematical expressions of these calculations. With regard to the case study data set, the results are illustrated in Table 3.10.

$$
\begin{aligned}
&CAE^{\mathrm{Bud}}{}_{\mathrm{i}} = \textstyle\sum_j CPE^{\mathrm{Bud}}{}_{\mathrm{i,j}} * (1 - V^{\mathrm{CP}}{}_{\mathrm{i,j}}) \\
&FAE^{\mathrm{Bud}}{}_{\mathrm{i}} = \textstyle\sum_j CPE^{\mathrm{Bud}}{}_{\mathrm{i,j}} * V^{\mathrm{CP}}{}_{\mathrm{i,j}} \\
&CDR^{\mathrm{Cap}}{}_{\mathrm{i}} = \frac{CAE^{\mathrm{Bud}}{}_{\mathrm{i}}}{AL^{\mathrm{Cap}}{}_{\mathrm{i}}} \\
&CDR^{\mathrm{Bud}}{}_{\mathrm{i}} = \frac{FAE^{\mathrm{Bud}}{}_{\mathrm{i}}}{AL^{\mathrm{Bud}}{}_{\mathrm{i}}}
\end{aligned}
\tag{3.8}
$$

Activity Pools I					
Planning Period ID	***Activity ID***	***Budgeted Committed Activity Expense ($CAE^{Bud}{}_i$)***	***Budgeted Flexible Activity Expense ($FAE^{Bud}{}_i$)***	***Capacity Cost Driver Rate ($CDR^{Cap}{}_i$)***	***Budgeted Cost Driver Rate ($CDR^{Bud}{}_i$)***
0	10	$18,100.00	$12,800.00	$2.59	$1.90
	20	$64,140.00	$26,310.00	$641.40	$271.94
	30	$193,740.00	$62,710.00	$84.23	$28.25
	40	$181,940.00	$75,360.00	$56.86	$24.39
	50	$86,580.00	$38,320.00	$266.40	$121.65
-	-	$544,500.00	$215,500.00	-	-

Table 3.10: Activity pools I of capacity-based ABC with committed and flexible res.

The next step of calculations (cf. Equation 3.9) is concerned with expenses charged to products, budgeted unused capacities, capacity utilization variances, flexible budgets, and spending variances. Table 3.11 shows the results of these calculations. Even if the formulas of unused capacities are the same as for the capacity-based ABC approach with committed expenses, the results are changed because the capacity cost driver rates have been determined in a different manner. Due to the use of variators, the portions of committed and flexible expenses are adjustable. On the one hand, if all variators are adjusted to 1.00 then all resources are considered as entirely flexible and the expense charged to products are corresponding to the results of simple ABC. On the other hand, when all variators are set to 0.00 the resources are assumed as entirely committed and the expenses charged to products are equally to the results of capacity-based ABC with committed expenses. The flexible budgets are corresponding to the results of budgeted cost functions that have been evaluated by using actual activity levels.

$$
\begin{aligned}
&ECP_{\text{i}} = AL^{\text{Act}}{}_{\text{i}} * (CDR^{\text{Cap}}{}_{\text{i}} + CDR^{\text{Bud}}{}_{\text{i}}) \\
&BUC_{\text{i}} = (AL^{\text{Cap}}{}_{\text{i}} - AL^{\text{Bud}}{}_{\text{i}}) * CDR^{\text{Cap}}{}_{\text{i}} \\
&CUV_{\text{i}} = (AL^{\text{Bud}}{}_{\text{i}} - AL^{\text{Act}}{}_{\text{i}}) * CDR^{\text{Cap}}{}_{\text{i}} \\
&FB_{\text{i}} = CAE^{\text{Bud}}{}_{\text{i}} + (AL^{\text{Act}}{}_{\text{i}} * CDR^{\text{Bud}}{}_{\text{i}}) \\
&SV_{\text{i}} = AE^{\text{Act}}{}_{\text{i}} - FB_{\text{i}}
\end{aligned}
\tag{3.9}
$$

Activity Pools II				
Budgeted Unused Capacity (BUC_i)	***Capacity Utilization Variance (CUV_i)***	***Expense Charged To Products (ECP_i)***	***Flexible Budget (FB_i)***	***Spending Variance (SV_i)***
$646.43	$1,034.29	$28,460.77	$30,141.48	-$5,641.48
$2,084.55	$3,527.70	$83,342.09	$88,954.34	-$7,204.34
$6,738.78	$10,950.52	$235,088.49	$252,777.79	-$11,027.79
$6,254.19	$10,234.13	$236,421.78	$252,910.10	-$14,410.10
$2,664.00	$4,662.00	$115,445.11	$122,771.11	-$9,271.11
$18,387.95	$30,408.63	$698,758.24	$747,554.82	-$47,554.82

Table 3.11: Activity pools II of capacity-based ABC with committed and flexible res.

This capacity-based ABC approach with committed and flexible resources enables product costing as well as detailed analysis of expenses. In contrast to previous ABC approaches, this one reveals the portions of committed and flexible resources. Therefore, managers are able to recognize which parts of expenses are expected to fluctuate in the short-run, and, as a result of that, they can benefit in their decision-making [6]. Since the conceptual model is characterized by the capacity-based ABC approach with flexible and committed resources, the Requirement 5.3 concerned with mapping of activity pools is derived.

Requirement 5.3 The conceptual model shall be able to depict activity pools based on the attributes: capacity driver rate, budgeted driver rate, budgeted unused capacity, capacity utilization variance, expense charged to products, flexible budget, and spending variance.

Although the expenses charged to products have already been explained before, the data set of the case study involves two different finished goods. For the purposes of product costing, it might be interesting to trace these expenses back to the finished goods. A proper way for doing this is stated in Equation 3.10. In addition, the material expenses are included based on the unit costs of the Bill of Material (BOM), which are derived from Table 2.5. Finally, the results are shown in Table 3.12.

$$
\begin{aligned}
ME_{\mathrm{k}} &= {Q^{\mathrm{Act}}}_{\mathrm{k}} * UC_{\mathrm{k}} \\
COE_{\mathrm{k}} &= {Q^{\mathrm{Act}}}_{\mathrm{k}} * \textstyle\sum_i ACD_{\mathrm{k,i}} * {CDR^{\mathrm{Cap}}}_{\mathrm{i}} \\
FOE_{\mathrm{k}} &= {Q^{\mathrm{Act}}}_{\mathrm{k}} * \textstyle\sum_i ACD_{\mathrm{k,i}} * {CDR^{\mathrm{Bud}}}_{\mathrm{i}}
\end{aligned}
\tag{3.10}
$$

Expenses charged to Finished Goods					
Planning Period ID	***Finished Good ID***	***Actual Vol.*** ***($Q^{Act}{}_k$)***	***Material Expenses*** ***(ME_k)***	***Committed Overhead Expenses*** ***(COE_k)***	***Flexible Overhead Expenses*** ***(FOE_k)***
0	120	450.00	$135,000.00	$287,526.92	$116,489.75
	140	185.00	$96,200.00	$209,176.50	$86,565.08
-	-	-	$231,200.00	$495,703.42	$203,054.82

Table 3.12: Expenses charged to finished goods

3.6 Demonstration of an arising Death Spiral

This section has been included for the demonstration of an arising death spiral in a simple ABC system. As already mentioned, such ABC systems fail when they are used for flexible budgeting purposes. The reason for this is that the budgeted operating expenses are solely adjusted to the anticipated activity levels. Unfortunately, this only works when the operating expenses and the activity levels are decreasing in almost the same dimension. However, when the activity levels are falling faster than the operating expenses are being reduced, usually, simple ABC approaches tend to fail and lead to so called 'death spirals' [6]. Subsequently, the arise of such a death spiral is demonstrated with regard to the three ABC approaches that have been introduced in Section 3.5.

For demonstration of the death spiral, a simulation is conducted over three planning periods. Shrinking markets are assumed, and a naive calibration is used for the determination of budgeted expenses and anticipated activity levels. Naive calibration means that the actual parameters of the previous period are utilized as budgeted parameters of the upcoming period [20]. As a starting point, the parameters of the initial planning period are determined through an expert estimation. The following assumptions are taken for conducting the simulation:

Planning Period 0 The parameters of this planning period are based on an expert estimation and therefore they correspond to the data that has been used for illustration purposes in previous sections.

Planning Period 1 The actual volumes are determined based on the budgeted volumes by considering a reduction of 5%. While the actual expenses correspond to the budgeted expenses after a reduction of 2%.

Planning Period 2 The parameters of the actual volumes are determined based on a reduction of 15%, and the actual expenses are only decreased by 2%.

Planning Period 3 The parameters are determined in the same manner as for the 'Planning Period 1'.

Table 3.13 shows the initial parameters when coming from the assumptions above. Afterwards, the simulation is conducted for all three different ABC systems based on that parameter setting.

Initial Parameters						
Planning Period ID	***Budgeted Overhead Expense***	***Actual Overhead Expense***	***Budgeted Volume***		***Actual Volume***	
			Slot Car X1	**Slot Car Z2**	**Slot Car X1**	**Slot Car Z2**
0	$760,000.00	$700,000.00	480.00	195.00	450.00	185.00
1	$700,000.00	$686,000.00	450.00	185.00	428.00	176.00
2	$686,000.00	$672,280.00	428.00	176.00	364.00	150.00
3	$672,280.00	$658,834.40	364.00	150.00	346.00	143.00

Table 3.13: Initial parameters of the simulation determined using a naive callibration

The simulation results of simple ABC are shown in Table 3.14. As expected, the increased reduction of activity levels at 'Planning Period 2' leads to a collapse according to expenses charged to products of 'Planning Period 3'. Even if the activity levels are reduced, a higher amount of expenses is charged to products. In other words, in 'Planning Period 3' a less amount of products is manufactured at a higher level of expenses. This contradictory result may cause mistakes in decision-making, and subsequently it can induce a potential death spiral. Due to such deficiencies, simple ABC approaches are clearly not appropriate for flexible budgeting purposes.

Simple ABC				
Planning Period ID	***Expense Charged To Products***	***Volume Variance***	***Spending Variance***	***Potentially arising Death Spiral?***
0	$716,082.45	$43,917.55	-$60,000.00	✗
1	$665,848.82	$34,151.18	-$14,000.00	✗
2	$583,943.86	$102,056.14	-$13,720.00	✗
3	$639,827.08	$32,452.92	-$13,445.60	✓

Table 3.14: Results based on simple ABC

Table 3.15 shows the simulation results of the capacity-based ABC system with committed expenses.

Capacity-Based ABC with Committed Expenses				
Planning Period ID	***Expense Charged To Products***	***Budgeted Unused Capacity***	***Capacity Utilization Variance***	***Spending Variance***
0	$691,915.07	$25,650.96	$42,433.97	-$60,000.00
1	$606,189.89	$62,718.86	$31,091.25	-$14,000.00
2	$505,687.26	$91,933.90	$88,378.84	-$13,720.00
3	$471,651.14	$176,706.46	$23,922.37	-$13,445.60

Table 3.15: Results based on capacity-based ABC with committed expenses

The results of the capacity-based ABC system with committed and flexible resources are shown in Table 3.16.

Capacity-Based ABC with Committed and Flexible Resources					
Planning Period ID	***Expense Charged To Products***	***Budgeted Unused Capacity***	***Capacity Utilization Variance***	***Flexible Budget***	***Spending Variance***
0	$698,758.24	$18,387.95	$30,408.63	$747,554.82	-$47,554.82
1	$622,581.40	$45,486.64	$22,540.53	$690,608.57	-$4,608.57
2	$527,195.58	$66,666.63	$64,073.45	$657,935.66	$14,344.34
3	$517,887.51	$128,125.27	$17,344.31	$663,357.10	-$4,522.70

Table 3.16: Results based on capacity-based ABC with committed and flexible resources

By involving the capacities of activity levels, both of these capacity-based ABC approaches are able to overcome the deficiencies of simple ABC. Therefore, they can effectively avoid the arise of potential death spirals. With respect to this benefit, such capacity-based

ABC systems are more sophisticated in terms of flexible budgeting purposes. However, the primarily focus of this thesis is on the capacity-based ABC approach with committed and flexible resources. Finally, the development of the ABC system has been finished, and the requirements regarding conceptual modeling have been identified too. So, the upcoming chapter is concerned with conceptual modeling of the developed capacity-based ABC system with flexible and committed resources for flexible budgeting.

CHAPTER 4

Conceptual Modeling

4.1 Discrepancies in Terminology

Conceptual modeling is a term that is frequently used in the literature, but so far there is no clear consensus about its orientation. In particular, it is arguable if conceptual modeling should focus on the creation of ontological representations of real world phenomenon, or rather focus on representations as captured in requirements engineering, which are derived from the perspectives of various stakeholders. On the one hand, we have ontological approaches that are concerned with representing the 'truth' of real world phenomenon by modeling things-as-they-are. And on the other hand, there exist further epistemological approaches that are more subjective in their nature by modeling things-as-we-know-them. So, these two opposing views of conceptual modeling are clearly distinct regarding the influence of an observer. While the content of epistemological models strongly depends on the perspective of an observer, ontological models are almost independent of an observer's perspective [22]. In addition, there is a discrepancy between the object-oriented terminology of software engineering and the terminology that is applied in philosophy (cf. Figure 4.1).

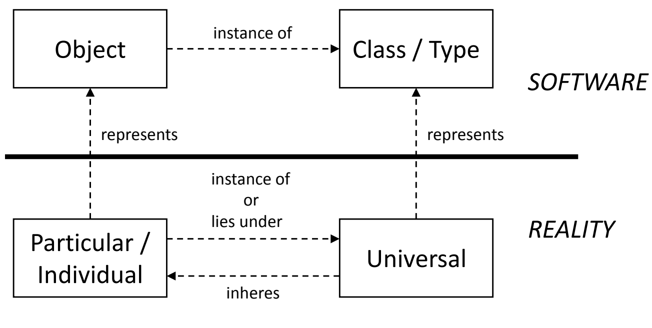


Figure 4.1: Linkage between object-oriented and philosophical terminology [22]

4.2 Introduction to OntoUML

Ontological and epistemological views of conceptual modeling are often confounded in current modeling languages, such as in the Unified Modeling Language (UML). Consequently, Guizzardi [7] proposed the Ontology-Driven Unified Modeling Language (OntoUML), which has been built upon as an extension of UML by incorporating the Unified Foundational Ontology (UFO). The OntoUML integrates ontological meta-properties by making them accessible in UML class diagrams through the use of stereotypes. Thus, it is declared as a foundational ontological language for conceptual modeling. Similarly to the concept of a metamodel that defines the elements of a General Purpose Language (GPL) such as UML, foundational ontologies are used to provide something in the sense of a metamodel for ontological-based languages. In contrast to metamodels, foundational ontologies are mainly intended to represent the real world without taking into account any model-specific characteristics [22].

The foundational ontology of the OntoUML that is called UFO has been developed using the four-category-ontology of Lowe [23]. Primarily, the UFO is aligned to cover three different scopes: UFO-A for the ontology of *Endurant Universals* and their relations, UFO-B that incorporates the ontology of *Perdurant Universals*, and UFO-C for the ontology of social aspects [24]. According to Henderson-Sellers [22], the instances of *Endurant Universals* are entities that are present whenever they are present, such as Person or Machine. While instances of *Perdurant Universals* are comprising entities with a spatial-temporal extent, which may look different at certain points of time e.g., events such as a football match. For the purposes of this paper, the focus is on *Endurant Universals* and therefore on the UFO-A part, which is also the most dominant part of the UFO.

Within the UFO, there are four ontological meta-properties of *Substantial Universals*: identity provision (O), identity condition (I), rigidity (R), and external dependency (D). In Table 4.1, an overview of these meta-properties is given according to their prefix notations.

Prefix	***Meta-Properties (MP)***
+O	Provides identity
-O	Does not provide identity
+I	Identity
-I	No identity
+R	Rigid
-R	Anti-Rigid
~R	Semi-Rigid
+D	Dependent
-D	Independent

Table 4.1: Meta-properties of the Unified Foundational Ontology (UFO) [25]

Figure 4.2 represents the hierarchy of *Monadic Universals* of the UFO-A. *Monadic Universals* correspond to meta-classes whose instances can be instantiated by *Individuals*. They are further specified by *Endurant Universals*, which ensure the persistence of *Individuals* over time. *Substantial Universals* and *Moment Universals* are both concretizing *Endurant Universals*. On the one hand, the instances of *Substantial Universals* are highly independent from the existence of other *Individuals*, which means they can exist alone. And on the other hand, the instances of *Moment Universals* are dependent on the existence of other *Individuals* and therefore cannot exist without them [26]. In general, the instantiation of *Individuals* is solely allowed for leaf classes, which have been shaded as grey in Figure 4.2.

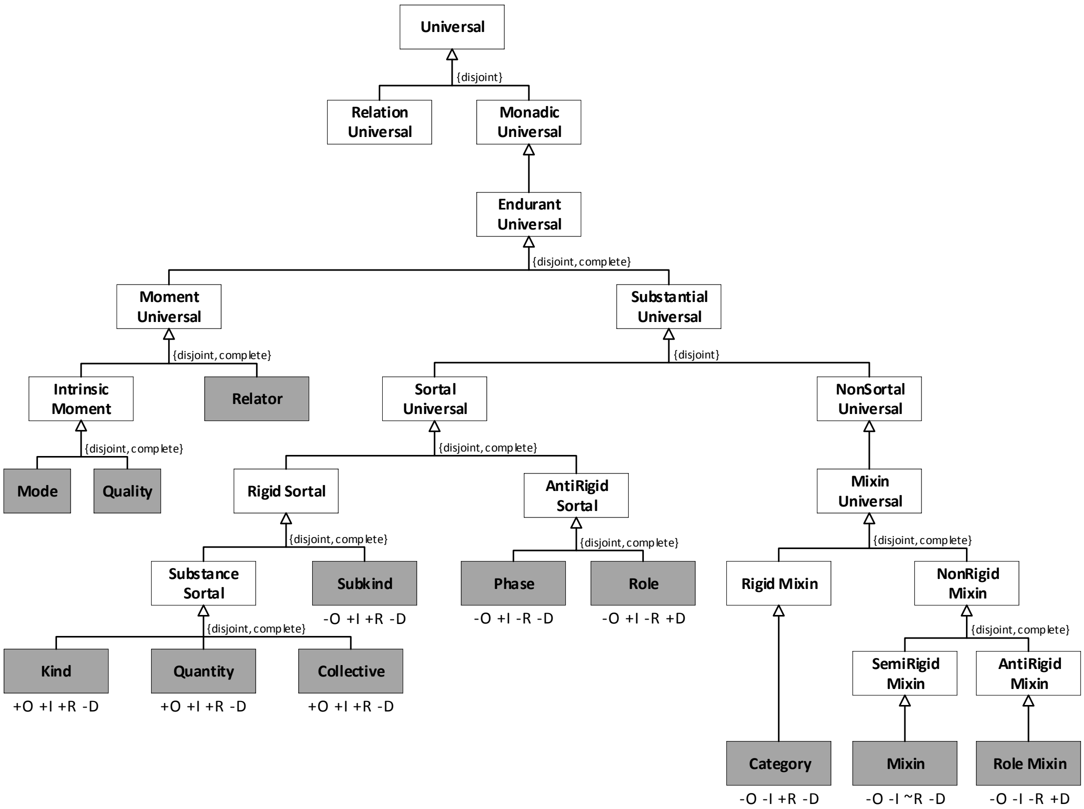


Figure 4.2: Monadic universal hierarchy of UFO-A adapted from [26]

The principle of identity is important for the UFO because only subtypes of *Substance Sortals* are able to provide their own identity. Since other leaf classes are merely able to carry identity, they need to acquire it somehow from a *Substance Sortal*. Another key principle of foundational ontologies is the rigidity, which is used to divide *Sortal Universals* into *Rigid Sortals* and *AntiRigid Sortals*. Due to the need of a *Kind* that is not only an instance of a *Sortal Universal* but also countable and able to remaining unchanged in all possible worlds, this concept of rigidity is essential for UFO [22].

With regard to ontological meta-properties, the *Endurant Universals* that are utilized for the purposes of this thesis are described in the following [25]:

Kind **(MP: +O +I +R -D)**
A *Kind* represents a functional complex subtype of a *Substance Sortal.* It is rigid, independent, and provides its own identity. An example of a *Kind* may be the entity 'Person', and then some possible instantiations are corresponding to the *Individuals* 'Alice' and 'Bob'.

Subkind **(MP: -O +I +R -D)**
A *Subkind* is a rigid, independent restriction of a Substance Sortal. It does not provide an own identity but carries the principle of identity that is supplied by an identity-providing Substance Sortal. Examples of *Subkinds* are the entities 'Male' and 'Female', which are complete and disjoint subsets of the *Kind* class 'Person'. The *Individual* 'Alice' is a possible instance of the Subkind class 'Female', while the *Individual* 'Bob' is not.

Phase **(MP: -O +I -R -D)**
A *Phase* is a subtype of an *AntiRigid Sortal.* It is defined as an anti-rigid and relationally independent universal part of a partition of Substance Sortals. Examples are the *Phases* classes 'Child' and 'Adult' of the *Kind* class 'Person'. If the *Individual* 'Alice' is currently twenty-five years old, she is a possible instance of the *Phase* class 'Adult'. Obviously, 'Alice' was a valid instance of the *Phase* class 'Child' when she was younger.

Relator
In contrast to *Substantial Universals*, a *Relator* is a special kind of *Moment Universals.* Therefore, an instance of a *Relator* is existentially dependent of at least two distinct *Individuals.* An example may be the *Relator* class 'Marriage' that mediates the marriage relationship between two instances of the *Kind* class 'Person'. A possible instantiation of the *Relator* class 'Marriage' may be the *Individual* that mediates the marriage of 'Alice' and 'Bob'.

The hierarchy of *Relation Universals* and their subtypes are illustrated in Figure 4.3. In contrast to *Monadic Universals*, a *Relation Universal* is something in the sense of a meta-concept that is applied to describe relationships between groups of two or more *Individuals.* The most common differentiation of *Relation Universals* is made between *Formal Relations* and *Material Relations.* While *Formal Relations* are utilized to describe relationships between two *Individuals* without the support of additional *Individuals*, a *Material Relation* requires a *Relator* that mediates between the involved *Individuals* [26]. As before, all classes that can be instantiated are shaded as grey in Figure 4.3.

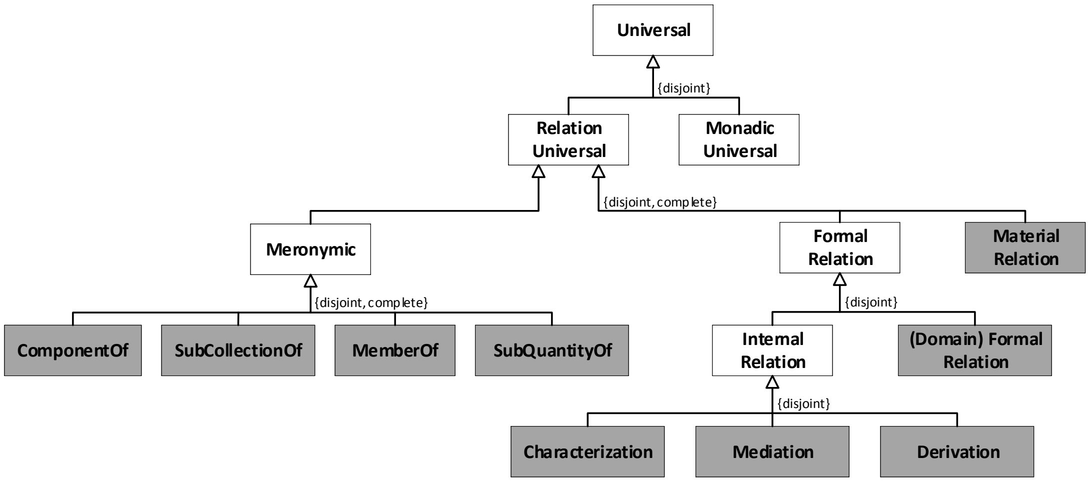


Figure 4.3: Relation universal hierarchy of UFO-A adapted from [26]

Subsequently, the instances of *Relational Universals* that are utilized for the purposes of this thesis are briefly described below [25]:

Material Relation
A *Material Relation* represents a *Relational Universal* that is induced by a *Relator*. An example may be the *Material Relation* 'Person is married to Person' with the possible instantiation 'Alice is married to Bob'.

(Domain) Formal Relation
A *Formal Relation* represents either a comparative relation that is based on intrinsic properties of the related entities, or an *Internal Relation*. For example, a *Formal Relation* may be 'Person is older than Person' with the possible instance 'Bob is older than Alice'.

Mediation
A *Mediation* is an *Internal Relation* that mediates between a *Relator* and the involved *Endurant Universals*. An example may be the *Mediation* that mediates between the *Relator* 'Marriage' with the *Roles* of 'Husband' and 'Wife'.

4.3 REA Accounting Model

The REA accounting model, which has been introduced by McCarthy [8], grasps the underlying economic logic of double-entry bookkeeping. It is composed out of economic resources (R) that are exchanged in economic events (E) by economic agents (A). Thus, the REA accounting model is based on a stock and flow perspective, which contradicts with the conventional accounting view of economic literature. The duality principle of the REA accounting model represents the economic rationale, in which scarce resources have a positive price on the market that has to be paid from the buyer to the seller for the exchange of resources.

Initially, the REA accounting model has been developed using data modeling techniques. To complete the existing accounting infrastructure by a policy infrastructure, the REA accounting model was extended by Geerts and McCarthy [27] [28] to the REA business ontology. This extension enables the consideration of business policies such as acquisition, conversion, revenue, financing and investment transactions. Gailly et al. [29] applied the OntoUML for classifying the REA primitives based on the metaphysical UFO. So, the economic resources, economic events, and economic agents as well as the REA duality are represented in the REA business ontology, which is based on the UFO. Thereby, the REA primitives are modeled by means of *Roles*, *Relators*, *Role Mixins*, and *Formal Relations*.

Fischer-Pauzenberger and Schwaiger [9] translated the REA accounting model into the OntoUML using a different mapping (cf. Figure 4.4). Consequently, the characteristics of the REA accounting model are described in respect to Fischer-Pauzenberger's and Schwaiger's translation:

- The REA primitives of economic resource, economic event, and economic agent are modeled using identity-providing *Kind* classes. The economic event is partitioned into *SubKind* classes of increment and decrement events via a disjoint and complete generalization. Apart from that, the balanced duality is modeled by a *Relator* class that mediates between increment and decrement events.

- The relationship between economic resources and increment/decrement events is described by *Formal Relations* regarding the inflow/outflow. In addition, a *Formal Relation* is used for the description of the relationship between economic events and economic agents. The cardinalities of this relationship indicate that two economic agents are involved in one economic event.

- The intermediation between the *Relator* class of REA duality and increment/decrement events is described by a *Material Relation* named 'duality'. The difference between *Formal* and *Material Relations* is based on the reification of relationships. While *Material Relations* are reified, *Formals* are not.

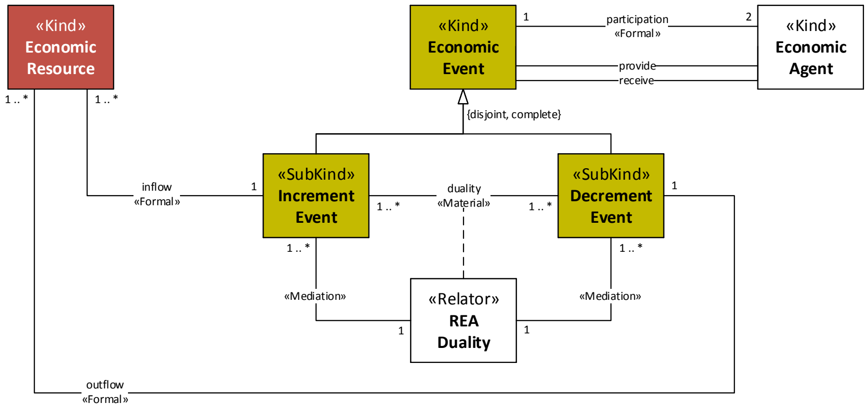


Figure 4.4: REA accounting model using the OntoUML [9]

Even if this aforementioned classification of the REA accounting model is valuable for the research area, it does not cover all essential elements of the accounting domain in a comprehensible manner. In order to overcome those practical constraints, Schwaiger [30] adapted the REA accounting model by including the debit and credit notions, so that its conformity with traditional accounting logic is ensured. Additional economic resource types for liabilities and equity are considered in order to complete the REA accounting model for its application in the accounting domain. As a result of that explicit distinction between the economic resource types of assets (A), liabilities (L), and equity (E), Schwaiger's extension of the REA business ontology is called 'REA-based ALE Accounting Ontology'.

With respect to the translation of the REA accounting model, Fischer-Pauzenberger and Schwaiger [9] also translated the REA-based ALE accounting model into the OntoUML. Figure 4.5 shows the result of this translation, which is called OntoREA accounting model. In comparison to the traditional REA accounting model of Figure 4.4, the following refinements have been made:

- The *Relator* class of the REA duality is replaced by a *Relator* class of the balanced duality, in which a value constraint is involved.
- The *SubKind* classes of economic event are now explicitly denoted as debit/credit instead of increment/decrement, as before. Considering the different resource types of the REA-based ALE accounting model, this change was required because, otherwise, it would be not allowed that different resource types are simultaneously increasing/decreasing when only one event type is involved.
- The *Phase* class is used for the mapping of different resource types. Since a *Phase* class is anti-rigid and inherits its identity from a superclass, it includes a modal

meta-property that allows an economic resource to change its resource type over time. Even if this modal behavior is usually not required for assets, liabilities, and equity, one example of resource types that require such a modal behavior are claims. With respect to derivative financial instruments, there are more resources which require this modal behavior of changing resource types over time. Further details of those derivative financial instruments in association with the OntoREA accounting model have been provided by the article of Fischer-Pauzenberger and Schwaiger [31].

- The *Formal Relations* between economic resources and debit/credit events are modeled by in- and outflow associations because both of them can occur related to debit as well as credit events. It depends on the involved resource types whether an in- or an outflow occurs at a certain debit/credit event.

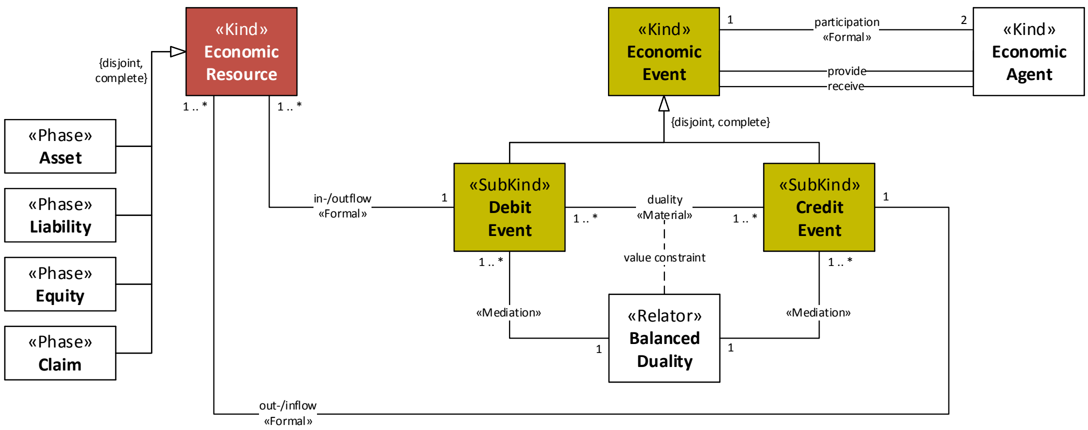


Figure 4.5: OntoREA accounting model using the OntoUML [9]

4.4 Modeling of the ABC Framework

The conceptual modeling part of the ABC framework is primarily focused on the parts of resource typification, integration of general ledger accounts, and allocation of resources. With reference to identified requirements concerning the ontological peculiarities of an ABC framework, which have been derived in Chapter 2, those aforementioned parts are conceptually modeled.

Resource Typification

As a starting point to conceptual modeling of the resource typification, the identified requirements of Section 2.3 are summarized in Table 4.2.

No.	Requirement
2.1	The conceptual model shall include a resource typification in conformity with the Enterprise Control System Integration (ECSI) standard (MAT/PERS/TECH).
2.2	The resource typification of the conceptual model must consider the mapping of finished goods with an unique identifier attribute.
2.3	The resource typification of the conceptual model must allow a distinction between finished goods and raw materials. In case of raw materials, an additional attribute for the unit costs must be considered.
2.4	The resource typification of the conceptual model shall ensure the correct integration of the Bill of Material (BOM) associated with the required quantities of the material resources.
2.5	The recursive relationships among raw materials shall be visible in the conceptual model.
2.6	The resource typification of the conceptual model shall ensure the correct inclusion of the routing (working plan) regarding the standard production coefficients of capacity resources (PERS & TECH).

Table 4.2: Identified requirements in regard to resource typification

Figure 4.6 shows the conceptual modeling part of the resource typification based on the requirements above. In order to ensure a standardized solution for implementation purposes, the resource typification is defined in conformity with the Enterprise Control System Integration (ECSI) standard [17] [18]. Since the REA accounting model already includes an identity-providing *Kind* class for economic resources, the resource typification is established on the basis of this class. The material and capacity resources, which are defined in the ECSI standard, are modeled using *SubKind* classes via disjoint and complete generalizations. A *Relator* class is used for modeling the Bill of Material (BOM) that mediates between raw materials and finished goods. Furthermore, a *Material Relation* is utilized to concise that finished goods are composed out of raw materials through a many-to-many relationship. The recursive relationships between raw materials are captured with a *Formal Relation*, as follows: A raw material may include an arbitrary number of subordinate raw materials, and a subordinate raw material may belong to one or more raw materials.

Similarly, the routing (working plan) is depicted using a *Relator* class. It mediates the coordination of the capacity resources of personnel (PERS) and equipment (TECH). This relationship of coordination is made visible with a *Material Relation* that describes a many-to-many relationship in the way of: One or more instantiations of the personnel class are coordinated with one or more instantiations of the equipment class. Finally, it can be seen that all cardinalities have been specified in Figure 4.6.

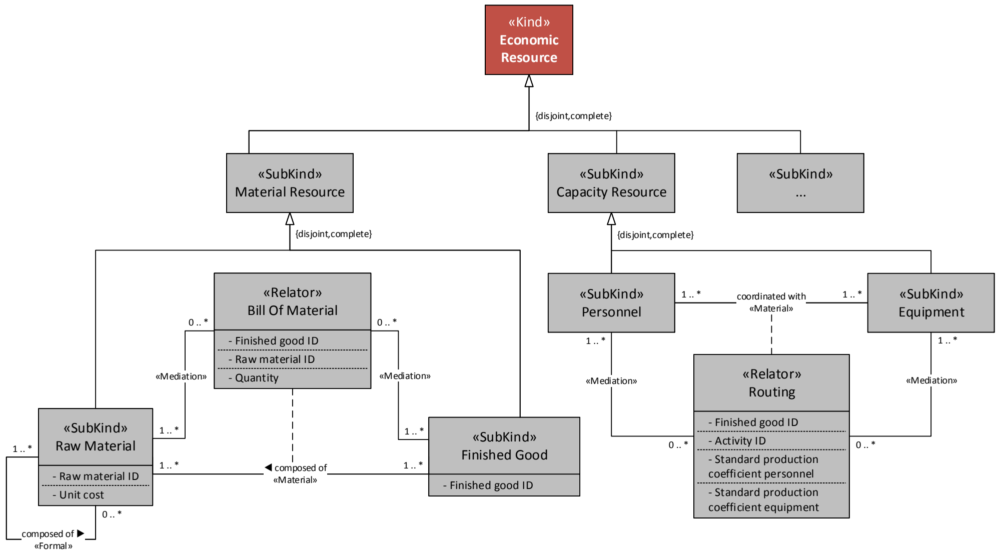


Figure 4.6: Conceptual modeling of the resource typification

Integration of General Ledger Accounts

The next step regarding conceptual modeling of the ABC framework is concerned with the integration of general ledger accounts. Table 4.3 shows the identified requirements of Section 2.4 according to the modeling of those general ledger accounts.

No.	Requirement
3.1	The conceptual model shall ensure the integration of general ledger accounts based on the Austrian uniform scheme of accounts with an emphasis on the account type and the unique identifier.
3.2	The conceptual model shall ensure a proper mapping of expense accounts by considering additional attributes for cost and resource type.

Table 4.3: Identified requirements concerning the integration of general ledger accounts

Based on those aforementioned requirements, the general ledger accounts are modeled in Figure 4.7. With respect to the REA accounting model, the *Kind* class of economic events is utilized for the integration of general ledger accounts. An identity-providing *Kind* class is included for modeling of the general ledger accounts. The relationship between economic events and general ledger accounts is described with a *Formal Relation* in the following way: An economic event triggers the posting of transactions in two general ledger accounts. Within one of those general ledger accounts, the economic event occurs in form of a debit transaction, while in the other account a credit transaction is posted. For reasons of standardization, the general ledger accounts are typified based on the Austrian uniform scheme of accounts [19]. The subtypes are modeled using *SubKind* classes and therefore acquire their identities from the *Kind* class of general ledger accounts. To enable the categorization of expenses, the *SubKind* class of expense accounts includes two additional attributes for resource and cost types.

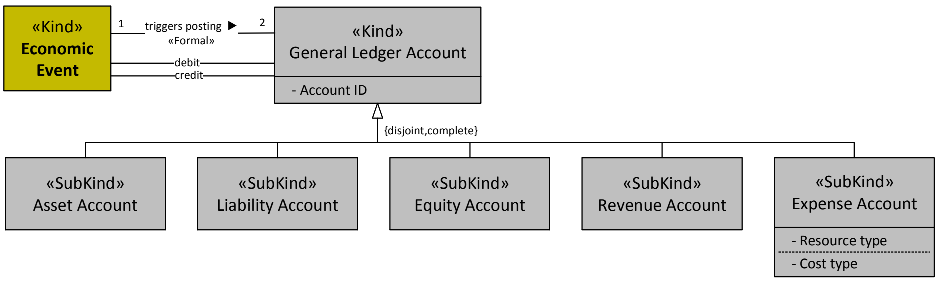


Figure 4.7: Conceptual modeling of the integration of general ledger accounts

Allocation of Resources

With regard to conceptual modeling of the ABC framework, the final stage is related to the allocation of resources. Table 4.4 presents the identified requirements of Section 2.5 according to the resource allocation.

No.	Requirement
1.1	The conceptual model shall be able to the depict activities with an unique identifier attribute.
1.2	The conceptual model shall enable the mediation between resources and activities using resource cost drivers. In case of resource cost drivers, the following attributes must be considered: resource type, cost driver quantity, and unique identifier of activities.
1.3	The conceptual model shall enable the mediation between finished goods and activities using activity cost drivers. In case of activity cost drivers, the following attributes must be considered: cost driver quantity, unique identifiers of finished goods and activities.

Table 4.4: Identified requirements in terms of resource allocation

Figure 4.8 shows the conceptual modeling of the resource allocation. This part is modeled on the basis of the identity-providing *Kind* class of economic resources, which is directly adopted from the REA accounting model. For the mapping of activities a *Kind* class is utilized as well.

The first stage of resource allocation is described through the *Relator* class of resource cost drivers, which mediates between economic resources and activities. Since these resource cost drivers are defined for each type of resources, the resource type is applied at the *Relator* instead of an unique identifier attribute of economic resources. The resource consumption of activities is visualized with a *Material Relation* in the following way: An activity consumes one or more economic resources, and a certain economic resource can be consumed by one or more activities. Economic resources include consumption factors, which are loosing their identity during the production process, as well as production factors, which keep their identity through several production processes.

Similarly, the second stage of resource allocation is illustrated by including the *Relator* class of activity cost drivers. It describes the relationship between finished goods and activities by means of a *Material Relation*, so that the manufacturing of finished goods requires the execution of one or more activities. An activity may be required by one or more finished goods because there are finished goods that require the same activities for their production process. Apparently, the resources or expenses that have been assigned to activities by resource cost drivers before, need to be traced back in such a manner from activities to finished goods now. As in Figure 4.8 shown, all cardinalities have been specified.

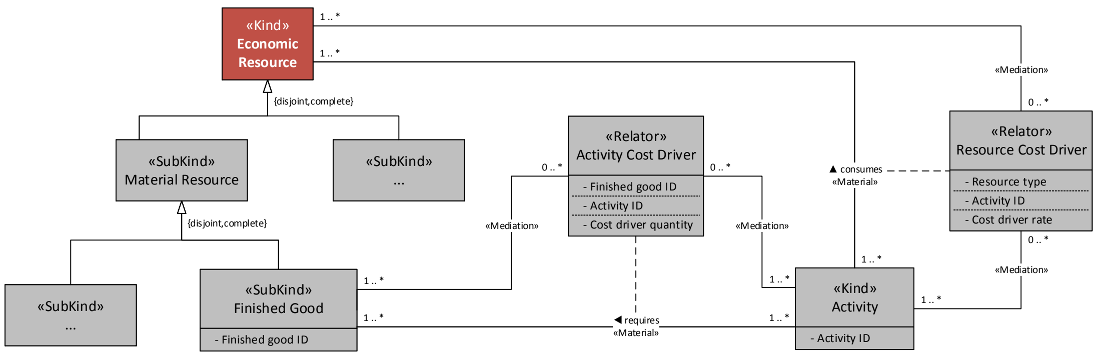


Figure 4.8: Conceptual modeling of the allocation of resources

4.5 Modeling of the Flexible Budgeting Fundamentals

This section is intended to describe the conceptual modeling part of flexible budgeting fundamentals. It is built upon the findings of the first part of conceptual modeling regarding the ABC framework. Analogically to before, the identified requirements of Chapter 3 are utilized as a foundation for conceptual modeling of the flexible budgeting fundamentals.

Inclusion of the Key Components

Table 4.5 provides a summary of identified requirements regarding the key components of flexible budgeting, which have been derived in the Sections 3.1, 3.2 and 3.4. Within this context, those key components are referred to operating expenses, production volumes, activity levels, and planning periods.

No.	Requirement
4.1	The conceptual model shall include the explicit mapping of planning periods with an unique identifier attribute.
4.2	The conceptual model shall be able to depict the production volumes of finished goods with an emphasis on their unique identifiers and quantities.
4.3	The conceptual model shall ensure the correct mapping of operating expenses in correspondence with the expense accounts of the general ledger by considering the following attributes: unique identifier, amount of expense, and variator.
4.4	The conceptual model shall include the mapping of activity levels based on the extent of activity level and an unique identifier.

Table 4.5: Identified requirements regarding the key components of flexible budgeting

With reference to the above mentioned requirements, the conceptual modeling part of flexible budgeting key components is shown in Figure 4.9. Since all flexible budgeting elements are referred to transactional data of recurring planning activities, their classes are highlighted in blue within the conceptual model. Thus, a clear separation from master data classes is ensured, which are highlighted in gray at this conceptual model. Figure 4.9 represents just a small fraction of the complete conceptual model and is used for explanatory purposes only. Therefore, it comprises merely the essential characteristics that are important in the context of this modeling section. However, when the modeling part of this figure is viewed as an autonomous conceptual model, it is neither consistent nor valid in the OntoUML [25] because some crucial elements are missing here.

Initially, the planning period is modeled using an identity-providing *Kind* class. As the flexible budgeting process is based on recurring planning activities, a series of transactional data records is produced over several planning periods. The components of each transactional data record belong to a certain planning period, or, in other words, a planning period has components such as operating expenses, production volumes, activity levels, and data pools. These components are part of a planning period. Therefore, the planning period class is utilized as a core element that establishes a linkage between all those components regarding the flexible budgeting process. With respect to conceptual modeling, the classes of those components are related to the planning period class through *Formal Relations* in the following way: All flexible budgeting components, such as operating expenses, production volumes, activity levels, or data pools, are exclusively allocated to a certain planning period. This means that the instances of flexible budgeting components are uniquely related to a certain instance of planning period as well.

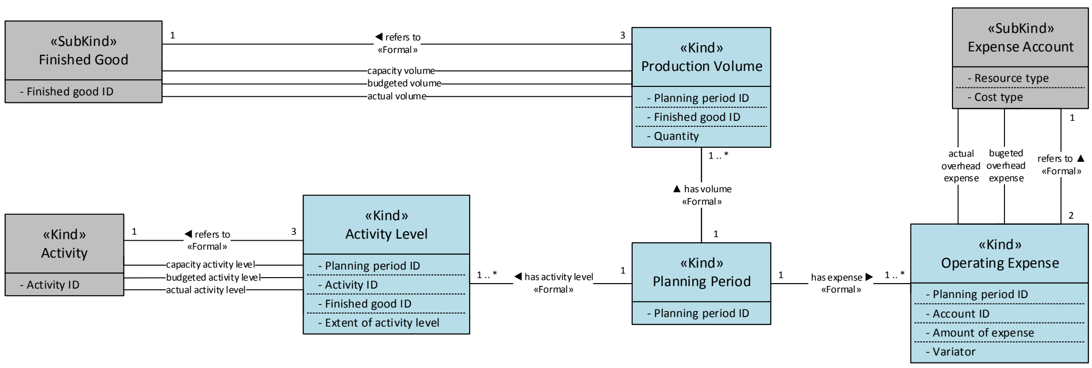


Figure 4.9: Conceptual modeling of the key components of flexible budgeting

The operating expenses are modeled by using a *Kind* class that contains the information of an operating expense about the amount of expense and its factor of variability, which is called 'variator'. Additionally, there is a *Formal Relation* that describes the relationship between the operating expense class and the expense account class in the following way: An operating expense always refers to exactly one expense account, and an expense account involves exactly two operating expenses at a certain planning period. The first operating expense is referred as budgeted expense of an expense account, and it is determined at the beginning of a planning period. Whereas the second operating expense corresponds to the actual expense of an expense account, which is realized at the end of a planning period.

Another component of flexible budgeting are the production volumes, which are also modeled through an identity-providing *Kind* class. Similarly, there is a *Formal Relation* that explains the relationship between production volumes and finished goods. It describes the relation as follows: A production volume is referred to exactly one finished good, while a finished good involves exactly three production volumes at a certain planning period. Therefore, these different production volumes are denoted as capacity volume, budgeted volume, and actual volume. Furthermore, the activity level class and its *Formal Relations* are defined in a similar way.

Mapping of Data Pools

The identified requirements regarding the mapping of data pools, which have been derived in Section 3.3 and Section 3.5, are summarized in Table 4.6.

No.	Requirement
5.1	The conceptual model shall include the explicit mapping of data pools with emphasis on the common attributes of cost and activity pools.
5.2	The conceptual model must be able to depict the cost pools with focus on the attributes: resource type, variator, budgeted expense, and actual expense.
5.3	The conceptual model shall be able to depict activity pools based on the attributes: capacity driver rate, budgeted driver rate, budgeted unused capacity, capacity utilization variance, expense charged to products, flexible budget, and spending variance.

Table 4.6: Identified requirements concerning the mapping of data pools

Figure 4.10 shows the conceptual modeling part of data pools. An identity-providing *Kind* is applied for the modeling of the data pool class. It captures the common characteristics of cost and activity pools. Data pools are linked to planning periods based on a *Formal Relation*, which describes the relationship in the following way: Each data pool belongs to exactly one planning period, and at a certain planning period several data pools may be involved.

Since the cost and activity pool are subtypes of the data pool class, they are modeled as *Subkind* classes. Obviously, the cost and activity pool classes are related to the planning period class because they inherit the *Formal Relation* from the data pool class. The cost pools are associated with the activities by using a *Formal Relation*: A cost pool instance is uniquely assigned to an activity, and one activity may involve several cost pool instances. Similarly, the activity pools are related to activities through a *Formal Relation* that is based on an one-to-one mapping: Each activity pool is referred to exactly one activity and vice versa.

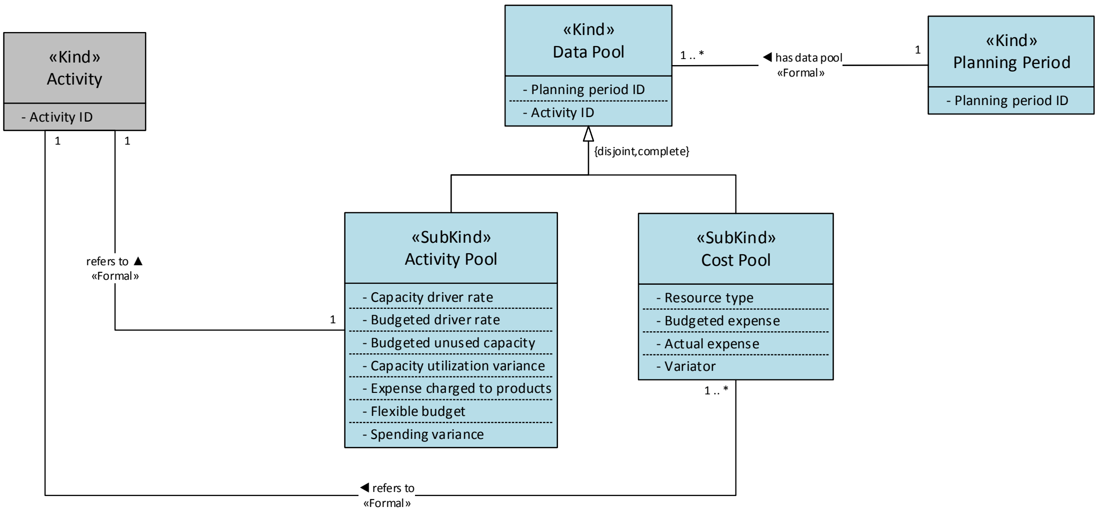


Figure 4.10: Conceptual modeling of the mapping of data pools

4.6 Conceptual Model of Capacity-Based ABC System

Finally, the conceptual model of the capacity-based ABC system (cf. Figure 4.11) is obtained by merging the conceptual modeling parts of preceding sections. It captures the ontology of the capacity-based ABC system in terms of flexible budgeting purposes. The conceptual model is constructed in conformity with the syntactical and semantical specifications of the OntoUML [25]. Another focal point is that the conceptual model is developed as an extension of the well-founded REA accounting model. Due to solely slight differences among the REA and OntoREA accounting model, the conceptual model can be easily adapted to the needs of the OntoREA accounting model as well. In this paper, the conceptual model corresponds to the primary research artifact. Therefore, it must be evaluated in accordance with the design-science research guidelines of Hevner et al. [10]. So, the conceptual model is utilized as a foundation for prototypical implementation in the course of an observational case study within the upcoming chapter.

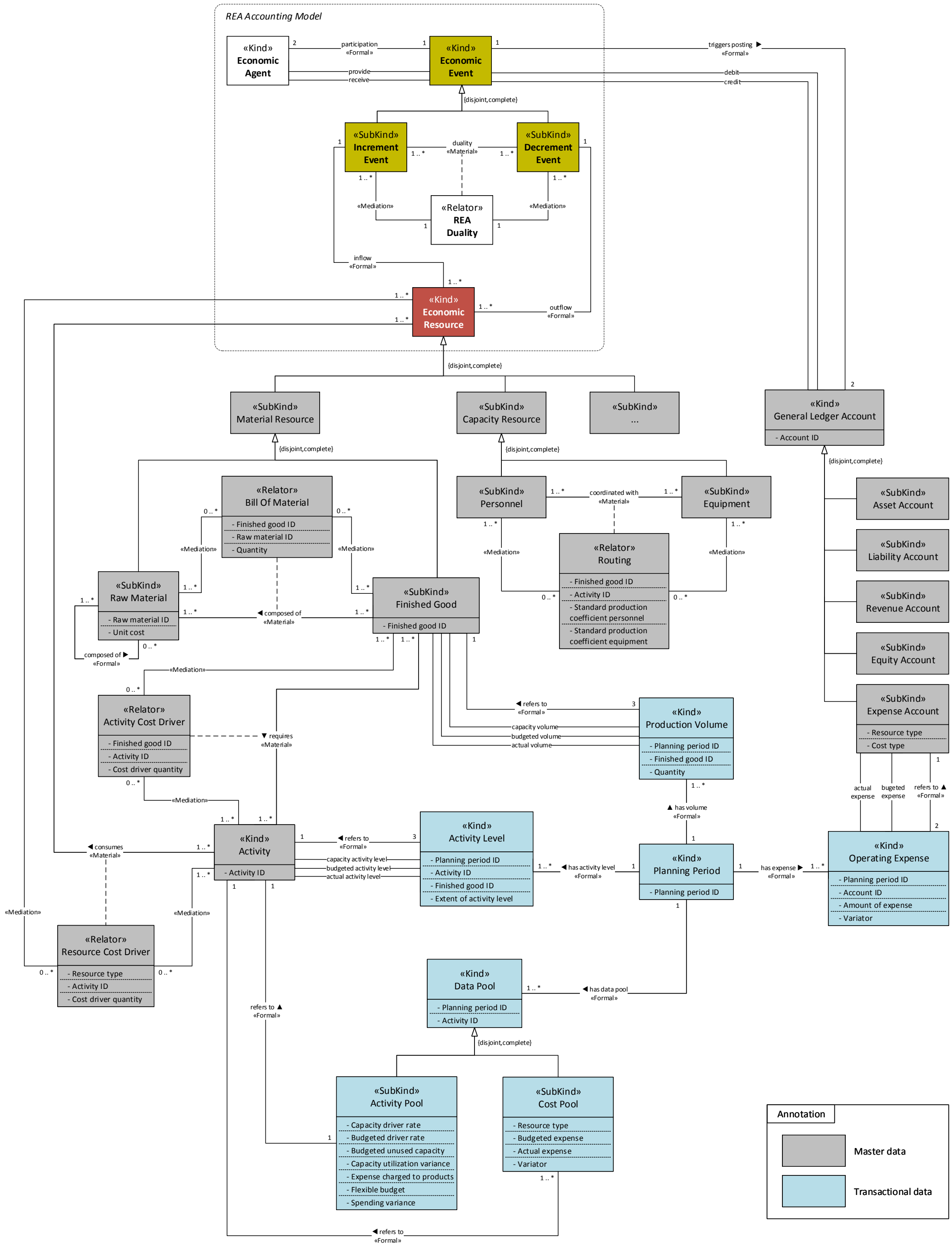


Figure 4.11: Conceptual model of the capacity-based ABC system

CHAPTER 5

Prototypical Implementation and Evaluation

The purpose of this chapter is twofold: On the one hand, it discusses the prototypical implementation of the capacity-based Activity-Based Costing (ABC) system for flexible budgeting, in which the conceptual model is applied. And on the other hand, this chapter describes the evaluation of the conceptual model. Firstly, it is evaluated in the course of an observational case study, whereby the aforementioned prototypical implementation is executed and demonstrated. Then the conceptual model is discussed within a qualitative analysis regarding the defined problem domain of this thesis.

5.1 Design of the Evaluation Process

The evaluation process of the conceptual model is designed based upon the prototypical implementation, which is composed of an Entity-Relationship (ER) model, two Unified Modeling Language (UML) activity diagrams, a database implementation and a web-based application for accessing the database. Since those components are emerged from the conceptual model, they are used for its evaluation later on. As outlined in Chapter 1, the evaluation process of research artifacts is based on three different evaluation stages (cf. Figure 5.1). Since the design of research artifacts is inherently incremental and iterative [10], each evaluation stage involves a feedback loop, so that refinements are enabled at any stage of the evaluation process. Subsequently, the stages of this evaluation process are described in regard to their corresponding research artifacts:

Evaluate/Refine I: The first evaluation stage is concerned with validating the solution-independent conceptual model by means of more concretized ER modeling. Thereby, the conceptual model is utilized as a starting point for transforming the capacity-based ABC system into a concretized ER diagram. In addition, two

UML activity diagrams are developed to visualize the activity/information flow of calculations, which are performed with the capacity-based ABC system.

Evaluate/Refine II: The second stage of evaluation takes place within the prototypical implementation. Thereby, the software-independent ER diagram is evaluated on the basis of a corresponding database implementation. Moreover, the UML activity diagrams are also incorporated in this evaluation stage.

Evaluate/Refine III: Finally, the third stage of the evaluation process is concerned with an observational evaluation of the prototypical implementation based on a use case demonstration. In detail, this means that the database implementation is evaluated using the data set of the case study regarding a fictional use case.

With respect to the above mentioned description of the evaluation process, the conceptual model is solely evaluated in an explicit manner in the first evaluation stage. Within the second and third stage, the conceptual model is merely evaluated in an implicit way by evaluating components that have been emerged from it.

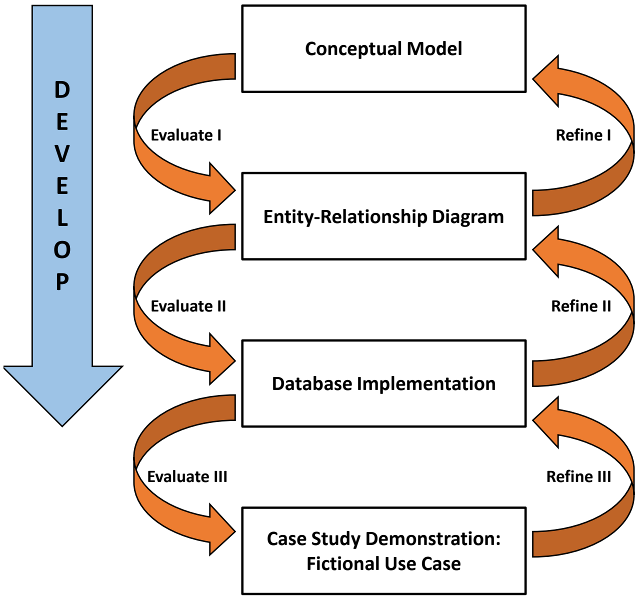


Figure 5.1: Designed evaluation process for the research artifacts of this thesis

According to the design-science research guidelines of Hevner et al. [10], the evaluation must ensure that utility, quality, and efficacy of designed artifacts are rigorously demonstrated by appropriate methods, which are available in the knowledge base of the respective problem domain. In regard to innovation and knowledge base of the conceptual model, an observational case study has been selected as the evaluation method for a rigorous demonstration.

5.2 Fundamentals of Prototypical Implementation

For the purposes of this thesis, a prototypical implementation of the capacity-based ABC system is performed, in which the conceptual model is applied. This prototypical implementation is carried out in the course of a case study. As outlined earlier, a fictitious data set has been constructed for carrying out the case study. It is comprised of sample data from the **Slot Car Manufacturing Ltd.**, which is a company for the manufacturing of slot cars. With respect to practical considerations, this data set has already been introduced during the investigations of Chapter 2 and Chapter 3.

The primary objective of the case study is to demonstrate utility and efficacy of the conceptual model. Therefore, this conceptual model is applied for performing a prototypical implementation. As a starting point, the prototypical implementation is supposed to cover the basic operating principles of Figure 5.2, which is illustrating them at a high level of abstraction. Consequently, this figure is considered as a valuable instrument for the further implementation process.

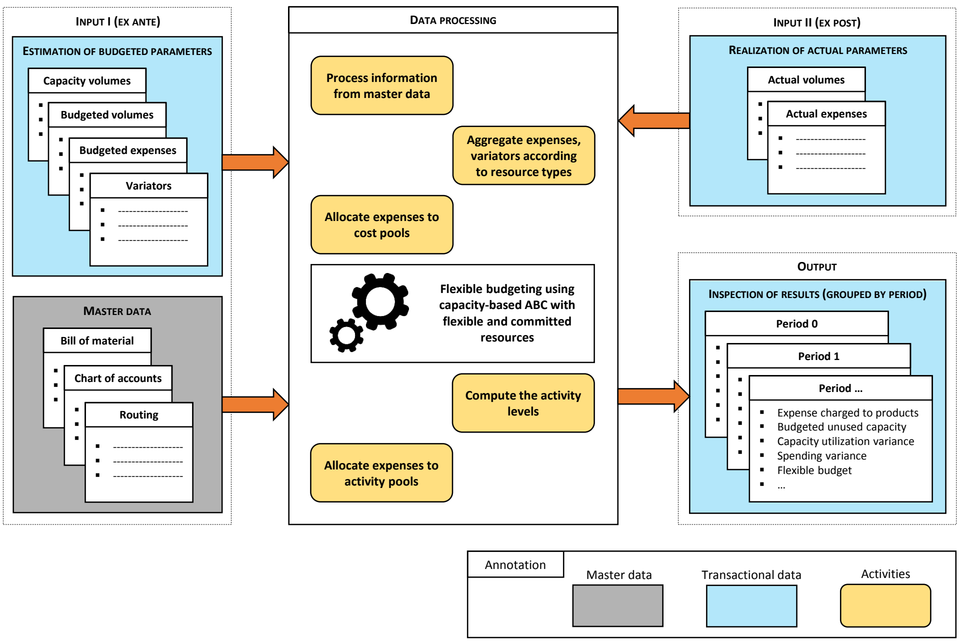


Figure 5.2: Illustration of basic operating principles of the prototypical implementation

At the beginning of a planning period (ex ante) the budgeted parameters are derived from an expert estimation. Thereby, the transactional data of the first input is collected from the Graphical User Interface (GUI) and then stored into the database. The master data can be queried on demand because the entire data processing is immediately performed at the database. After the information of first input is processed, the output fields of resulting parameters, which can be computed ex ante, are filled with data. However, the majority of resulting parameters requires information of actual parameters, which can only be obtained at the end of a planning period (ex post). Until this information of actual parameters is incorporated, the affected output fields are displayed as empty fields. At the end of a planning period, when the second input of actual parameters is gathered from the GUI and stored into the database, all results of the respective planning period are displayed.

Based on the identified operating principles above, the goal is to provide a prototypical implementation that facilitates the input/output of parameters as well as the data processing in regard to aforementioned functionalities. Within the upcoming sections of this chapter, the prototypical implementation is described regarding the development of its particular components.

5.3 Modeling of the Database Design

As a starting point to prototypical implementation, the modeling of the database design is discussed with regard to the conceptual model. In fact, the conceptual model is utilized as a foundation for the modeling of the database design. Here, one may ask why someone should develop another model when there already exists one, but there are distinct models with varying levels of abstraction, which are developed for distinct purposes.

With reference to Section 4.1, there are fundamental differences between ontological and epistemological modeling approaches. Even if there is no clear consensus regarding the orientation of conceptual modeling within scientific community [22], the conceptual model of this paper is developed based on an ontological modeling approach. When interpreting the term 'conceptual modeling' as primarily ontologically-oriented, it is recognizable that there is almost always a conceptual model for any conceivable system. In practice, such conceptual models are often not modeled in an explicit manner, and therefore they merely exist in the minds of involved stakeholders. However, an explicit version of the underlying conceptual model is mostly recommended for implementation processes of complex systems, as is the case with the capacity-based ABC system for flexible budgeting.

The database design of prototypical implementation is modeled through an ER diagram by means of the standardized database notation of the UML. In contrast to the conceptual model which is based on an ontological approach, the ER diagram is mainly modeled from an epistemological perspective. Therefore, this ER diagram is more subjective in its nature and it strongly depends on the perspective of an observer. Even if the solution-independence of an ontology-driven conceptual model is beneficial for its universal applicability, a more concretized model is usually required for implementation purposes. Hence, the ER diagram is developed as a concretization of the underlying conceptual model.

Figure 5.3 represents the ER diagram of the prototypical implementation regarding the case study. With respect to an appropriate concretization for implementation purposes, the following adaptations are made when developing the ER diagram:

- The activity cost driver class is rather integrated into the routing class than modeled as an autonomous entity. Since both classes are using the same key attributes, this reduction of entities is viable.
- The material table contains data of all material resources such as finished goods and raw materials. Within this table, there is a differentiation between material resources that is made by using the material type attribute. On the one hand, there are material resources that are composed of other materials, such as finished goods and assembled raw materials. And on the other hand, there are basic materials that can be interpreted as elementary and therefore they are not comprising other material resources. In addition, there is a separate table of finished goods that is required for the representation of logical relationships through facilitating an unambiguous inclusion of finished goods. Furthermore, the Bill of Material (BOM) table establishes a linkage between material resources and finished goods as well as it describes the recursive relationships among material resources.
- In contrast to conceptual model, two additional tables that are not directly derivable are involved at the ER diagram. The first one corresponds to the resource expense structure table, which is used for aggregating the operating expenses according to their underlying resources types. While the second table is related to the cost object structure of finished goods and therefore it allocates the expenses at the unit level of cost objects. Both of those aforementioned tables are storing redundant information that can be retrieved through calculations from other tables too. However, this is justifiable due to performance reasons, because the stored information is often queried but rarely changed.
- With respect to future work, especially focusing on the integration of general ledger bookings, a booking matrix attribute is added at the general ledger account table.
- For the planning periods table, two boolean flag attributes are added in order to check whether or not the budgeted/actual parameters for a particular planning period have been already confirmed.
- Moreover, additional attributes are specified at some entities, which have been neglected at the conceptual model. These attributes are mainly included for explanatory purposes, such as naming or description of other parameters and therefore they usually involve only less information gain.
- Attributes that must be specified without accepting null values are highlight in bold at Figure 5.3. Otherwise, the attributes that are not highlighted in bold are defined as optional and thus can take on null values too.

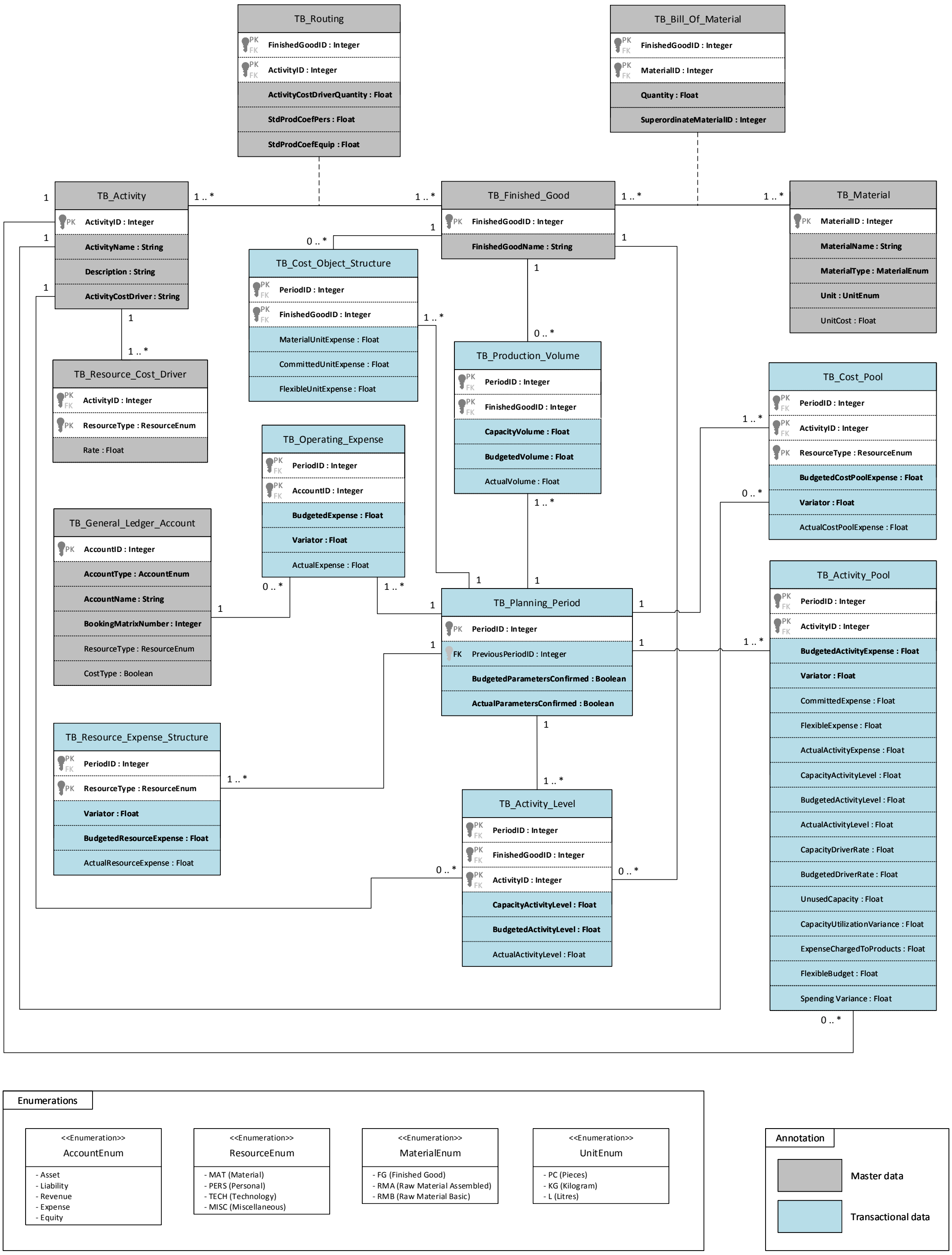


Figure 5.3: Entity-relationship (ER) diagram of the database

Another focal point of the database design is related to the development of UML activity diagrams. Given the fact that all calculations are directly performed on the database, activity diagrams are utilized to enhance the comprehensibility of these calculation procedures. Unfortunately, neither the ER diagram nor the conceptual model are appropriate for the mapping of activity/information flows. Therefore, the calculation steps are directly gathered from the identified formulas of Chapter 2 and Chapter 3. With respect to flexible budgeting fundamentals, two UML activity diagrams are required for visualizing the activity and information flow of calculations to be performed.

Figure 5.4 shows the first activity diagram that is intended to visualize the activity/information flow of calculations at the beginning of a planning period, or in other words ex ante. These calculations are triggered when the estimation of budgeted parameters is entered and confirmed. Within this context, the budgeted parameters are referring to capacity volumes, budgeted volumes, budgeted expenses, and variators. As a result of calculations, which are solely based on budgeted parameters, the following information can be obtained: budgeted activity expenses, capacity driver rates, budgeted driver rates, and budgeted unused capacities.

The second activity diagram of Figure 5.5 visualizes the activity and information flow of calculations that is processed at the end of a planning period, so ex post. The entering and confirmation of actual parameters, such as actual volumes and actual expenses, are triggering these calculation processes. Finally, the missing flexible budgeting information of the respective planning period is obtainable as well: actual activity expenses, expenses charged to products, capacity utilization variances, flexible budgets, and spending variances.

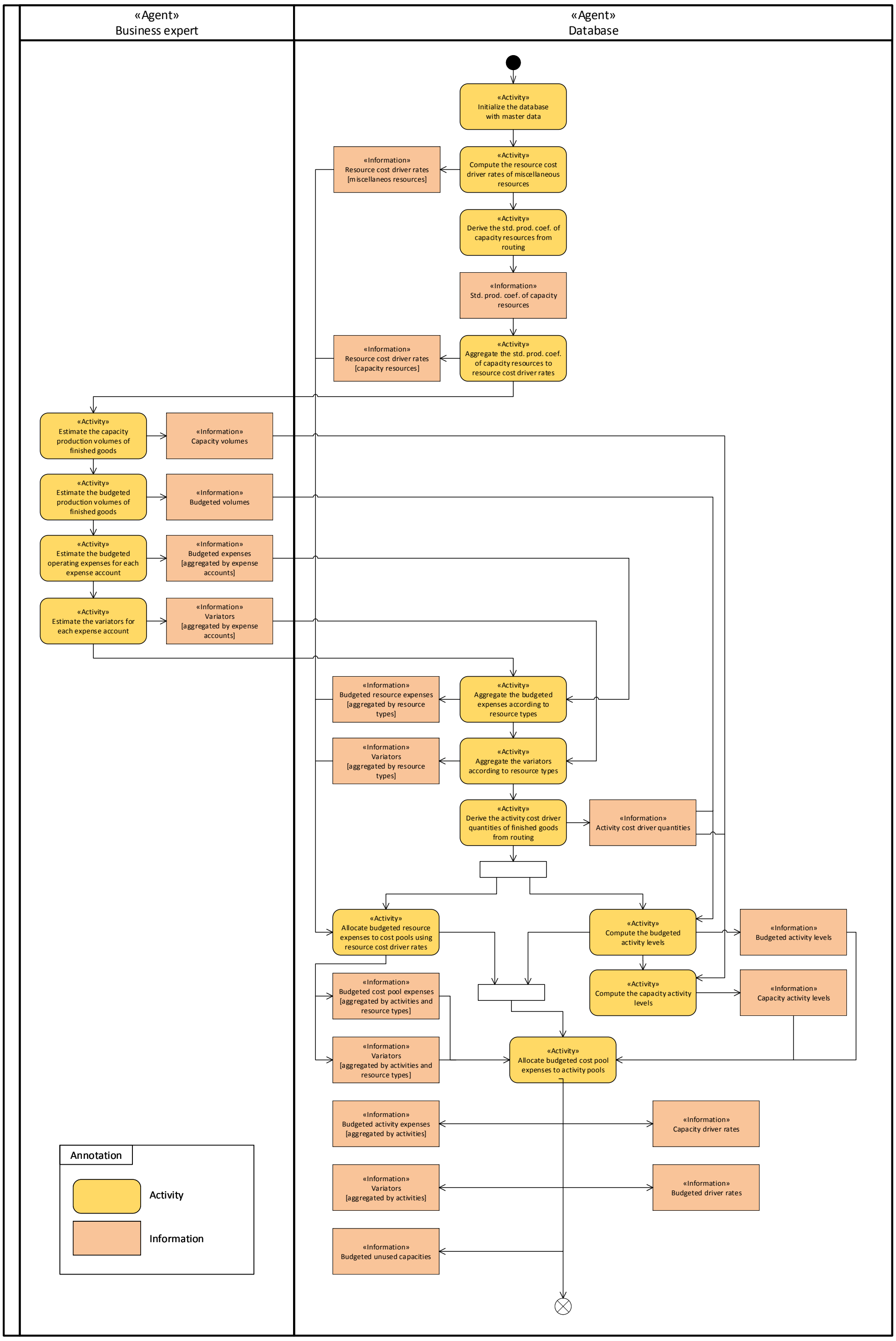


Figure 5.4: UML activity diagram I of the activity and information flow (ex ante)

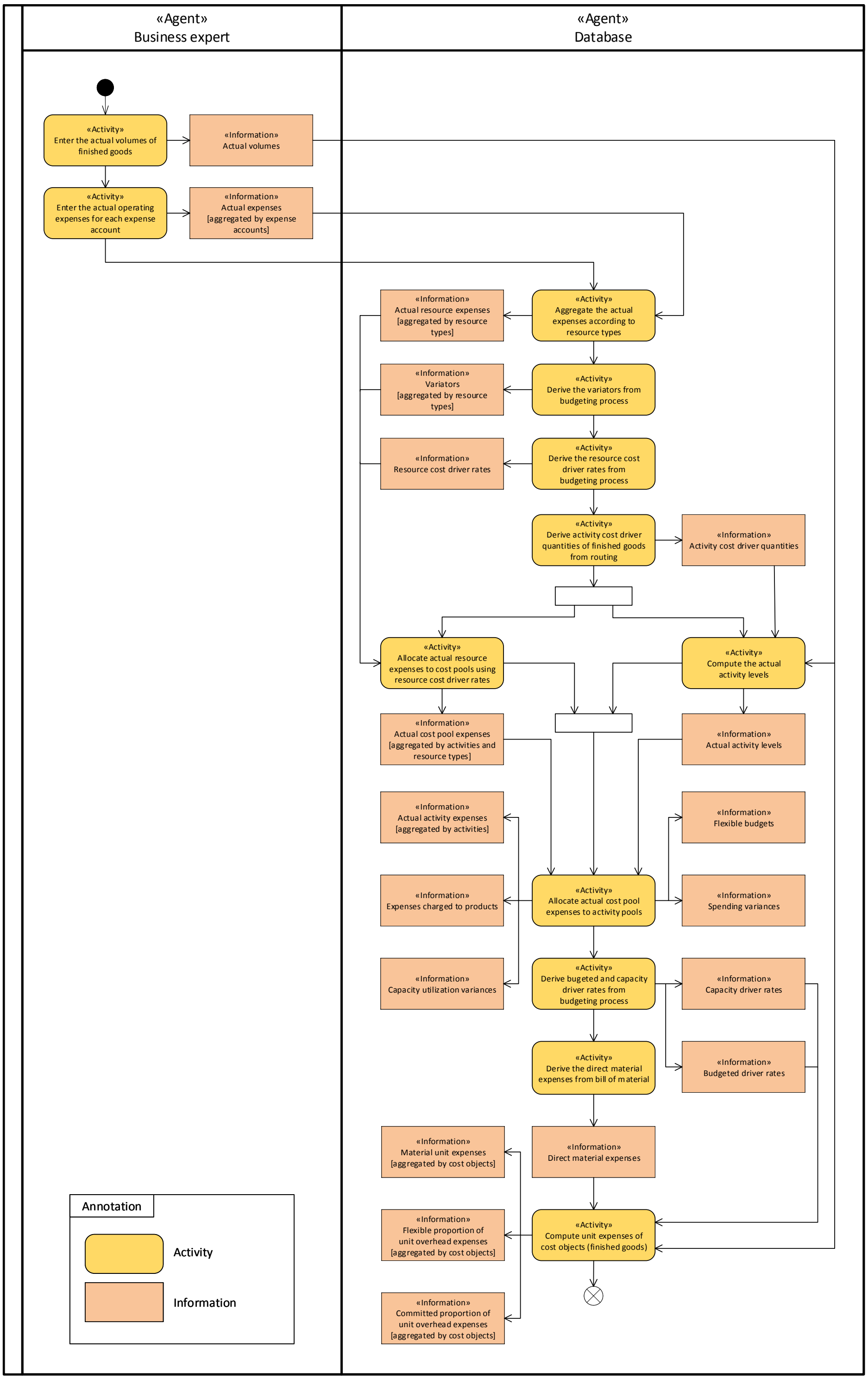


Figure 5.5: UML activity diagram II of the activity and information flow (ex post)

5.4 Database Implementation

The ER diagram captures all essential characteristics of the underlying capacity-based ABC system in such a manner that it supports a database implementation. Consequently, the implementation of the database is almost directly derived from that ER diagram. In addition, the UML activity diagrams are utilized for implementing the calculation procedures at the database. As mentioned beforehand, all calculations that are illustrated at the UML activity diagrams are performed right at the database.

It should be noted that the web-based application of Section 5.5 requires a running PostgreSQL[1] database at the localhost with below mentioned configurations. Otherwise, the database settings of the web-based application must be adapted. The default configuration of the database corresponds to the following required credentials:

- **Host name/address:** localhost
- **Port:** 5432
- **Database name:** postgres
- **User name:** postgres
- **Password:** »by default, there is no password specified«

The database implementation is based on SQL files, which can be accessed through the Git repository[2] of the prototypical implementation. Furthermore, all other components of the prototypical implementation are accessible via this repository.

5.5 Architecture of the Application

The web-based application is written in the R[3] programming language by using the development environment of RStudio[4]. R is known as an interpreter language that supports procedural as well as object-oriented programming. Typically, it is used for statistical computing and graphics. However, the Shiny[5] package of R enables the building of web applications within the development environment of RStudio. Hence, the web application of this thesis is developed based on R Shiny.

First of all, the web-based application is composed out of two files: the **server.R** file that contains the application logic, and the **ui.R** file that defines the output of data at the GUI. This clear separation of application logic from output is characteristically for

[1] https://www.postgresql.org/, Version 11
[2] https://github.com/CFraller/mt_prototypical_impl.git
[3] https://cran.r-project.org/, Version 3.4.4
[4] https://rstudio.com/, Version 1.2.1335
[5] https://shiny.rstudio.com/, Version 1.2.0

a web application that is developed using R Shiny. Thus, the database implementation is integrated into the web-based application at the **server.R** file. Moreover, the database settings can be changed at this file when changes are required due to a different configuration of the database. Both of these files are accessible through the aforementioned Git repository of the prototypical implementation.

Figure 5.6 shows the graphical layout that is used for the estimation of budgeted parameters as well as for the realization of actual parameters. Thereby, the web application provides two options for determining those parameters. The first option of flexible budgeting is based on a naive calibration, which assumes the historical values of the previous planning period as budgeted parameters. While the actual parameters are determined by specifying the percentage variance of volume and expense. On the other hand, the second option corresponds to flexible budgeting using an expert estimation for the determination of budgeted parameters. Thereby, the budgeted and actual parameters can be specified in more detail than at the naive calibration.

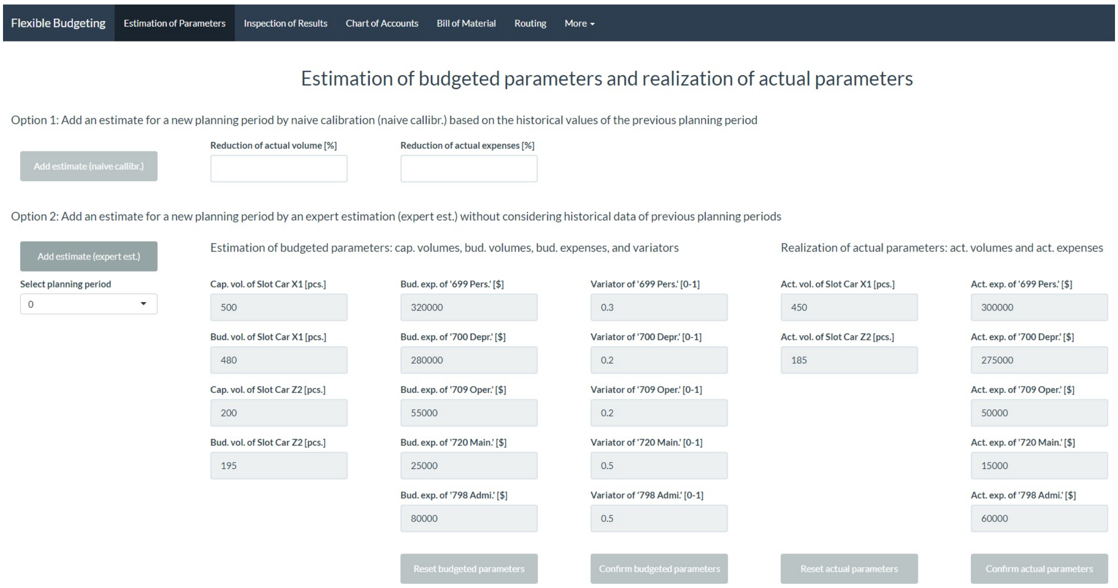


Figure 5.6: Estimation of budgeted parameters and realization of actual parameters

The second tab of the web-based application is concerned with the inspection of results. It is illustrated in Figure 5.7 and presents the most relevant results of flexible budgeting. The first table of this figure shows the aggregated results of all planning periods for comparison purposes. The rows of this table are selectable in order to enable the inspection of data from a selected planning period in more detail. By selecting a row *Table 1*, the cost pool and activity pool data of the corresponding planning period are displayed.

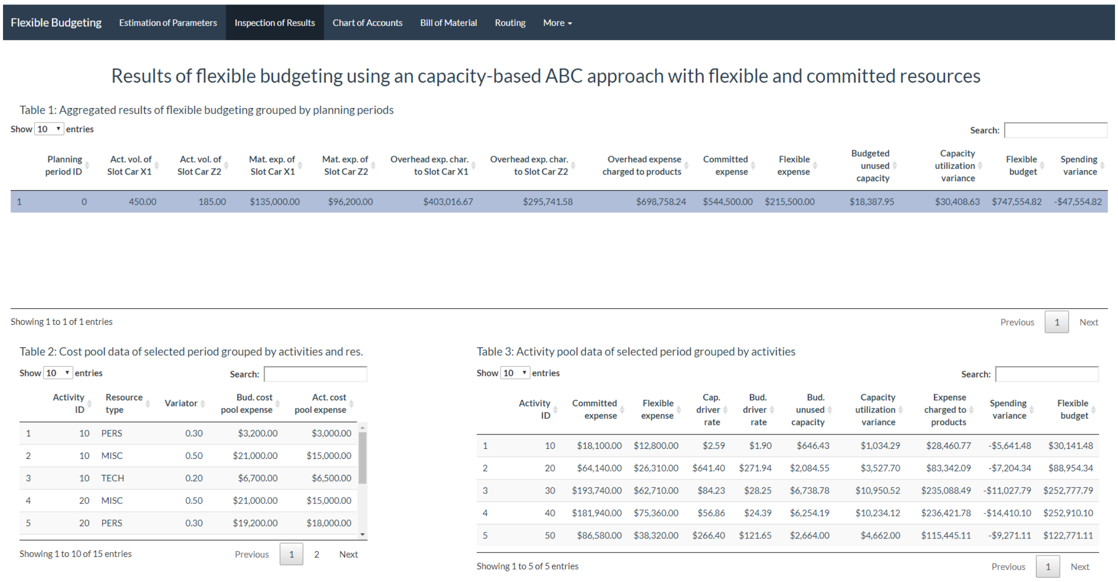


Figure 5.7: Inspection of flexible budgeting results

Figure 5.8 illustrates the viewing of database tables at the web application. This function is integrated in order to facilitate the traceability of results in case of obscurities through enabling a direct access to database. In addition, a reset button is included for resetting the database to its initial state.

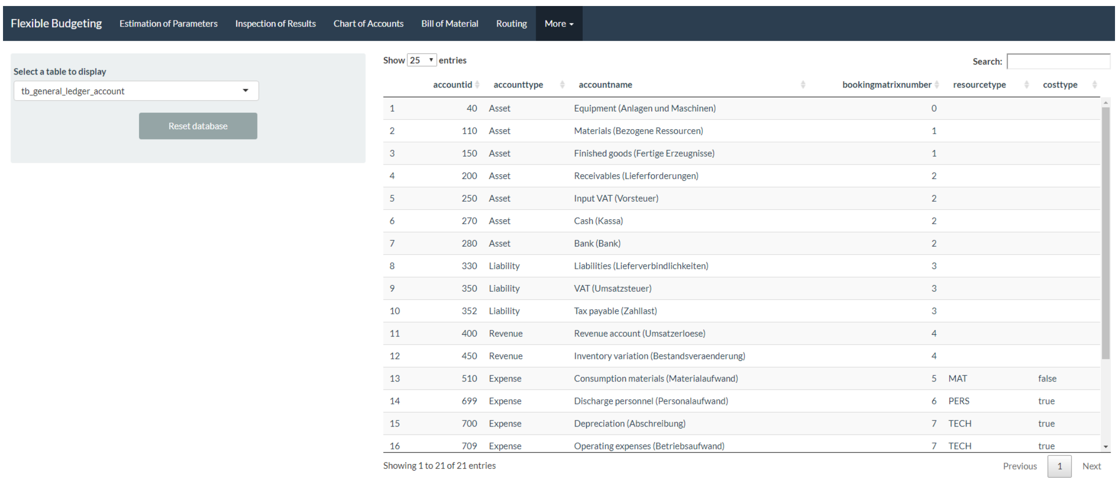


Figure 5.8: View of the database tables

5.6 Demonstration and Evaluation

This section discusses the final step of the case study demonstration as well as the qualitative analysis of the conceptual model. First, the case study demonstration is observed by using a fictional use case in order to conclude the rigorous demonstration of utility and efficacy regarding the conceptual model. Then it is discussed concerning the identified shortcomings of this paper based on a qualitative analysis. This ensures that the quality of the conceptual model is rigorously demonstrated as well. Therefore, the qualitative analysis shows the completeness and consistency of the conceptual model in respect with the defined problem domain of this thesis.

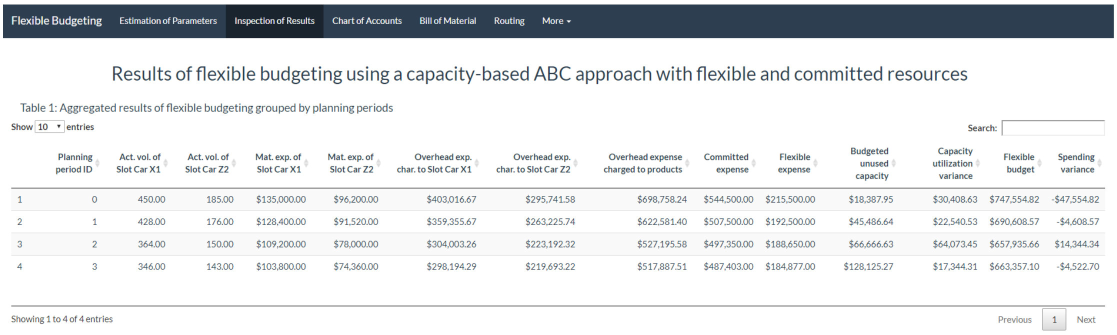
Case Study Demonstration: Fictional Use Case

The final part of the case study is concerned with its demonstration based on an observational evaluation of the prototypical implementation. Thereby, the database implementation is evaluated by using the data set of the case study regarding a fictional use case. For accessing the database implementation, the web-based application is utilized. In the end, a conclusion is drawn whether or not the expected results have been achieved.

The fictional use case is based on the example of Section 3.6, in which the arise of a death spiral has been demonstrated. For entering the data of input parameters, the GUI of the web-based application is utilized. Since the initial values of this use case are already stored at the database, both options can be selected for estimation of parameters. Nevertheless, the first option is recommended because its estimation method corresponds to a naive calibration, which is needed for the use case too. With regard to this option, it is sufficiently to enter the percentage variances of actual volumes and expenses compared with their corresponding budgeted parameters. On the other hand, when the expert estimation is used for determining the parameters, they need to be calculated manually in advance before entering. Table 3.13 shows these parameters for the expert estimation, which have already been calculated. As a result, the reproducibility of this use case is ensured for both estimation methods.

Independently of the selected option for estimation of parameters, the achieved results should be the same. Figure 5.9 shows the results that are obtained from the prototypical implementation regarding this use case. Next, those results are compared with the results of Table 3.16, which have been previously calculated using Excel sheets. This comparison clearly shows that the obtained results are correspond to each other. Furthermore, the results of the prototypical implementation provide more details for decision-making due to the material expenses are included as well as the overhead expenses are partitioned according to different finished goods.

Consequently, the case study is successfully completed through the observational evaluation, in which a use case demonstration has been performed. Within this case study, the utility and efficacy has been rigorously demonstrated for the prototypical implementation as well as for the conceptual model.



	Planning period ID	Act. vol. of Slot Car X1	Act. vol. of Slot Car Z2	Mat. exp. of Slot Car X1	Mat. exp. of Slot Car Z2	Overhead exp. char. to Slot Car X1	Overhead exp. char. to Slot Car Z2	Overhead expense charged to products	Committed expense	Flexible expense	Budgeted unused capacity	Capacity utilization variance	Flexible budget	Spending variance
1	0	450.00	185.00	$135,000.00	$96,200.00	$403,016.67	$295,741.58	$698,758.24	$544,500.00	$215,500.00	$18,387.95	$30,408.63	$747,554.82	-$47,554.82
2	1	428.00	176.00	$128,400.00	$91,520.00	$359,355.67	$263,225.74	$622,581.40	$507,500.00	$192,500.00	$45,486.64	$22,540.53	$690,608.57	-$4,608.57
3	2	364.00	150.00	$109,200.00	$78,000.00	$304,003.26	$223,192.32	$527,195.58	$497,350.00	$188,650.00	$66,666.63	$64,073.45	$657,935.66	$14,344.34
4	3	346.00	143.00	$103,800.00	$74,360.00	$298,194.29	$219,693.22	$517,887.51	$487,403.00	$184,877.00	$128,125.27	$17,344.31	$663,357.10	-$4,522.70

Figure 5.9: Results of case study demonstration based on a fictional use case

Qualitative Analysis of Conceptual Model

The aim of this thesis is to provide a conceptual model that closes the gap between economic sciences and modeling techniques in terms of conceptual modeling of capacity-based ABC for flexible budgeting. In order to establish a solid foundation for conceptual modeling, a capacity-based ABC system has been designed. Next, the requirements for conceptual modeling have been identified based on the ontological properties of this capacity-based ABC system. Finally, the conceptual model has been developed based on those identified requirements.

Even if the utility and efficacy of the conceptual model have already been demonstrated at the case study demonstration, the quality must be rigorously demonstrated as well. In conformity with the design-science research guidelines of Hevner et al. [10], the quality the conceptual model is demonstrated regarding its completeness and consistency. So, this part of the evaluation is concerned with the qualitative analysis of the conceptual model in respect with the defined problem statement of this paper. Consequently, the focus of this analysis is to ensure that the identified problems are entirely clarified with the conceptual model.

Figure 5.10 shows a separation of the conceptual model according to the identified shortcomings. Therefore, it is ensured that the conceptual model provides a proper solution for each identified shortcoming. In other words, this figure visualizes the completeness of the conceptual model regarding the particular problem domain of this thesis. For the demonstration of consistency, the proposed solutions of the conceptual model are examined in more detail with respect to identified shortcomings of Table 1.1:

1. **Resource Typification**
   The conceptual model provides a fully conceptualized typification of resources regarding the implementation of a capacity-based ABC system. In order to ensure

a standardized resource typification, resources have been typified in conformity with the Enterprise Control System Integration (ECSI) standard [17] [18]. This standardization facilitates a seamless integration in respect to the implementation of information systems, such as for a Management Information System (MIS).

2. Integration of General Ledger Accounts
For reasons of practicability, the general ledger accounts have been integrated on the basis of the Austrian uniform scheme of accounts [19]. In addition, this issue is concerned with the distinction of expenses according to cost and resource types. Hence, appropriate attributes for the expense account have been added in order to enable a clear distinction between these cost and resource types.

3. Allocation of Resources
The allocation of resources has been established on the findings of the cost allocation of Kaplan and Cooper [16]. First, the mapping of resources to activities is enabled by using resource cost drivers. Next, activity cost drivers have been introduced to allocate the resources from activities to cost objects, such as finished goods. This resource allocation approach enables clear assignment of resources as well as their traceability during the various stages of allocation.

4. Inclusion of Key Components for Flexible Budgeting
As shown in Figure 5.10, the conceptual model provides an appropriate solution to the inclusion of key components for flexible budgeting into an ABC framework. Within the conceptual model, all identified key components for flexible budgeting have been included, which are namely: operating expenses, production volumes, activity levels, and planning periods.

5. Mapping of Data Pools
The conceptual model presents an option for the mapping of data pools, such as activity and cost pools. Thereby, the cost pools have been integrated to aggregate expenses according to activities and resource types in order to enable further assignments to activity pools. Whereas the activity pools have been included to present the results of flexible budgeting as stated in the calculation procedures of Kaplan [6].

The quality of the conceptual model has been rigorously demonstrated in terms of its completeness and consistency. Since the conceptual model is able to solve all the identified shortcomings that are addressed in this thesis, it represents an improvement compared with existing literature of this research area. Initially, the design goals of the conceptual model have been twofold: On the one hand, the conceptual model was supposed to be developed as an extension of the well-founded REA accounting model of McCarthy [8]. And on the other hand, the goal was to keep the conceptual model as generic as possible. Thus, an universal applicability of the conceptual model is ensured due to both of those design goals are fulfilled.

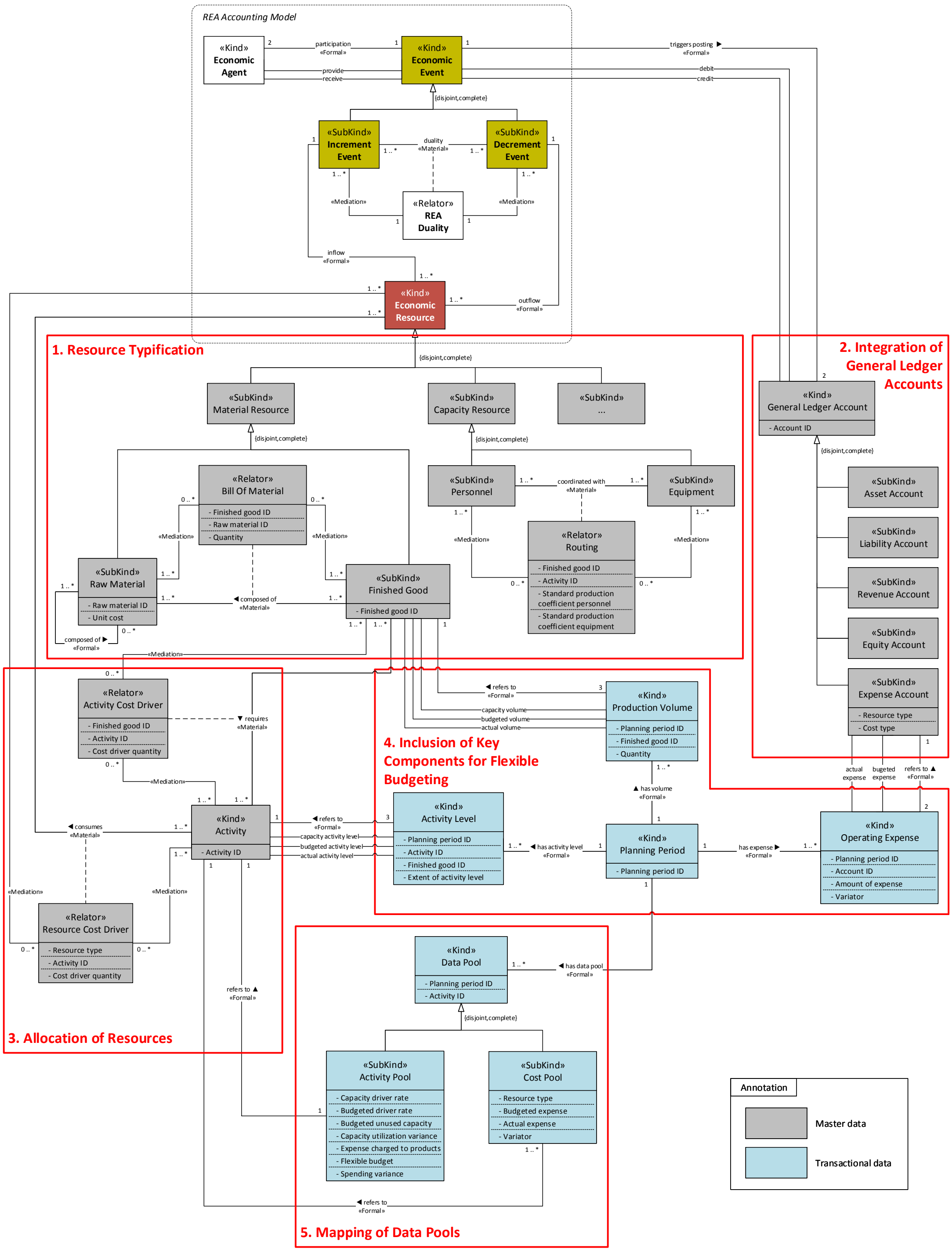


Figure 5.10: Qualitative analysis of conceptual model regarding identified shortcomings

CHAPTER 6

Related Work

Conceptual modeling and prototypical implementation of an ABC framework for flexible budgeting is clearly an interdisciplinary task. Thus, there exists a large number of literary work from related areas, such as management accounting/control and conceptual modeling. Nevertheless, there are solely a few publications in literature that are concerned with ontology-driven conceptual modeling of such economic approaches. At the time of writing this thesis, it was not possible to find any existing literature on the exact topic of flexible budgeting in an ABC framework that was concerned with conceptual modeling to prototypical implementation. Therefore, this chapter introduces some related work of product costing systems from the area of management accounting. In addition, it further includes some related articles of ontology-driven conceptual modeling.

6.1 Product Costing Systems

Van Der Merwe and Keys [32] proposed the Resource Consumption Accounting (RCA) approach, which is declared as a method in management accounting for computing product costs. They argued that one of the main differences of RCA compared with other product costing systems is that resources are considered as the cause of all costs. Additionally, this approach differentiates between flexible and committed costs. In case of RCA, all costs are inherently bound to the flow of resources and to the outputs of resource pools. Hence, the view of resources can be stated as one of the core aspects of RCA. According to the definition of Van Der Merwe and Keys, RCA is denoted as compound of features from ABC with the German cost accounting system that is termed 'Grenzplankostenrechnung (GPK)'. Due to this merger, the RCA approach promises more reliable cost information for decision-making relevance. Whereas the initial design of RCA is inherently more complex than the design of other product costing systems like ABC. Furthermore, the authors also illustrated the practical application of RCA based on a small business example to demonstrate its inner workings.

White [33] published an article on emphasizing the benefits of RCA through comparing it with other management accounting techniques. This article substantiated that the RCA approach is a credible management accounting solution. Therefore, RCA was discussed in terms of what is making it different from other management accounting approaches. Moreover, White highlighted the RCA approach as a panacea for improving operational and cost knowledge in order to optimize arbitrary business enterprises.

Kaplan and Anderson [34] proposed the Time-Driven Activity-Based Costing (TD-ABC) approach to overcome the common pitfalls of conventional ABC approaches. They encountered the following problems when implementing conventional ABC systems: time-consuming and costly survey processes, subjective data that is difficult to validate, expensive data storage/process costs, missing integrated view of enterprise-wide profitability opportunities, and difficult to update when changes are required. TDABC is promised to solve all those problems that are existing within conventional ABC approaches. It facilitates the costing process by avoiding interviews and surveys, which are required for the allocation of resources to activities at conventional ABC systems. Furthermore, the activity-definition stage is skipped because there is no need to allocate department costs to multiple activities first when applying the TDABC approach. By using time equations, the resource costs can be directly assigned to the activities performed and transactions processed. Therefore, only two parameters must be estimated: the capacity cost rate of a department and the capacity usage by each transaction, which is processed within a department. Even if conventional ABC systems are using durations drivers as well, there is a fundamental difference when comparing them with TDABC. In conventional ABC systems duration cost drivers add more accuracy, but they do not eliminate the cost allocation stage from resources to activities. However, TDABC uses such duration cost drivers to assign resources costs directly to cost objects. Thereby, it skips the first stage of cost allocation, which is merely annoying and error-prone in most practical cases.

Balakrishnan et al. introduced a two-part paper according to illustrate the commonalities and differences among four kinds of product costing systems: traditional volume-based systems, ABC systems, TDABC systems, and RCA systems. In the first part of their work [35], they described the mechanics of these product costing systems by incorporating a common platform and terminology. In the second part of this paper [36], the aforementioned product costing systems were compared along the following dimensions: costs of system implementation, decision-making relevance, and incentives provided in order to manage the demand of resources. Since the selection of the most suitable approach is strongly dependent on its underlying production environment, this paper was not focused on discovering the best costing system in general. Thus, the analysis was merely concerned with the best features of current costing systems, and how future approaches might blend them together. In terms of implementation costs, the finding of this paper was that the costs of implementation are increasing with the complexity of a system. In general, ABC systems require more information than traditional volume-based systems, and RCA systems even need a greater level of detail in information than ABC systems do.

With respect to decision-making relevance, they noticed that RCA is providing the most relevant decision-making information for product costing. Even if TDABC exposed to be easier to implement than ABC or RCA, it was not convincing in terms of decision-making relevance. Furthermore, they offered suggestions how to blend the best features of RCA and TDABC by the creation of a new blended product costing system.

6.2 Ontology-Driven Conceptual Modeling

Verdonck et al. [37] conducted an empirical study that examines the model consistency between Traditional Conceptual Modeling (TCM) and Ontology-Driven Conceptual Modeling (ODCM). The objective of their paper was to examine, how the applied conceptual modeling approach influences the consistency of resulting models. In particular, their research interest was to assess whether or not the adoption of ontologies may lead to an increased consistency of resulting conceptual models. Therefore, an empirical experiment was performed, in which a hundred students from two different universities participated. In this experiment, the ER modeling approach based on the UML class diagram notation was utilized for TCM, whereas the OntoUML was applied for ODCM. The results were acquired through three different kinds of questions: competency questions, content interpretation questions, and content sophistication questions. Furthermore, the results of questionnaire were evaluated based on a conventional statistical evaluation. The findings of this empirical study discovered some meaningful differences in consistency of resulting conceptual models between the TCM and the ODCM approach. More specifically, novice modelers that applied the ODCM approach were capable to achieve more consistent models than the novice modelers of the TCM approach. Finally, the authors concluded that one experiment might not be sufficient to deduce that the application of ODCM approaches generally result in a higher consistency of conceptual models. However, the findings of this paper may encourage future research in this field of study.

Carvalho et al. [38] extended the UFO with the Multi-Level Theory (MLT) in order to provide foundations for ontology-driven multi-level conceptual modeling. Initially, the UFO was primarily focused on the support of types whose instances are individuals without providing types of types. The combination of UFO-MLT enables the provision for types of types by incorporating the basic concepts and patterns of multi-level modeling. The MLT is based on the concept of ontological instantiations, in which instantiations of different levels/orders are possible. Another focal point of the MLT that affected the investigations of this article was the following basic pattern: *"Types instantiate a type at an immediately-higher order and specialize the basic type of the order to which they belong"* [38]. As a result of their work, the authors provided the UFO-MLT approach that enables the definition of conceptual models through representing types as well as types of types. Furthermore, this approach ensures the conformity with the rules of UFO. Since the objective of this paper was solely to provide theoretical foundations for multi-level conceptual modeling, this paper did not discuss a modeling language that enables the application of such an approach.

Fonseca et al. [39] proposed the Multi-Level Conceptual Modeling Language (ML2), which extends conventional two-level classification schemes through incorporating the feature that classes can be instantiations of other classes as well. Thereby, their developed modeling language overcomes the limitations of rigid two-level structures, in which classes can be instantiated by individuals only. The abstract syntax of ML2 is defined by the formal theory for multi-level conceptual modeling of Almeida et al. [40], which is called 'MLT*'. It defines the constructs and syntactical constraints of the ML2. Based on those theoretical foundations, the textual concrete syntax of this modeling language has been developed by using the Xtext[1] framework of Eclipse. Furthermore, the ML2 has been implemented into an Eclipse-based modeling editor that enables some validation capabilities of models in order to ensure their conformity with the underlying theory. With respect to ML2, future work is concerned with transforming the language into an semantic web approach [41] as well as the development of a graphical concrete syntax to complement the existing textual concrete syntax.

Due to empirical evidences of the community that were evolved from practical modeling applications of UFO and OntoUML, a need for improvement has been emerged regarding the modeling language and its underlying theory. Guizzardi et al. [42] recognized this need for improvement and therefore they started to adapt the theory of types in UFO. With respect to their adapted version of the UFO theory, the meta-types of OntoUML are not any longer restricted to substantial types. Instead the meta-types of this new UFO version are enabled to model endurant types in general because the aforementioned restriction of substantial types has been removed for these meta-types. In regard to those refinements of the formal theory, the new UFO version was proposed and has been subsequently used to enhance the metamodel for OntoUML 2.0. In order to ensure its consistency, the adapted theory was analyzed through using theorem provers. Furthermore, a computational support tool for implementing the updated metamodel of OntoUML 2.0 has been provided. Even if the authors of this paper are intending to address other relations in their future research, this paper was solely focused on endurant types and taxonomic relations.

[1] https://www.eclipse.org/Xtext/

CHAPTER 7

Summary and Conclusion

This thesis aimed at conceptual modeling and prototypical implementation of an ABC framework for flexible budgeting. Initially, an ABC system was designed on the foundations of a capacity-based approach in order to overcome the limitations of potential death spirals, which may arise when using ABC approaches for flexible budgeting. During the development of the capacity-based ABC system, the requirements concerning its ontological peculiarities were identified to facilitate the subsequent proceedings of conceptual modeling. After the flexible budgeting fundamentals have been incorporated into the designed ABC system, the next stage was concerned with the conceptual modeling part of this system from an ontological perspective. As a starting point to conceptual modeling, the previously identified requirements regarding the ontology of the capacity-based ABC system were considered. In order to facilitate the applicability and understanding of the conceptual model in the accounting domain, it was developed as an extension of the well-founded REA accounting model. Thereby, the OntoUML was applied for the development of the conceptual model. Subsequently, a prototypical implementation of the aforementioned capacity-based ABC system was performed in the course of a case study. In doing so, the conceptual model was utilized as a foundation for the implementation process, or, in other words, the prototypical implementation was established in accordance with the conceptual model. So, the prototypical implementation was applied for the validation of this conceptual model. The case study concluded with an observational evaluation that has been based on the demonstration of a fictional use case. After that a qualitative analysis was performed, in which the conceptual model was discussed regarding the defined problem domain of this thesis. Furthermore, this chapter is concerned with the critical reflection of results as well as suggestions for future work. Finally, a conclusion is drawn whether or not the anticipated contribution of this thesis has been achieved.

7.1 Discussion of Results

The primary outcome of this paper corresponds to the conceptual model of a capacity-based ABC system for flexible budgeting. It was developed to balance the identified deficiencies between economic sciences and conceptual modeling regarding flexible budgeting in an ABC framework. Thereby, the focus has been on ontology-driven conceptual modeling in order to provide a solution-independent conceptual model that does not consider any software-specific characteristics. The provision of a conceptual model from such an ontology-based perspective encourages its general applicability and enables further a profound understanding from the underlying system, which was captured through the conceptual model.

Another focal point of this thesis was the prototypical implementation that was built on the foundations of the previously developed conceptual model. This prototypical implementation was conducted for a fictitious company in the course of a case study. The implementation process involved all stages from ER modeling through a database implementation up to the development of a web-based application. So, the prototypical implementation was engaged with demonstrating the utility and efficacy of the conceptual model in a business environment. However, a serious weakness of this prototypical implementation is that it was carried out for fictitious company with a constructed sample data set. Consequently, this point of criticism also indirectly affects the conceptual model because it was validated based on that prototypical implementation. In order to gain more valuable empirical evidence regarding the utility and efficacy of the conceptual model, its application in one or more real-world scenarios might be desirable.

Finally, a qualitative analysis was performed in order to ensure that the conceptual model addresses all identified shortcomings of the defined problem domain of this paper. Thereby, the conceptual model was investigated regarding its completeness and consistency. Furthermore, the validity of the conceptual model has been ensured through its conformity with the syntactical and semantical specifications of the OntoUML. Even if a rigorous research methodology was applied for the proceedings of this thesis, the constructed data set of a fictitious company is rather less conclusive for the practical applicability of the conceptual model.

7.2 Comparison with Related Work

As mentioned in Chapter 6, there was no related work on the exact topic of this thesis at the time of writing. Thus, this section is focused on comparison with related economic approaches as well as recent scientific insights of ontology-driven conceptual modeling.

Since common RCA approaches are inherently based on simple ABC and therefore may involve potential death spirals, they are not a viable option for flexible budgeting purposes. In contrast to RCA approaches, TDABC seems more appropriate when looking forward to improve the underlying economic approach that was applied for the design of the ABC system. One reason for this is that the TDABC approach is easier to implement than conventional ABC approaches, such as the capacity-based ABC approach that has been discussed in this thesis. However, there is a trade-off between implementation costs and decision-making relevance among TDABC and conventional ABC systems. Further investigations regarding the implementation processes of such systems might be recommended. Because the lower their implementation costs are, the greater their potential will be in practice. Perhaps also ODCM may help to reduce the implementation costs of an ABC system through facilitating a deep understanding of its inner workings. Thus, further research regarding the implications of ODCM on the implementation costs might be interesting.

Apart from those considerations concerning the underlying economic approach, there have been some recent insights in the ODCM domain over the last few years. In particular, these insights led to the integration of MLT into theoretical foundations and modeling languages of ODCM. With respect to this thesis, MLT-ODCM provides some interesting capabilities to improve the developed conceptual model. Considering the current version of the conceptual model from Figure 4.11, it is not discernible how such attributes of types are derived, as in the case of the resource type attribute. MLT-ODCM approaches might provide a sophisticated solution to this issue through enabling the provision for types of types. In regard to improve comprehensibility of the developed conceptual model of this thesis, further investigations in accordance with MLT-ODCM might be recommended.

7.3 Limitations and Future Work

With respect to the findings of this thesis, this section is intended to induce further research that is located in the field of this paper. As there are points of criticism and open problems that are related to the topic of this thesis, we provide some suggestions for future work, in which these inadequacies should be discussed. Consequently, the following issues have been identified:

- **Integration of general ledger bookings**
  In this thesis, we did not discuss any research regarding the integration of general ledger bookings. Even if the conceptual model is based on the REA accounting model, it is not clarified which adaptations are required in order to integrate general ledger bookings in a comprehensible way. However, this problem must be addressed to enable further proceedings of the accounting domain.

- **Facilitating the implementation process of ABC systems**
  In practice, the implementation of ABC systems is inherently a complex process that may involve frequent pitfalls. Therefore, this complexity of ABC often discourages people from implementing such an ABC system at all. Although conceptual

modeling may contribute to the understanding of an ABC system, there is still the need of making its implementation more intuitive. For example, the selection of activity cost drivers is a complex task and subjective in its nature, but crucially for a well-functioning ABC system.

- **Revising the conceptual model based on MLT-ODCM approaches**
  MLT-ODCM approaches provide an interesting option for revising the conceptual model of this thesis, since the specified resource type attribute cannot be derived unambiguously from the developed conceptual model. Therefore, further investigations in relation to such approaches might be recommended to assess their improvement potential regarding the conceptual modeling part of this paper.

- **Acquiring empirical evidence from practical applications**
  At present, there is less empirical evidence concerning the practical application of the conceptual model and its underlying capacity-based ABC system that has been designed for the purposes of this thesis. In order to assess the utility and efficacy of these research artifacts in a real-world setting, further studies would be necessary.

- **Implications of ODCM on the implementation costs of a system**
  In addition, it would be interesting whether or not there is a significant impact of ODCM on the implementation costs of a system. Hence, empirical research is desirable, in which the implementation costs of systems are compared based on implementation processes that are involving ODCM and others that do not.

Although there still exist open problems and less empirical evidence regarding the research artifacts of this thesis, the findings provide some interesting contributions to this domain of research. More specifically, the conceptual model of this thesis rectified the discrepancy between economic sciences and conceptual modeling in terms of flexible budgeting in an ABC framework. Furthermore, this thesis demonstrated the entire process from conceptual modeling to prototypical implementation based on a capacity-based ABC system for flexible budgeting purposes. In conclusion, it must be noted that the expected extent and value of the contribution have been achieved in this thesis.

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Acronyms

ABC Activity-Based Costing. vii, ix, 2–4, 6, 8–12, 19–23, 26, 29, 31–40, 49–51, 53, 56, 59–62, 68, 72, 73, 75–77, 79–82

ALE Asset-Liability-Equity. 47

BOM Bill of Material. 15, 16, 37, 49, 63

COA Chart of Accounts. 19

ECSI Enterprise Control System Integration. 13–15, 17, 49, 73

ER Entity-Relationship. 1, 4, 6, 59, 60, 62, 63, 65, 68, 77, 80

GPK Grenzplankostenrechnung. 75

GPL General Purpose Language. 42

GUI Graphical User Interface. 4, 61, 62, 68, 71

MIS Management Information System. 1, 6, 10, 11, 73

ML2 Multi-Level Conceptual Modeling Language. 78

MLT Multi-Level Theory. 77, 81, 82

ODCM Ontology-Driven Conceptual Modeling. 8, 77, 81, 82

OntoREA REA-based ALE Accounting Model based on OntoUML. 8, 47, 48, 56

OntoUML Ontology-Driven Unified Modeling Language. vii, ix, 3, 4, 6, 8, 42, 46, 47, 53, 56, 77–80

RCA Resource Consumption Accounting. 75–77, 80

REA Resource-Event-Agent. vii, ix, 3, 4, 6–8, 13, 14, 20, 46, 47, 49, 51, 52, 56, 73, 79, 81

SQL Structured Query Language. 68

TCM Traditional Conceptual Modeling. 77

TDABC Time-Driven Activity-Based Costing. 76, 77, 80, 81

UFO Unified Foundational Ontology. 42, 43, 46, 77, 78

UML Unified Modeling Language. 3, 4, 42, 59, 60, 62, 65, 68, 77

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