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Web 2.0 based ERP System for Planning and Control of Financial Instruments

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submitted by
Stefan Achleitner
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Supervising
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Abstract

Context and definition of the thesis

Especially the current economic crisis has proven the lack of controlling in our economic system. State of the art software technologies in combination with the “Resources, Events and Agents”, short REA, model, first introduced by W. E. McCarthy in 1982 within the *The Accounting Review* journal provides the foundation for a controlling based modern ERP system. It ensures every resource leaving a company or an organization comes back in an appropriate value.
The realization with state of the art Web 2.0 technologies is intended to create a completely new approach of a modern Enterprise Resource Planning software system.

Scientific question

Based on the software technical implementation of the Resources, Events and Agents model, the system allows controlling and monitoring of all resource flows within a company as well as with other economic agents. On the basis of this REA software kernel, an application for the planning and control of financial instruments should be developed.

Scientific methods and procedures to realize this thesis

To realize the above-mentioned software application, every business transaction within the software needs, in addition to the implementation of user interfaces and Java Entity- and Session-Beans, specific booking methods to update the balance sheet of a company so that the output of resources equals the amount of incoming resources. Besides various frameworks and software engineering technologies the ISO/IEC 15944-4:2006 standard, specifying the REA model, is used as the theoretical foundation of this thesis. This approach should help to bring the aspect of controlling into the system.

Result of the thesis

The result of this master thesis consists of the design, implementation and documentation of software components dealing with the planning and control of financial instruments.
The software modules are implemented as Web 2.0 applications realized in the Java Programming Language and the JBoss Seam Framework. The final application will be available as part of the ERPControl System which will be offered as an online Enterprise Resource Planning System.

Kurzfassung

Kontext und Aufgabenstellung der Diplomarbeit

Besonders die aktuelle Wirtschaftskrise hat das Fehlen von Controlling in unserem Wirtschaftssystem gezeigt. Software Technologien auf dem neuesten Stand der Technik in Kombination mit dem „Resources, Events and Agents“, kurz REA, Model, erstmals vorgestellt 1982 von W. E. McCarthy im *The Accounting Review* Journal stellt die Grundlage für ein Controlling basiertes modernes ERP System dar. Es versichert, dass jede Ressource, die ein Unternehmen oder eine Organisation verlässt, mit einem entsprechenden Wert wieder zurückkommt.

Die Realisation mit „State Of The Art“ Web 2.0 Technologien beabsichtigt die Erstellung eines komplett neuen Ansatzes für ein modernes Enterprise Resource Planning System.

Wissenschaftliche Fragestellung

Auf der Basis der softwaretechnischen Implementierung des Resources, Events und Agents Models, erlaubt das System die Steuerung und Überwachung aller Ressourcen Flüsse innerhalb eines Unternehmens sowie auch mit anderen wirtschaftlichen Agenten.

Auf der Basis dieses REA Software Kernels soll eine Anwendung zur Planung und Steuerung von Finanz Instrumenten entwickelt werden.

Wissenschaftliche Methoden und Prozesse um die Arbeit zu realisieren

Um die genannte Software Anwendung zu realisierten braucht jede Geschäftstransaktion innerhalb des Systems, neben der Implementierung von Benutzerschnittstellen als auch Java Entity- und Session Beans, spezifische Buchungsmethoden um die Bilanz eines Unternehmens aktualisieren zu können, so dass die abfließenden Ressourcen dem Betrag der zufließenden Ressourcen entsprechen. Neben verschiedenen Frameworks und Software Engineering Techniken, stellt der ISO/IEC 15944-4:2006 Standard, der das REA Model spezifiziert, das theoretische Fundament dieser Arbeit dar. Dieser Ansatz soll helfen den Aspekt des Controllings in das System zu bringen.

Ergebnisse dieser Arbeit

Das Ergebnis dieser Diplomarbeit besteht aus dem Design, der Implementierung und der Dokumentation von Softwarekomponenten die die Planung und Steuerung von Finanz Instrumenten behandeln.

Die Softwaremodule sind implementiert als Web 2.0 Anwendungen, realisiert mit der Java Programmiersprache und dem JBoss Seam Framework. Die endgültige Applikation wird als Teil des ERPControl System verfügbar sein, welches als online Enterprice Resource Planning System angeboten werden wird.

„Have a healthy disrespect for the impossible“

Larry Page

Google Co-Founder & President, Products

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1. Introduction

Modern Enterprise Resource Planning (ERP) Systems enable the planning of resources within a company. That involves the management of material, tangible assets, human resources and of course financial resources. The central database, which is one of the most important parts of the software architecture of an ERP system makes a holistic view on the inside and outside business transactions possible.
Representing all kinds of business processes, the application of an ERP system makes the management and monitoring of various departments and their processes much easier.
The overall goal of information and software technology is to serve and support human beings in doing their work and improve the quality.

The economic system is the foundation of our modern, highly developed modern life. Every day countless streams of resources are flowing between companies and organizations all around the world. Especially financial transactions, supported by huge software systems, happen at the speed of light, often in an obscure way.
There is no doubt that undefined streams of money, flowing uncontrolled between companies, organizations and governments are one of the main reasons for huge economic crises.

The design and implementation of the ERPControl System is based on the Resources, Events and Agents Model which controls all incoming and outgoing as well as internal flows of resources in a company or an organization. The booking of resource exchanging, defined within various business cases, is designed in a way that the same value of an outgoing resource has to come back as an incoming resource flow with an appropriate value.

The following chapters discuss the theories, approaches and implementation techniques of the process to create a totally new and innovative Enterprise Resource Planning Software. The main focus of this thesis lies on the software based planning and control of financial instruments within a controlling based ERP system.

2. REA Model

2.1 Overview

Having its roots in the field of accounting the REA Model was first introduced by William E. McCarthy within the July 1982 issue of The Accounting Review as *“The REA Accounting Model: A Generalized Framework for Accounting Systems in A Shared Data Environment.”.*
In 1996 the REA Model was given the first *Seminal Contribution to the Accounting Information Systems Literature Award* and in 2003 it was awarded the *Innovation in Accounting Education Award*, both by the American Accounting Association (AAA).
Today the concept of REA is specified within the *ISO/IEC 15944-4:2006 Information technology – Business Operational View – Part 4: Business transaction scenarios – Accounting and economic ontology* standard. From now on I will use *AEO-Standard* as a shortcut.
In the next couple of pages I will introduce the concepts of REA as well as the REA implementation approach within the ERPControl software.

The name of the REA model is derived of a configuration of economic **R**esources, economic **E**vents and economic **A**gents.
Successful business collaboration involves one or more instances of all these three objects.

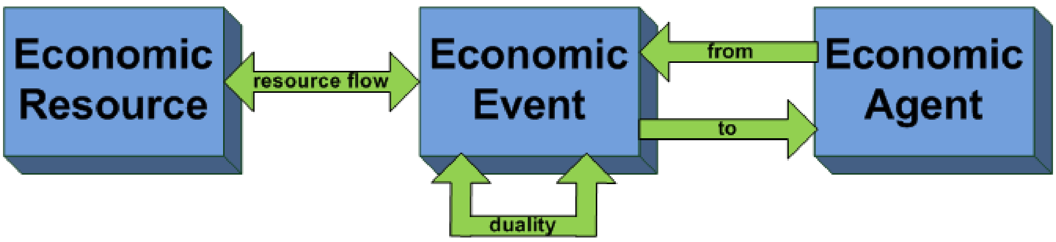


Figure 1: Basic structure of the REA Model

One basic business transaction consists of one economic resource, one economic event and two economic agents. This means two different economic agents are exchanging a specific economic resource within a specific economic event.

An example could be a car producer (economic agent 1) sells a car (economic resource) to a specific customer (economic agent 2) within a sales process (economic event).

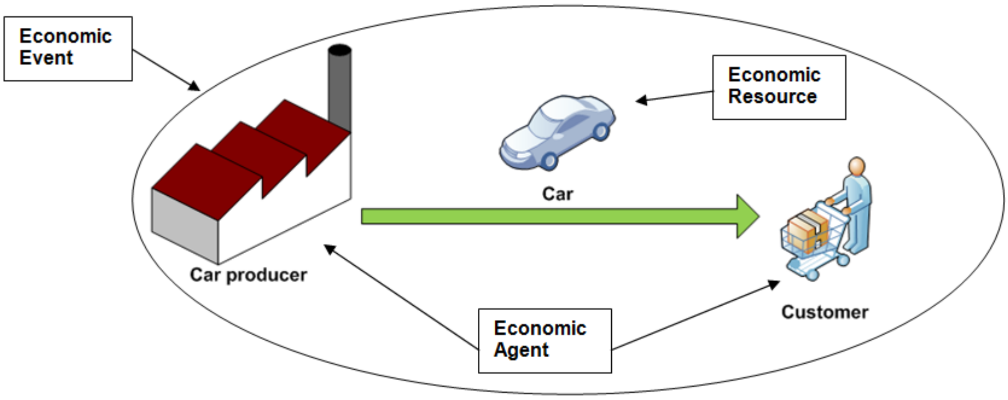


Figure 2: Economic event, exchange of resource car

In the REA terminology the displayed business transaction above is a decrement event for the car producer because it is an outgoing of the resource car and an increment event for the consumer, an incoming of the resource car.
But the transaction of the car from the producer to the customer is only half of the necessary resource transactions. Due to the REA specification the same amount of resources going out has to come back in an appropriate value and vice versa. So the car producer is missing an increment event and the customer is missing a decrement event.

In the example the customer has to pay for the received product, so the transaction of an appropriate amount of money from the customer to the producer fulfills the business case.

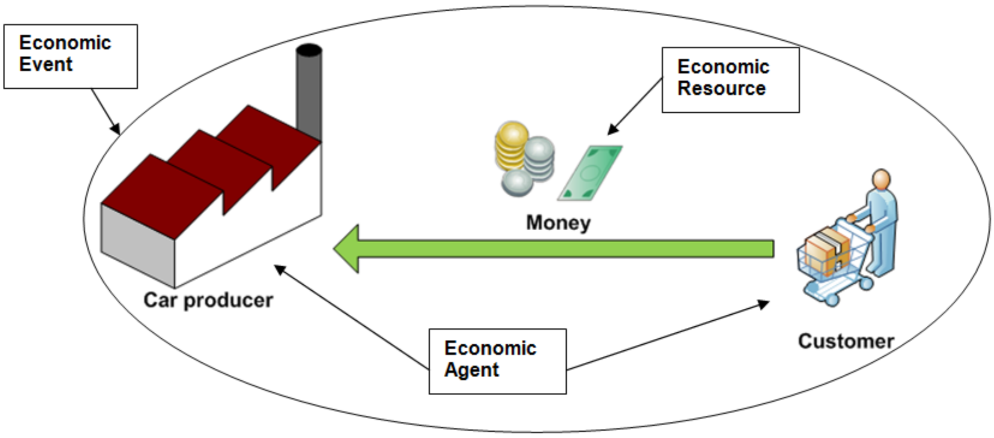


Figure 3: Economic event, exchange of resource money

We speak of “value restriction” that every outgoing resource has to come back in an appropriate way.

In a real world business transaction a certain amount of money, taxes, would also flow from the customer to the state. To demonstrate the example as easy as possible we will ignore this for now.

In the ERPControl System agents, resources and various increment and decrement events are combined to a business case which can be entered with a specific booking method to update the balance sheet of a company. A business case can also be identified as a business transaction.

Illustrated in the following figure, a business case is the combination of an economic event, two economic agents and an economic resource.

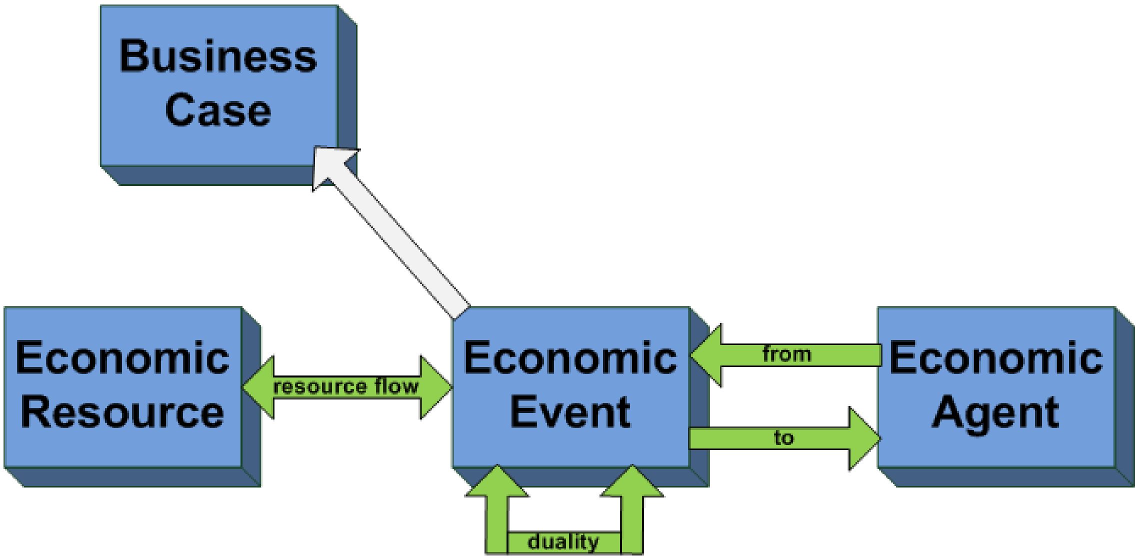


Figure 4: Composition of a REA Business Case

In real business transactions trading partners need a more reliable structure for the exchange of resources. This is accomplished through the agreement of contracts.

To realize this we extend the REA model with the objects *Economic Commitment, Economic Contract* and *Agreement*.

With an economic commitment two trading partners agree to fulfill an economic event in the future. An economic commitment should always be reciprocated by the other trading partner so that another type of economic event is initiated in return. An economic commitment establishes an economic contract which is a subtype of the object class agreement.

In the previous example the car producer agrees to accept the delivery of a vehicle on a certain date and get a specific amount of money from the customer in return.

Two additional objects within the REA ontology are *Economic Claim* and *Location*. Economic claims are needed when a trading partner insists on the documentation of a partially completed exchange of resources.

Sometimes the determination of a certain location is needed to fulfill the specification of an economic transaction. It defines where exactly an economic event takes place.

The so called extended REA Model is the basis of the implementation approach of the ERPControl Software. This makes it possible to create a new and innovative way to execute booking activities within a company, but more on that later.

This extended REA Model is illustrated in figure 5.

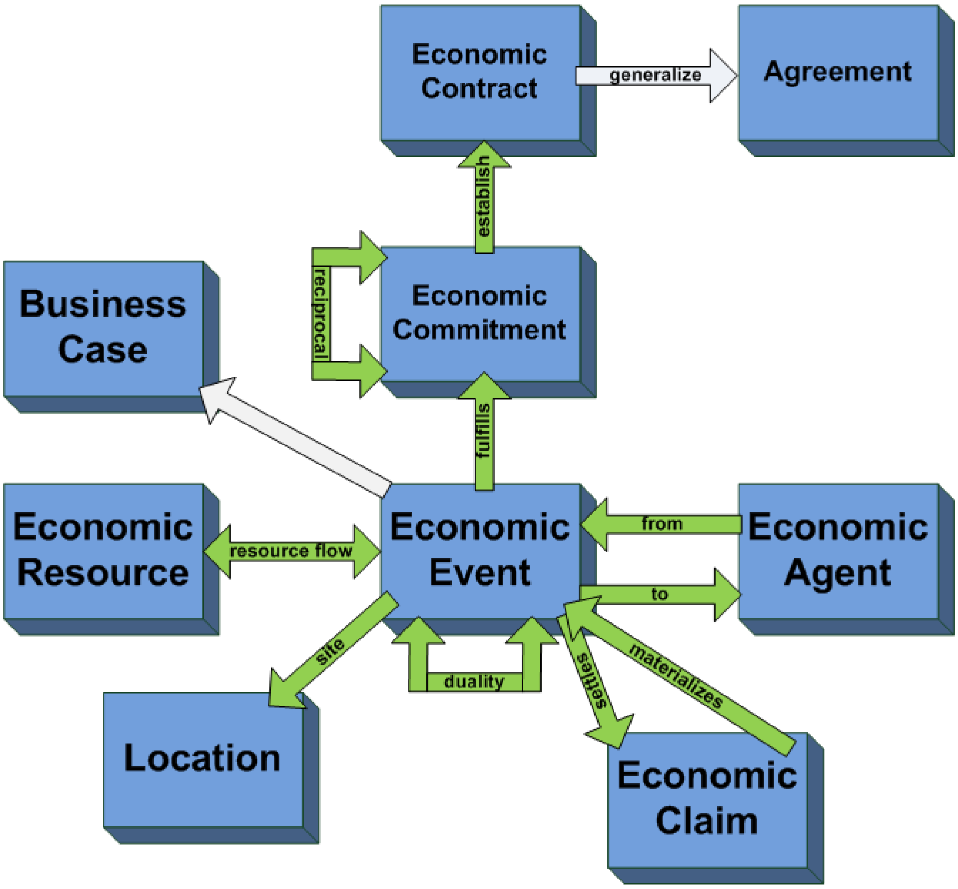


Figure 5: REA Model extended

2.2 Economic Agents

A Person is a natural or legal unit empowered to control the flow of economic resources (including his or her own labor) by engaging in economic events. Persons are also empowered to make commitments or promises to execute resource flows in the future. The Persons class may also include persons who are responsible for subordinates' participation in economic events.
[AEO06 p.26]

This is the definition of the AEO-Standard for economic agents as participants in a business transaction.

In the AEO-Standard an economic agent is also identified as *Person*. A Person is an entity that has legal rights and duties, is able to make commitments and fulfill resulting obligations. Within the standard a *Person* can be decomposed into three separate subtypes, *individual, organization* and *public administration.*

Despite the alternative notation of *Person* for an economic agent, in my thesis I will use the term economic agent.

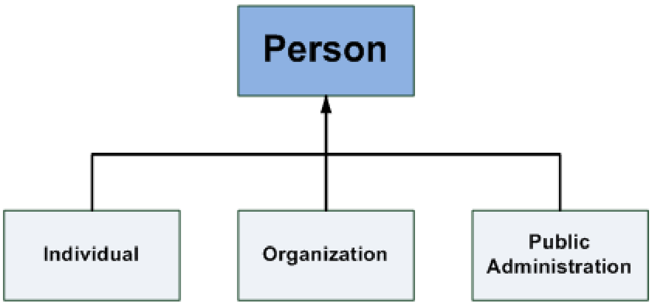


Figure 6: Decomposition of Person (Economic Agent)

A person (economic agent) is also an entity that owns control over an economic resource. The person either owns the resource or is otherwise able to derive economic value from it. If two persons have control over economic resources that are desired be the opponent, a business transaction exchanging the resources can be reached.

In addition to being classified on identity, economic agents may also be classified on the basis of their roles, which is equal to the specification of the functions they perform in business transactions. For example a *Business Partner* could either be specified as *Buyer* (has money, desires goods) or as *Seller* (desires money, has goods).

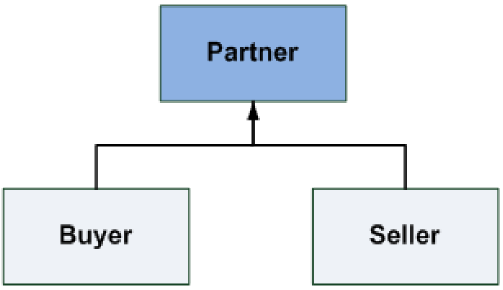


Figure 7: Decomposition of Partner to Buyer or Seller

In the ERPControl system economic agents are subdivided into internal agents and external agents. Internal agents, summarized with the parent class *OrgUnit (Organizational Unit)* are agents within the organization. External agents are economic agents outside the considered organization. Figure 8 illustrates an example of composition of external and internal agents in the ERPControl system.

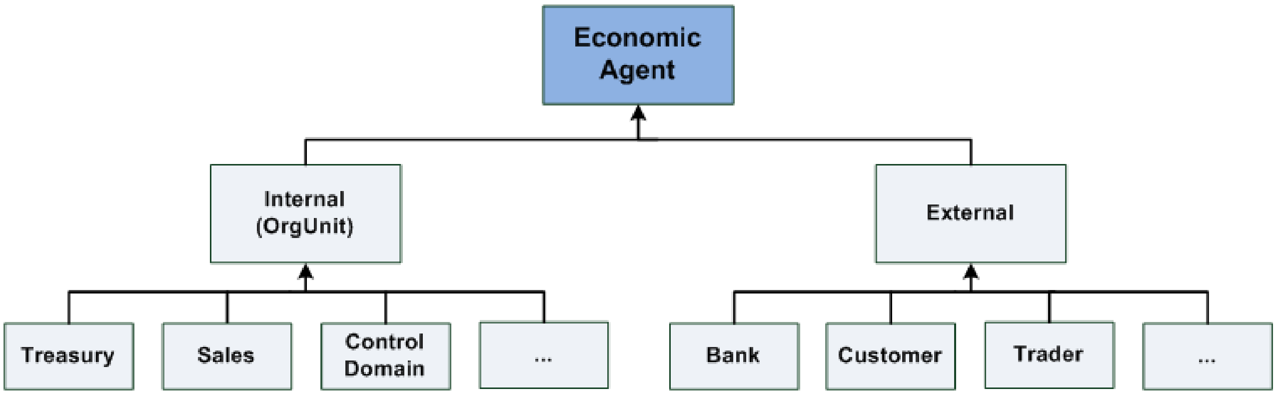


Figure 8: Breakdown of external and internal agents within the ERPControl System

Figure 8 illustrates some possible subdivisions of internal and external economic agents. This taxonomy could be extended with every industry-specific specialization of various role levels.

In ERPControl this structure is realized with the concept of class inheritance. Inheritance is a core concept within Java where a parent class is literally extended by a child class. So in this case the class *OrgUnit* extends the class *EconomicAgent*, and for example the class *Treasury* extends the class *OrgUnit*. So every attribute and method of the class *EconomicAgent* is also available in the class *Treasury.*

2.3 Economic Resources

An Economic Resource is a scarce good, right, or service that possesses utility (economic value) and that is presently under the identifiable control of a particular Person. [AEO06: p.27]

As defined in the AEO-Standard above, economic resources are goods owned or controlled by economic agents.
Economic resources can be substantial, for example materials, as well as insubstantial, for example transportation services.

The AEO-Standard specifies the following classification of economic resources.

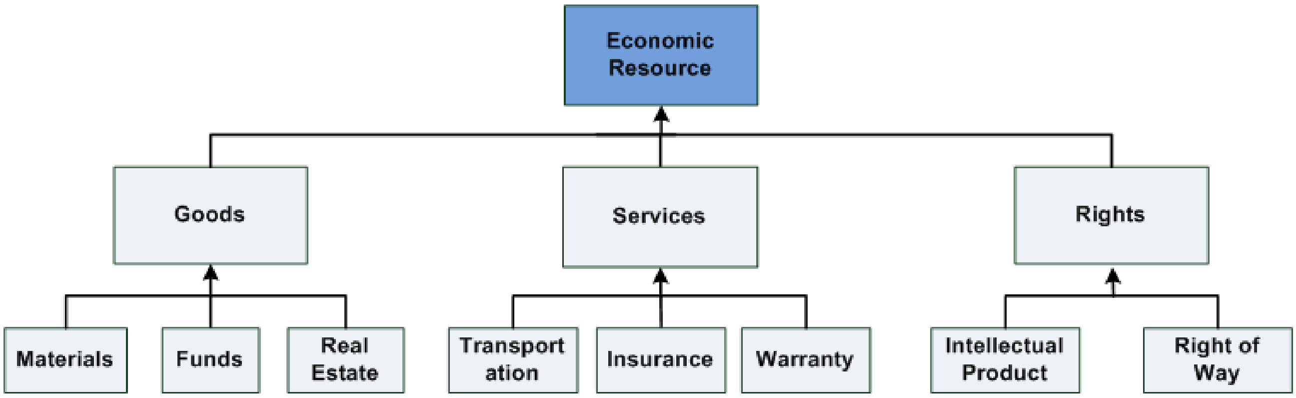


Figure 9: Economic resource classification

This subdivision of economic resources can be further specialized for particular industry fields. The ERPControl system, focused on the virtual training company *KerzenEWF* extends this standard as illustrated in figure 10.

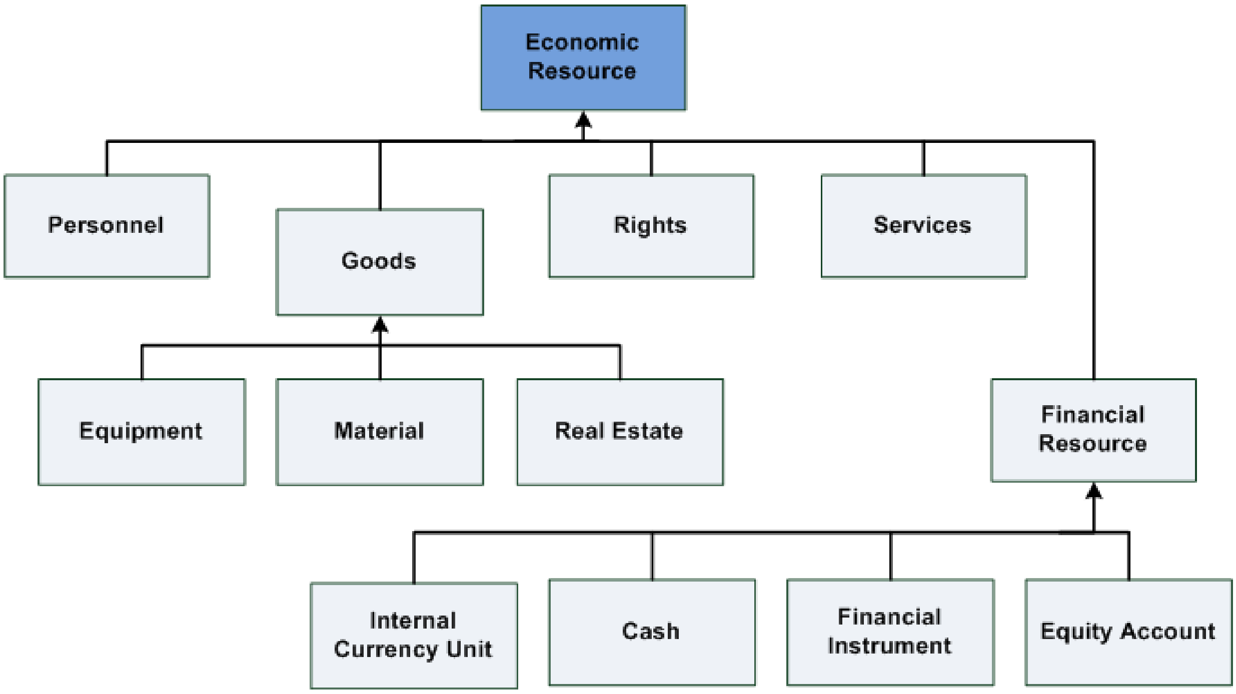


Figure 10: ERPControl classification of economic resources

The subdivision of economic resources in the ERPControl System is just an example for a subdivision of resources in a real company. The child nodes in the illustrated hierarchical structure in figure 10 are further subdivided till every single entity is realized within a specific Java class.
In the Java programming language the hierarchical structure is again realized with the use of class inheritance.

The EPRControl software modules I implemented for my thesis are especially dealing with the economic resource *Financial Instrument*. For this reason the subdivision of the most important kinds of Financial Instruments I am using in my thesis is illustrated in figure 11.

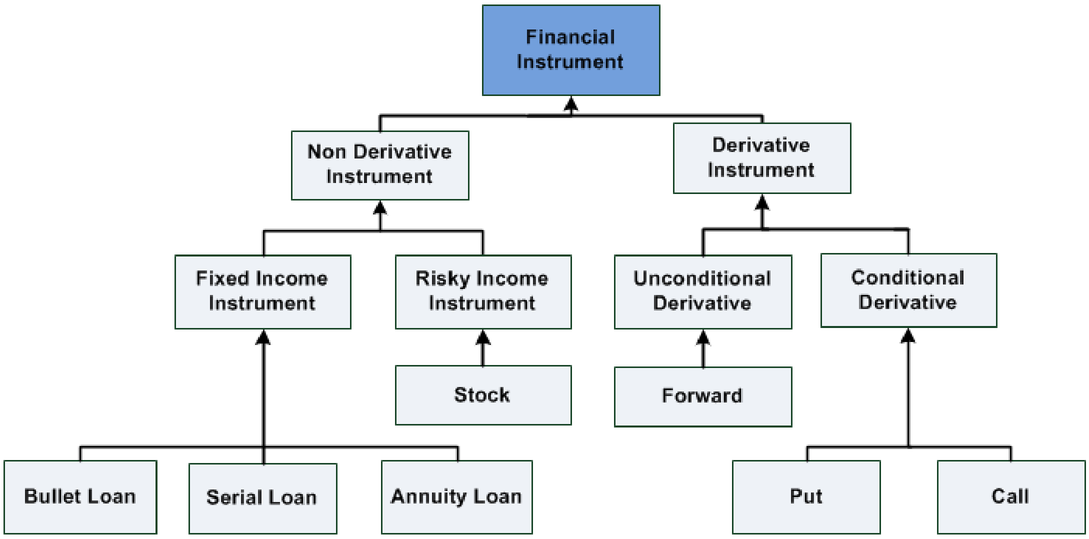


Figure 11: ERPControl classification of financial instruments

A core concept of the REA model is the duality principle, a verification that every outgoing of an economic resource is coming back in an appropriate way, implemented as the value restriction within the ERPControl System.
For the trading with physical products it is no problem to implement this concept, every outgoing resource has a specific value of money. So the equality of the income amount and the outgoing amount of money can be checked easily.
More difficult is the verification of *Services* or *Intellectual Products*. In the case of an exchange of a non substantial economic resource the involved agents have to define the exact value of the insubstantial resource in a mutual consistent way.

2.4 Economic Events

An Economic Event most simply is an inflow or outflow of an economic resource. Economic events reflect changes in economic resources resulting from exchanges, conversations, or transportation. [AEO06: p.27]

As defined in the specification of the AEO-Standard above, an economic event is an activity realizing the exchange of resources between two economic agents. An economic event is always connected with an economic resource and two economic agents. In the following figure an example for an economic event is illustrated.

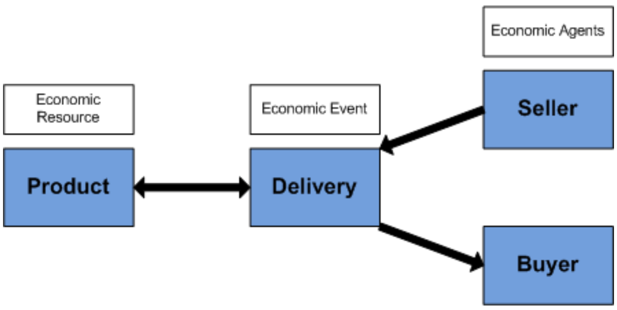


Figure 12: Economic event

The AEO-Standard defines only one type of economic event and doesn't provide a further breakdown.
Within the ERPControl System economic events are classified in three different kinds:

- Increment event
- Decrement event
- Internal event

The type of event depends on the economic agents involved in the exchange of resources. In the following figures the three different types of economic events in ERPControl are illustrated.

An economic event of the type *Increment Event* results in the increase of an economic resource for an internal economic agent within an organization and a resource decrease for an external economic agent. For example the buying of a product would increase the amount of a specific economic resource within an *internal organization unit* and a decrease of this product for the external economic agent *trader*.

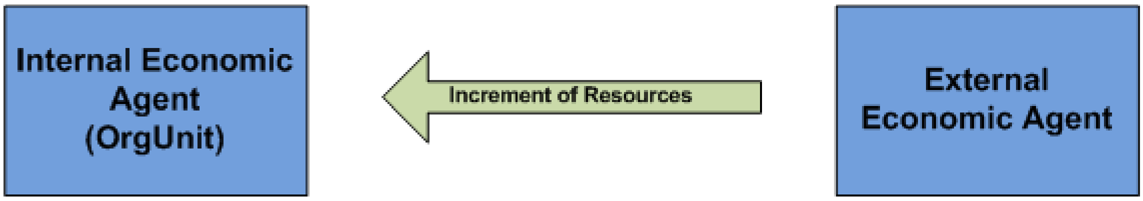


Figure 13: Economic event type: increment event

An economic event of the type *Decrement Event* results in the decrease of an economic resource for an internal economic agent within an organization and a resource increase for an external economic agent. The payment for a specific purchased product causes a decrease of the economic resource cash for the internal organization unit *treasury* and an increase of cash for the external agent *trader*.

Figure 14: Economic event type: decrement event

An economic event of the type *Internal Event* results in the increase of an economic resource for an internal economic agent within the organization and a resource decrease for another internal economic agent. The internal flow of resources could be the transfer of a specific product from an internal production facility, which would cause a decrease, to a product storage where the amount of the specific product would be increased.

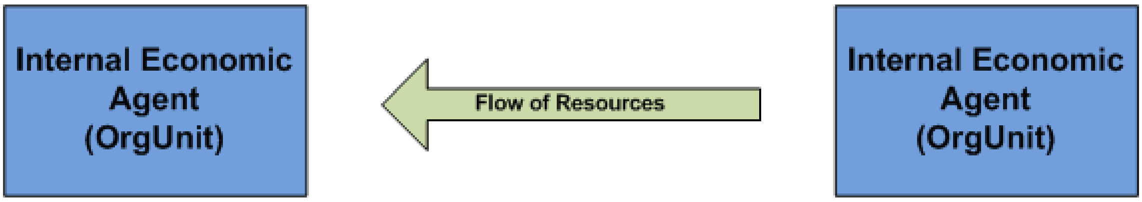


Figure 15: Economic event type: internal event

Depending on the field of industry and the current business activities all kinds of resource flows and exchanges can be mapped as a specific economic event. Thereby it is possible to monitor every kind of resource flow in a specific organization.

2.5 Business Transactions

A business transaction involves an economic exchange of resources between Persons with competing economic interests, each attempting to maximize his or her own economic utility.

This is the definition specified within the AEO-Standard for REA based business transaction. Within the ERPControl System a business transaction is specified as a business case. I will use both names as synonyms.

For the specification of a business transaction the AEO-Standard defines four basic questions:

- ***Who** is involved in the collaboration (Persons)?*
- ***What** is being exchanged in the collaboration (Economic Resources)?*
- ***When** (and under what trading conditions) do the components of exchange occur (Economic Events)?*
- ***Why** are the trading partners engaged in the collaboration (duality relationships between resource flows)?*

[AEO06: p.25]

This definition means that a full economic exchange of value in collaboration space is defined as a business transaction. A valid business transaction that fulfills the duality principle, or value restriction in ERPControl, involves a resource transfer from one economic agent to another followed by another resource-event-person pattern instance for a requiting resource transfer.

Within an economic event the AEO-Standard defines a number of relationship definitions to guarantee a valid execution of a business transaction.

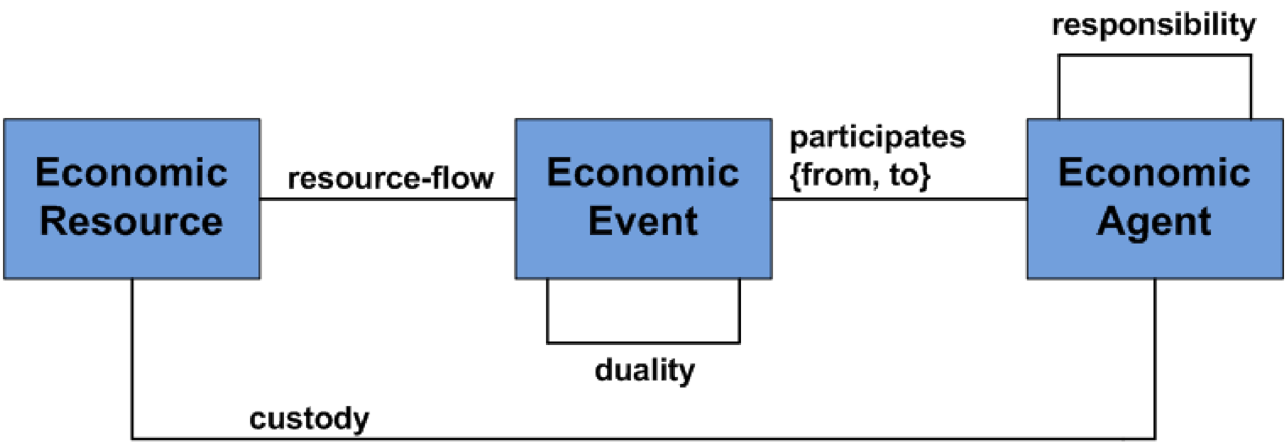


Figure 16: Economic event relationship definitions

- *A **resource-flow** relationship is an association between an economic resource and an economic event. Resource-flow instances are matched in bi-directional fashion with each party both giving and taking in the same exchange.*

- *A **participates relationship** is an association between an economic agent and an economic event. Economic events normally have two participates relationships with independent parties who have competing economic interests. One of these is specialized as "to" and the other one as "from".*

- *A **duality relationship** is an association between two (or more) economic events where one is the economic or legal consideration for the other in an economic exchange.*

- *A **custody relationship** is an association between an economic agent and an economic resource where physical control indicated.*

- *A **responsibility relationship** is a relationship between (among) two or more economic agents which indicates hierarchical orderings within an enterprise that are necessarily revealed to trading partners in a collaboration model.*

[AEO06: p.27]

The relationship definitions above are taken from the AEO-Standard, but modified to fit into this document.

So the minimum constellation for a valid business transaction includes economic resources, economic events and economic agents as well as their exchange relationship.
Figure 17 illustrates the exchange of a product for cash from a buyer to a seller.

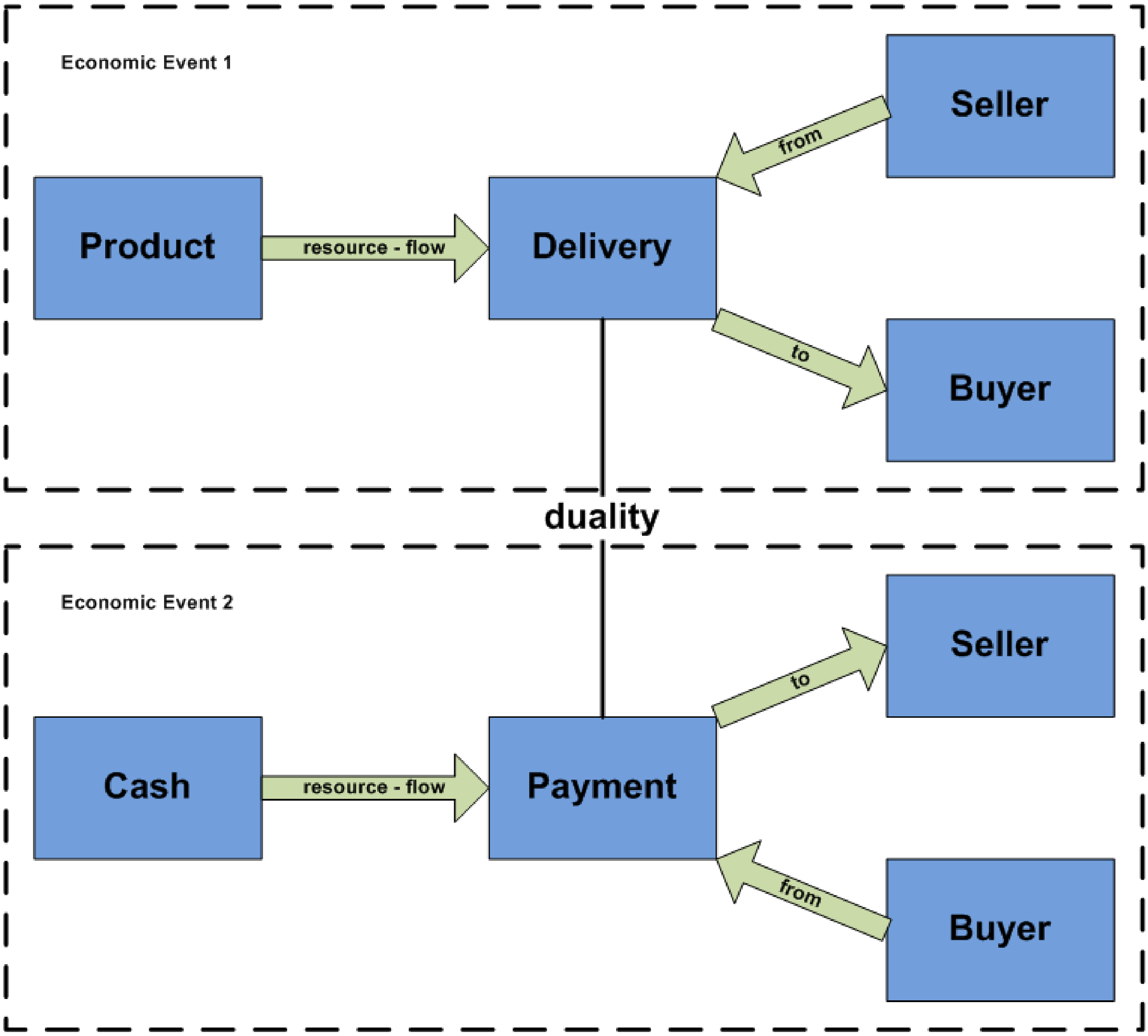


Figure 17: A complete business transaction (business case)

The displayed business transaction contains the minimum constellation for a resource exchange between two economic agents. The exchange of resources involves the same value for both economic agents, so within the ERPControl system a business case like this would satisfy the value restriction and therefore the changes of the amounts of resources can be entered and persisted within the database.

2.6 REA Implementation Approach

The ERPControl software consists of a kernel implementing of the REA model and various modules extending the system with different functions to deal with various economic assignments.

Figure 18 illustrates a very basic view on the ERPControl system consisting of the REA kernel and various additional modules.

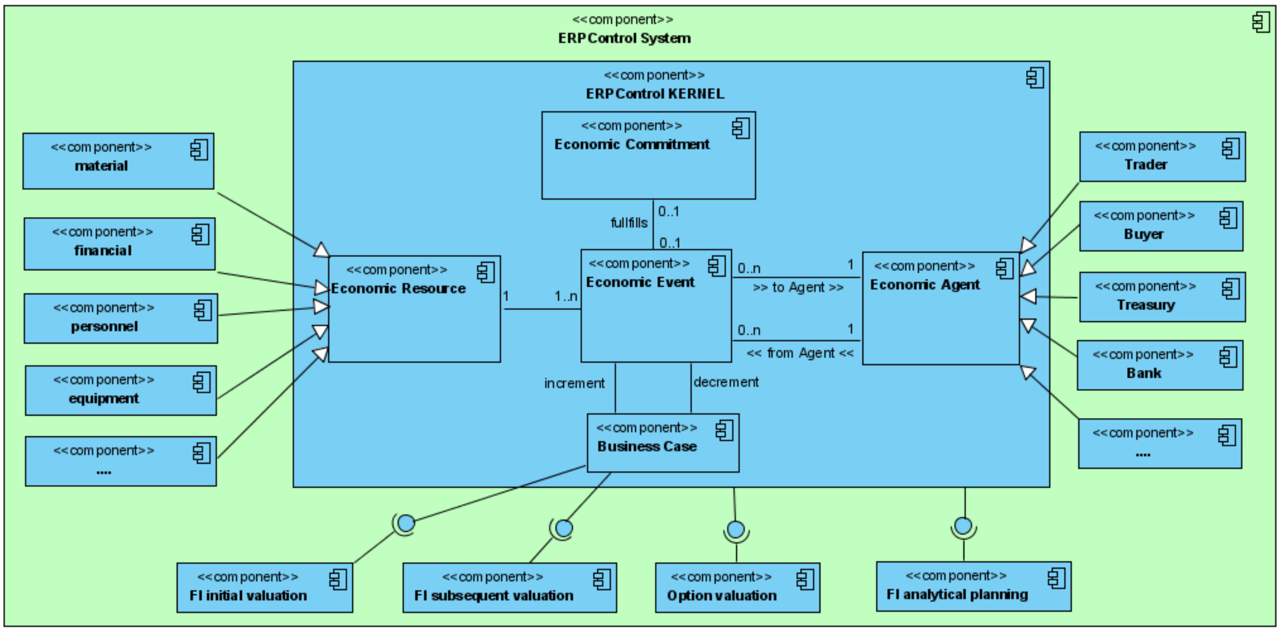


Figure 18: UML component of the ERPControl Software System

The ERPControl KERNEL shows the basic Java classes realizing the fundamental components of the REA model, *Economic Resources*, *Economic Events* and *Economic Agents*. These components are extended by the appropriate child classes that are visible on the left side of *Economic Resource* and the right side of *Economic Agent*. An economic event can be connected to an economic commitment which leads to an economic contract.
All needed data represented by the mentioned classes are tied together within the class *Business Case.* This class verifies if the duality principle, implemented as the value restriction, is fulfilled and then the data and changes in resources are persisted to the database.

As illustrated, the REA KERNEL is extended by various software components dealing with different economic tasks, for example the control and planning of financial instruments. The function of the software models are tasks like the valuation of loans, the pricing of options, etc. Only the optional booking function of such a software component accesses the REA KERNEL to make the calculated results persistent.

3. Technology

In the last chapter I introduced an overview on the REA theory which is the economic foundation of the ERPControl software.
In this chapter I will present an overview on the various technologies that are the basis for the implementation part of this thesis.

3.1 Java Enterprise Edition

The Java Enterprise Edition (Java EE) is a platform mostly used for the programming of large distributed applications in the Java programming language. In contrast to the Java Standard Edition (Java SE), the Java Enterprise Edition contains various libraries which provide functionality to develop distributed, multi-tier Java applications based on components running on application servers as for example the JBoss Server.
The ERPControl System is implemented in the Java EE Version 6.

Source: www.sun.com

The next Figure illustrates the architecture of the used technologies within the ERPControl System.

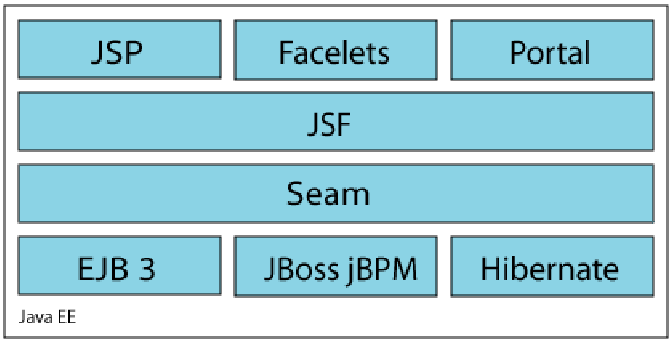


Figure 19: Technology Architecture of the ERPControl Software System (source: http://docs.jboss.com/seam)

The displayed technologies will be introduced within in the upcoming sections. Due to the fact that all these frameworks are very large high end technologies, the following introduction gives only an overview and doesn't contain much detail about these technologies.

3.1.1 Distributed Systems with Java

Built as a three-tier architecture distributed system, the ERPControl application consists of a presentation layer, a business logic layer and a data layer. The architecture is illustrated in the following figure.

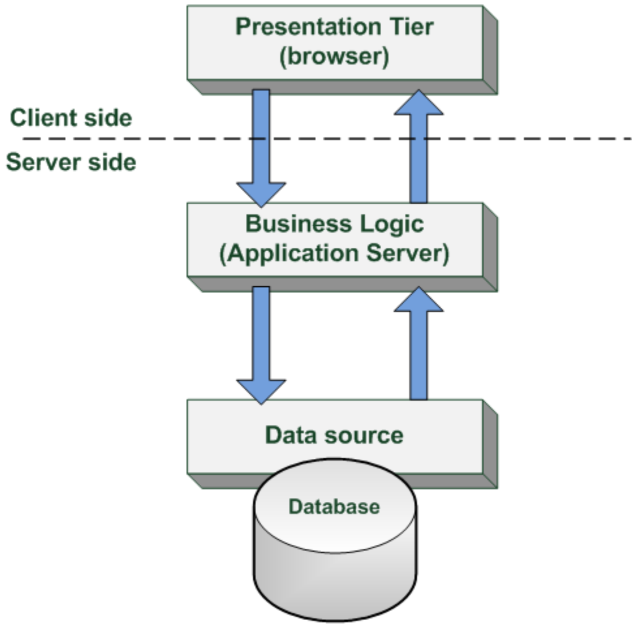


Figure 20: Three-Tier architecture of the ERPControl system

The illustrated architecture represents a thin-client-architecture. This means most of the functionality is located on the server. The client, which is a HTML webpage rendered by a specific browser, has only the function to display the processed data.
The heart of the application is the business logic which is hosted by the JBoss Application Server Version 4.2.2.
The business logic of the application is realized with so called Enterprise Java Beans, reusable software components to provide various kinds of services and represent data.
Via object relational mapping the Java Beans are connected with the database and are able to access the persisted data.

3.1.1.1 Enterprise Java Beans

Enterprise Java Beans represents the core components of a Java based distributed system as the ERPControl System. Therefore three different types of Java Beans are available.

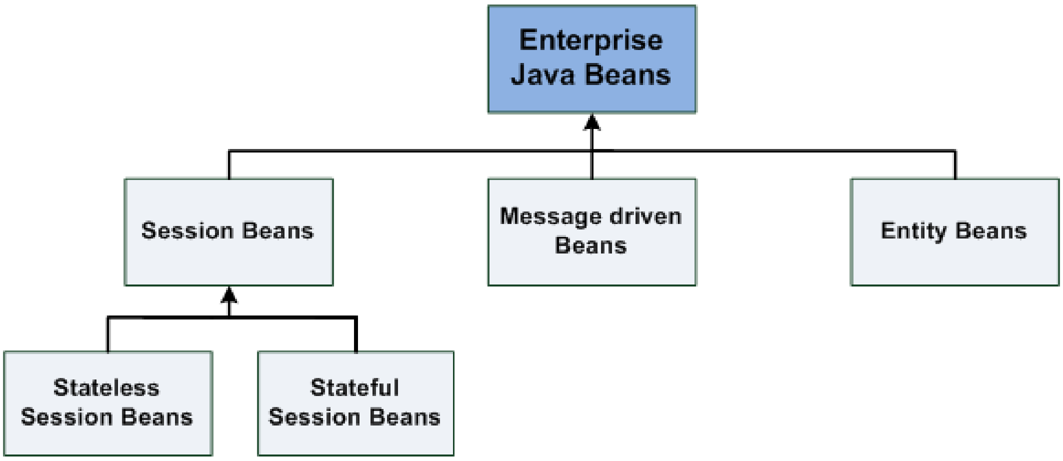


Figure 21: Subdivision of Enterprise Java Beans

Message driven Beans are not used in the ERPControl system so I will ignore them for now.

3.1.1.1.1 Entity Beans

Entity Beans represents the business objects within a specific software application. Entity Beans can be mapped into the database by the *Entity Manager* and can be transferred back to object instances. This operation is called *Object Relational Mapping.* I will give a detailed description of this process in the next section.
While Entity Beans are transferred between persistent database objects and object instances they occupy various life cycle states illustrated in figure 22.

Transient state
Being in the *Transient state* means a new object is instantiated.

Persistent state
An object in the *Persistent state* is synchronized with the database and refers to a valid database table row.

Removed state
An object in the *Removed state* is removed from the *Persistent state* and not synchronized with the database.

Detached state
An object in the *Detached state* exists and holds data but is not synchronized with the database.

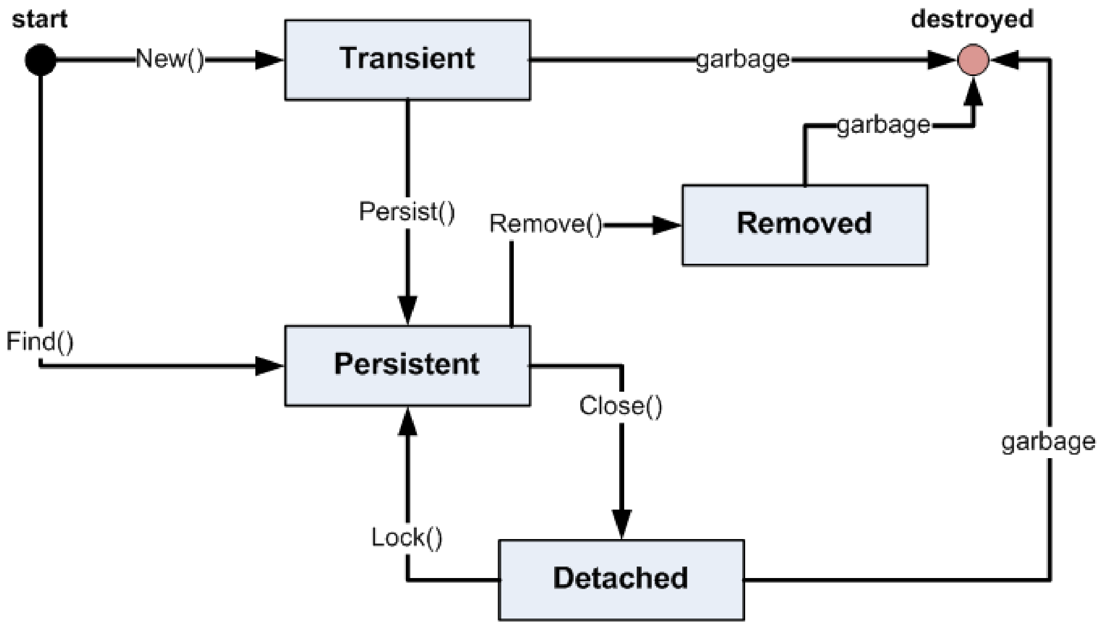


Figure 22: Entity Beans life cycle

Object instances no longer used are garbage collected and so deleted from the system.

To make an ordinary Java object an Entity Bean, the specific Java class has to be annotated:

```
@Entity
public class NameOfEntityBean {

}
```

An Entity Bean is identified by a primary key. The specific key field in the Java class has to be annotated with @Id. The attributes of a valid Entity Bean can be mapped to a single database row.

3.1.1.1.2 Session Beans

Session Beans are a collection of services each represented by a method. User inputs are validated, data is processed, Entity Beans are handled, algorithms are executed, and there are a lot of other tasks Session Beans have to perform, so these beans are representing the business logic of the system.
So EJB Session Beans are filling the gap between user interface and the domain model (data model) of a Java Enterprise Edition distributed system.

As mentioned above there are two different types of *Session Beans:*
- Stateful Session Beans
- Stateless Session Beans

Stateful Session Beans are retaining their status during multiple invocations, that means submitted values and the status of a previous invocation of a bean are still available after an invocation has ended. Stateful Session Beans are annotated with @Stateful and have to implement either a remote or a local interface containing all methods available to the client.

```
@Stateful
public class NameOfStatefulSessionBean implements NameOfTheInterface {

}
```

The second type, a Stateless Session Bean, doesn’t retain any status after a client request, so the submitted values and changed status of the bean are reset after every invocation. Stateless Session Beans have to be annotated with @Stateless.

```
@Stateless
public class NameOfStatelessSessionBean implements NameOfTheInterface {

}
```

Session Beans also have to implement either a *Remote Interface* which can be invoked by clients outside the system and is annotated with @Remote or *a Local Interface* which can be invoked only by clients inside the system and is annotated with @Local.

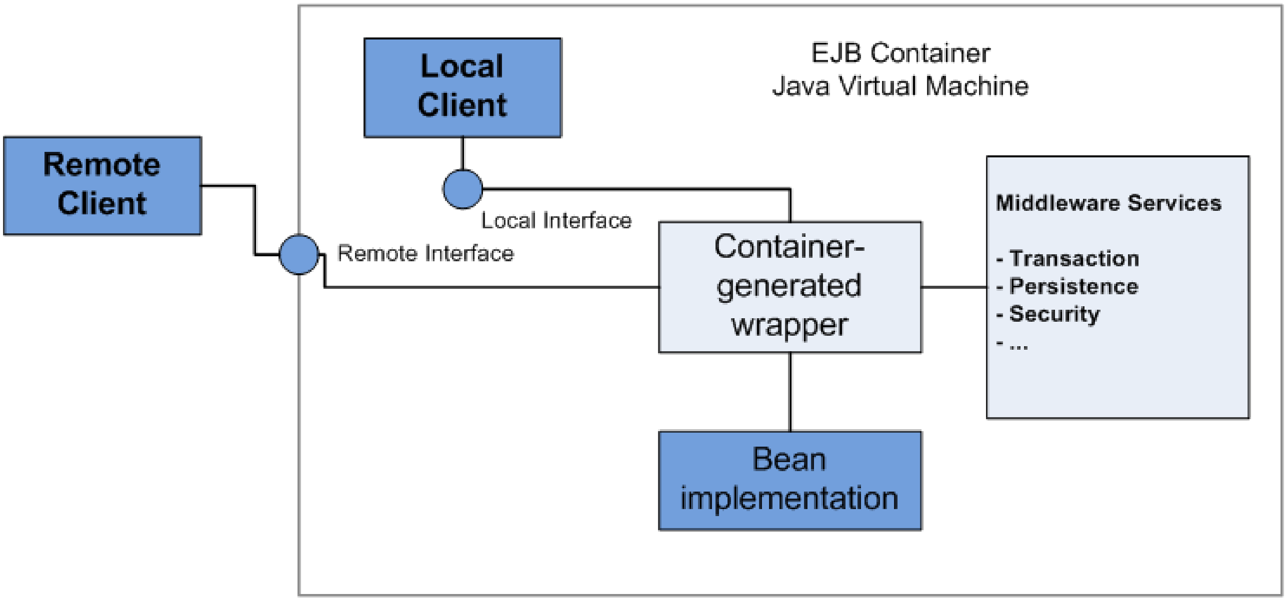


Figure 23: Session Beans implementation model

Figure 23 illustrates the implementation model of an EJB Session Bean. Services implemented by a bean are provided via interfaces.

3.1.1.2 Object Relational Mapping

Relational database management systems are still the state-of-the-art. They are a stable and well developed concept that stood the test of time. Unfortunately there is a paradigm mismatch between the object-orientation and the relational model. This requires a mapping of objects onto a relational database. Another goal is to encapsulate and hide SQL within the data source layer.

To reach these goals an additional software layer is inserted between the business logic and the data source layer. In the case of the ERPControl software, the Java persistence API which is based on the Hibernate Framework is used as mapping software.

Every Entity Bean object has its own table within the database. The columns of the table are equal to the attributes of the Entity Bean. All attributes of an object instance are mapped to a row in a specific database table.

The actual mapping of an object to a specific database row is done by a so called *Mapper*. A *Mapper* is able to execute all *CRUD (Create, Read, Update, Delete)* operations for a specific object on the database.

Figure 24 illustrates the connection between a *Mapper,* an object and a database.

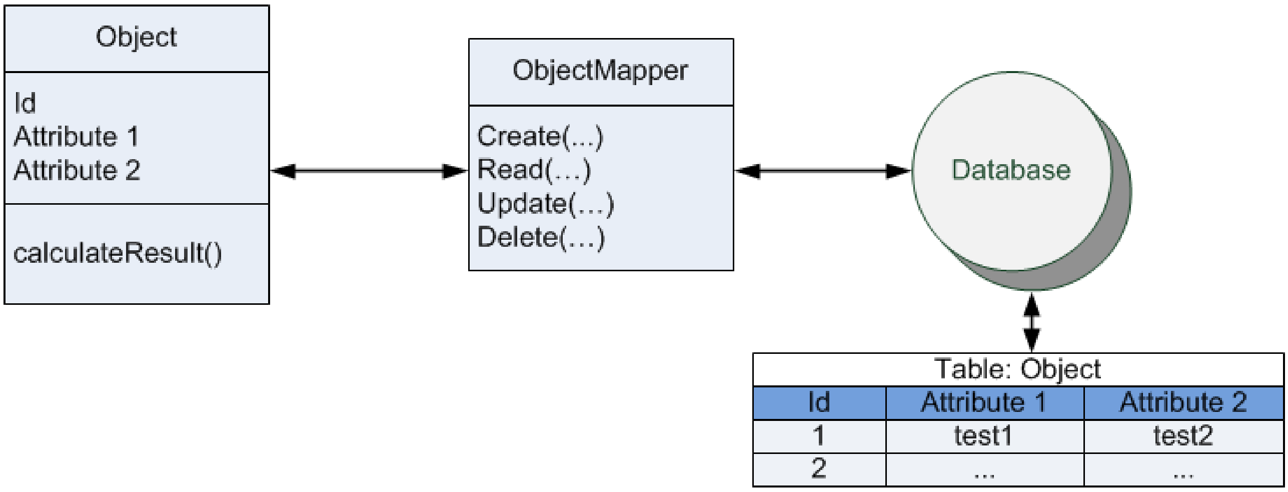


Figure 24: Object Relational Mapping

3.1.1.3 Web 2.0 Interfaces with Seam

Web based user interfaces (UI) are state of the art in distributed enterprise information systems because of several advantages:

- No client software has to be installed
- Common user interface approach
- Easy universal access
- Good software support

Seam realizes this approach by combining two frameworks, Enterprise Java Beans (EJB3) and Java Server Faces (JSF). Seam applies the Model View Controller (MVC) pattern which is a separation of the presentation (view) issues from the domain model (model) issues. The implementation of the *Model View Controller* is one of the core principles of good software design.

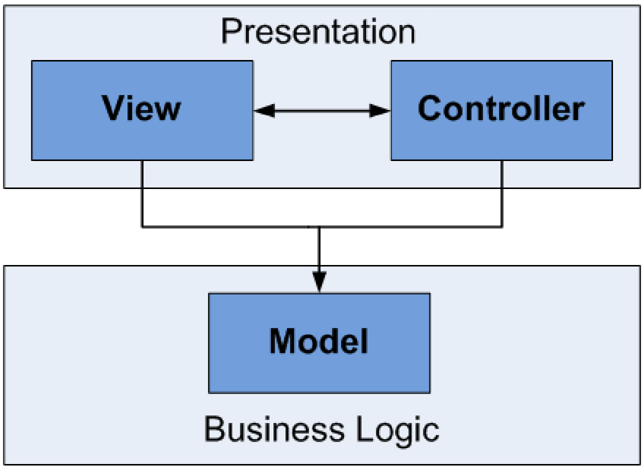


Figure 25: Model View Controller Pattern implemented by Seam

Model: Contains domain logic, the object of a domain model.
View: Visual representation of the model in the user Interface.
Controller: Takes user input, manipulates the model and causes view to update.

Seam enables the communication between EJB Session Beans and the JSF view components. To access a Session Bean from a JSF view element the specific Java class has to be annotated with @Name.

```
@Stateful
@Name("fi_interestTreeCreation")
public class InterestRateTreeCreator implements IInterestRateTreeCreater {

	private double interestRate = 0.012;

	public dobule getInterestRate() {
		interestRate = interestRate*100;
		return interestRate;
	}

	public void setInterestRate(double interestRate) {
		this.interestRate = interestRate;
	}
}
```

Attributes of an annotated Session Bean need to have so called getters and setters which are also specified within the implemented interface to be accessible in a view component by the specified name.

```
<tr>
	<td>
		<div>Interest Rate:</div>
	</td>
	<td>
		<h:outputText value="#{fi_interestTreeCreation.interestRate}%"/>
	</td>
</tr>
```

The class and its attributes are now available in the view components. In the displayed code snippets an *outputText* element of a view component is accessing the attribute *interestRate* from the Session Bean annotated with the name *fi_interestTreeCreation.* The rendered output of a specific internet browser would look like this:

```
Interest Rate: 1.2%
```

This code example also clarifies the application of the MVC pattern within the Seam Framework. So the calculation of the interest rate is done inside a Session Bean, the presentation of the result happens in a specific view component.

3.1.1.4 ERPControl Technology Architecture

Figure 26 gives a basic illustration of the architectural structure of the technological components of the ERPControl system and shows how the single components are working together during a user request.

A web browser receives data from users which are sent to a specific Seam annotated Session Bean where the data is processed and transformed into an Entity Bean which is persisted in the database using the Java Persistence API.

If a user requests some data from the system, the specific Session Bean accesses the database retrieving the requested data which are then converted into HTML code and displayed by a web browser.

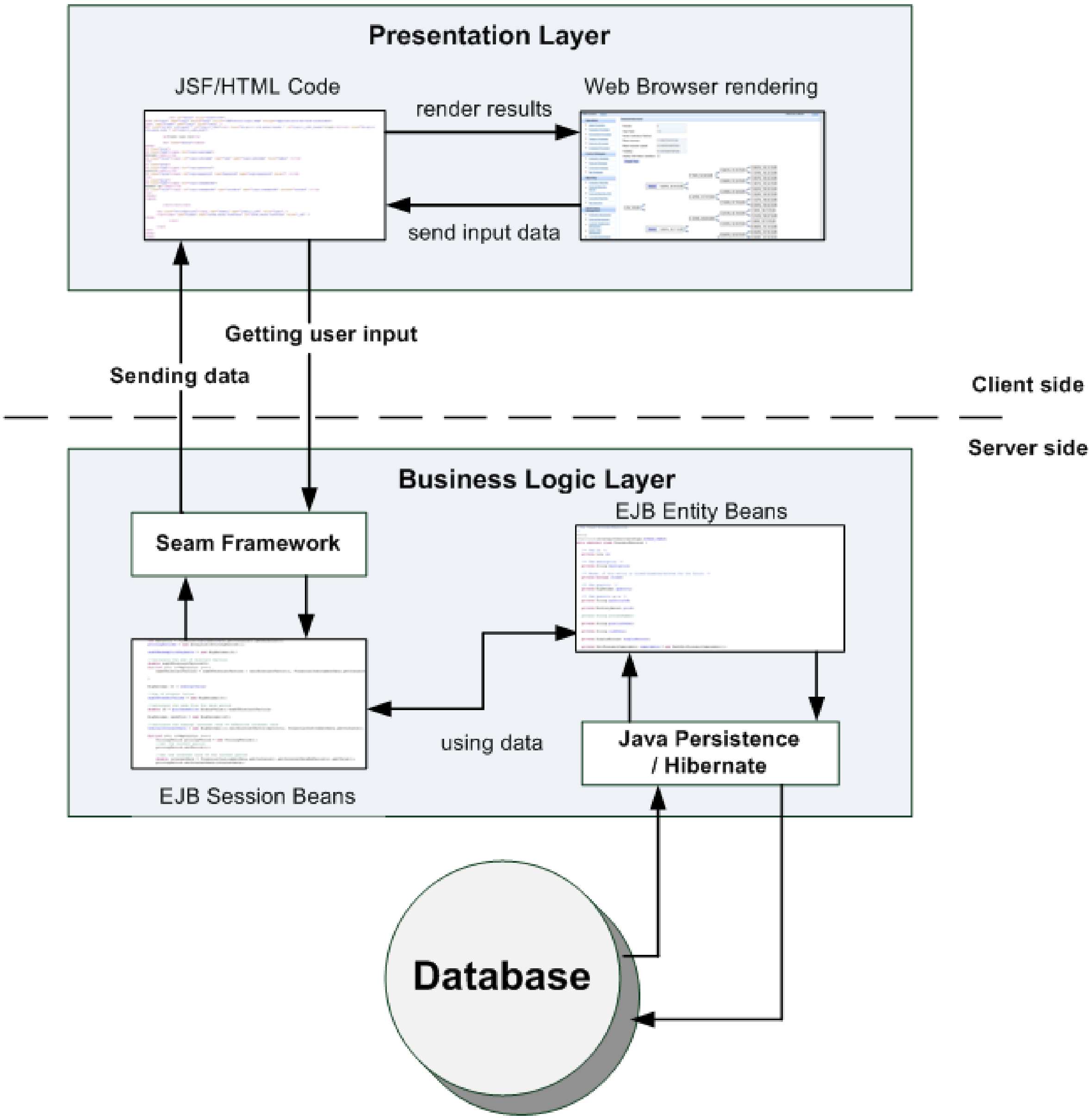


Figure 26: Overview of the ERPControl system architecture

The JBoss Business Process Manager (jBPM) combines all the introduced components of the software to business processes which reflects the application flow of a business process in a real company.

3.2 Software Testing

While the complexity of big software systems is increasing very fast, the error rate is also increasing which leads to unreliable software and a bad user experience. Test driven development (TDD) is a core concept for developing innovative high end software systems and helps to keep the error rate very low. When applying test driven development, an automatic unit test for a specific component has to be written before the actual component is developed. This concept helps the software developer to avoid implementation errors during the development. Thereby the development time and costs are kept low because expensive redesign of components as well as debugging are avoided in most cases.

The development of the ERPControl system doesn't consider any kind of test strategy till now. To keep the system safe and the error rate as low as possible it is highly recommended to introduce automated unit testing for the development of the ERPControl software.

Especially for software written in Java, like ERPControl, the JUnit Framework is recommended to create automated test cases for developing new software components. A unit test case describes the expected behavior of a software component. During the development of a software component, if the behavior of that component changes or some implementation errors are made, an automated unit test checks the outcome of the software component and reports the results to the software developer. This approach ensures the expected behavior of the software and avoids implementation errors.

Although software testing is not a part of this thesis, I highly recommend the usage of a test strategy for the further development of the ERPControl system.

A test strategy should contain at least:

- A test plan covering the complete test strategy for the whole system
- JUnit tests for the automated testing of single components
- Approaches for manual testing of the user interface
- A full system test ensuring that all components of the system are working together in a correct way

A well planned test strategy does not only help to keep the development time and costs low, it is also an indicator for a high quality of the software.

4. ERPControl

The ERPControl software is a revolutionary new and innovative Enterprise Resource Planning (ERP) System which is based on the Resources, Agents and Events (REA) model and implemented with modern state of the art Web 2.0 technologies.
The project was started by the Institute of Management Science at the Vienna University of Technology.

ERPControl includes not only ERP-System functionality it also involves production engineering and production planning, financial and managerial accounting, business finance, enterprise risk management, planning and control techniques as well as various other functionalities and business administration tools.
This wide range of functionality makes ERPControl a complete Management Information System (MIS) and a useful tool for managers as well as engineers to monitor and control all areas of a company.

4.1 ERPControl Core System

The ERPControl System consists of a REA Kernel which is extended by various modules adding functionality for all areas of business administration to the system. The REA Kernel provides the data structure and the interfaces to manage the different kinds of REA objects, for example resources, business transactions, agents, etc. and to monitor all incoming, outgoing and internal resource flows of a specific company or organization.
Figure 27 shows the menu structure of the ERPControl system where the different function categories are visible.

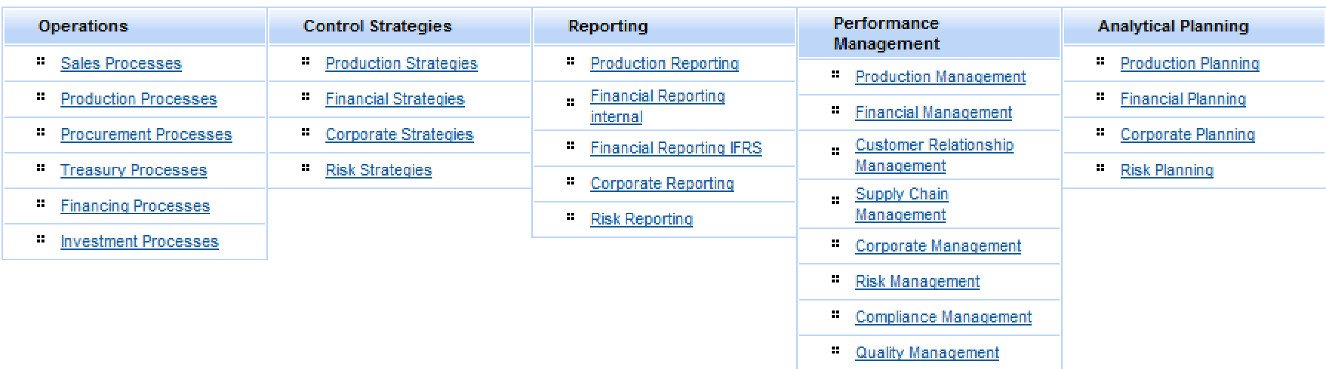


Figure 27: Function categories of the ERPControl system

Most of the functions of the displayed categories are provided as software modules which extends the core functionality of the system.

A core functionality of the system is the possibility to create an up to date financial statement of the whole organization at any time. Compared to today’s most used ERP systems this is really a big innovation.

Figure 28 shows the finance section of the resource list created with the ERPControl *resource list creation* function. It illustrates the current amount of cash in the treasury, the amount of revenue and profit account as well as taxes and financial liabilities.

Cash	EUR Cash	256.75	PCS	EUR 1.00	EUR 256.75
Cash	USD Cash	0.00	PCS	$ 1.00	$ 0.00
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	56.23	PCS	EUR 1.00	EUR 56.23
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	4.36	PCS	EUR 1.00	EUR 4.36
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	0.00	PCS	EUR 1.00	EUR 0.00
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
AnnuityLoan	AFV Loan	-150.00	PCS	EUR 1.00	EUR -150.00
AnnuityLoan	AFV Loan	-78.45	PCS	EUR 1.00	EUR -78.45

Figure 28: Finance section in the resource list of the ERPControl system

After a successful execution of business operation processes, the calculated results are entered accessing the interfaces provided by the REA Kernel. This operation makes the resource changes persistent which are then immediately visible at the current balance sheet.

id	description	eventType	quantity	price_currency
1	Treasury -> Bank (Financial Liability=Loan)	DECREMENT	-105.00	USD
2	Bank -> Treasury (Cash)	INCREMENT	105.00	USD
3	Bank -> Treasury (Cash)	INCREMENT	105.73	EUR
4	Treasury -> Bank (Financial Liability=Loan)	DECREMENT	-105.73	EUR
5	Treasury -> Bank (Cash)	DECREMENT	-25.56	USD
6	Bank -> Treasury (Loan)	INCREMENT	25.56	USD
7	Treasury -> Bank (Cash)	DECREMENT	-1.38	USD
8	Bank -> Treasury (Expense Account)	INCREMENT	1.38	USD
9	Bank -> Treasury (Revaluation Reserve Account)	INCREMENT	0.53	USD
10	Treasury -> Bank (Loan)	DECREMENT	-0.53	USD
11	Bank -> Treasury (Loan)	INCREMENT	25.00	EUR
12	Treasury -> Bank (Cash)	DECREMENT	-25.00	EUR
13	Bank -> Treasury (Expense Account)	INCREMENT	4.00	EUR
14	Treasury -> Bank (Cash)	DECREMENT	-4.00	EUR
15	Treasury -> Bank (Expense Account)	DECREMENT	-3.54	EUR
16	Bank -> Treasury (Loan)	INCREMENT	3.54	EUR

Figure 29: List of Economic events in the ERPControl database

The flow of resources is represented by economic events. When accessing the REA Kernel to book a specific business case, the accessing software module has to provide at least two economic events describing the incoming and outgoing or the internal flow of resources. Figure 29 shows a list of economic events after the successful execution of various business transactions.
The description of the shown economic events displays the "*from Agent*" registering an outflow of a specific resource to the "*to Agent*" which receives an incoming of resources.

As an example the economic event with id 2 of the above list, *Bank -> Treasury (Cash),* describes a payment of the resource *Cash* from the economic agent *Bank* to the internal organization unit *Treasury* with an amount of 105.00 US Dollars. Here the event type is an *increment event* because the flow of resources happens from an external to an internal agent.

Every resource within the ERPControl system is represented by a specific Java class that is a child object of the *EconomicResource* class.

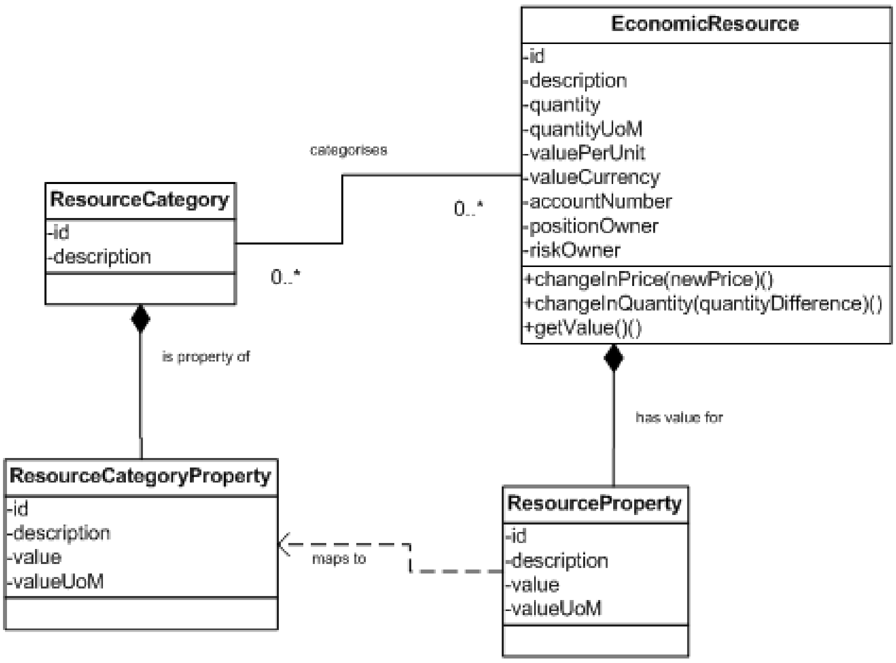


Figure 30: ECSI based resource modeling

The modeling of the resources is based on the different resource models discussed in the ECSI standard part 1 and 2. The concept of these models follows a generic modeling, hierarchical structuring and reification of properties. The illustration in figure 30 shows the generalized resource model.

This general modeling pattern can be used to describe various types of resources and their specific properties:

- the ECSI material model for real resources
- the ECSI personnel model
- the ECSI equipment model
- financial resources

The implementation and class structure of economic resources within the ERPControl system follows these models and is also extended with classes like real estate, rights and services. The structure of the material, personnel, equipment and financial resources model is equal to the structure illustrated in figure 30.

Economic agents are represented by the *EconomicAgent* class within the ERPControl system. Each child class of the *EconomicAgent* class adds details necessary for a specific agent. Figure 31 shows an example list of available agents in the system.

DTYPE	id	description
OrgUnit	1	KerzenEWF
OrgUnit	2	Enterprise Domain
OrgUnit	3	Control Domain
OrgUnit	4	Treasury
OrgUnit	5	Sales
Customer	6	Customer - No 20001
Trader	7	Universal Product Trader
Bank	8	Bank Austria
State	9	Austria

Figure 31: Example list of economic agents

The type *"OrgUnit"* suggests an internal agent. All other economic agent types are external agents.

An extension of the core REA Model is the implementation of *EconomicCommitments,* like production plans or special agreements, as well as the *EconomicContract* class to specify agreements of future business cases.

Another extension of the REA Model and the ECSI standard is the technology package of the ERPControl system. In this package classes for planning and controlling of the production and process segment are included.

The implementation of various planning strategies is also specified within the ERPControl core system. These functionalities are needed to plan future events like the production schedule or the development of financial instruments.

4.2 Distribution of the ERPControl System

The ERPControl system is designed as a distributed enterprise system realized as a Java EE Web 2.0 application. One of the biggest advantages of a web application is that the system is available worldwide and a user does not have to install a specific client software to use the application.
After compiling the Java and HTML files the software code is deployed to the JBoss Server which makes the system accessible with a standard web browser. Figure 32 illustrates the distribution of the ERPControl system.

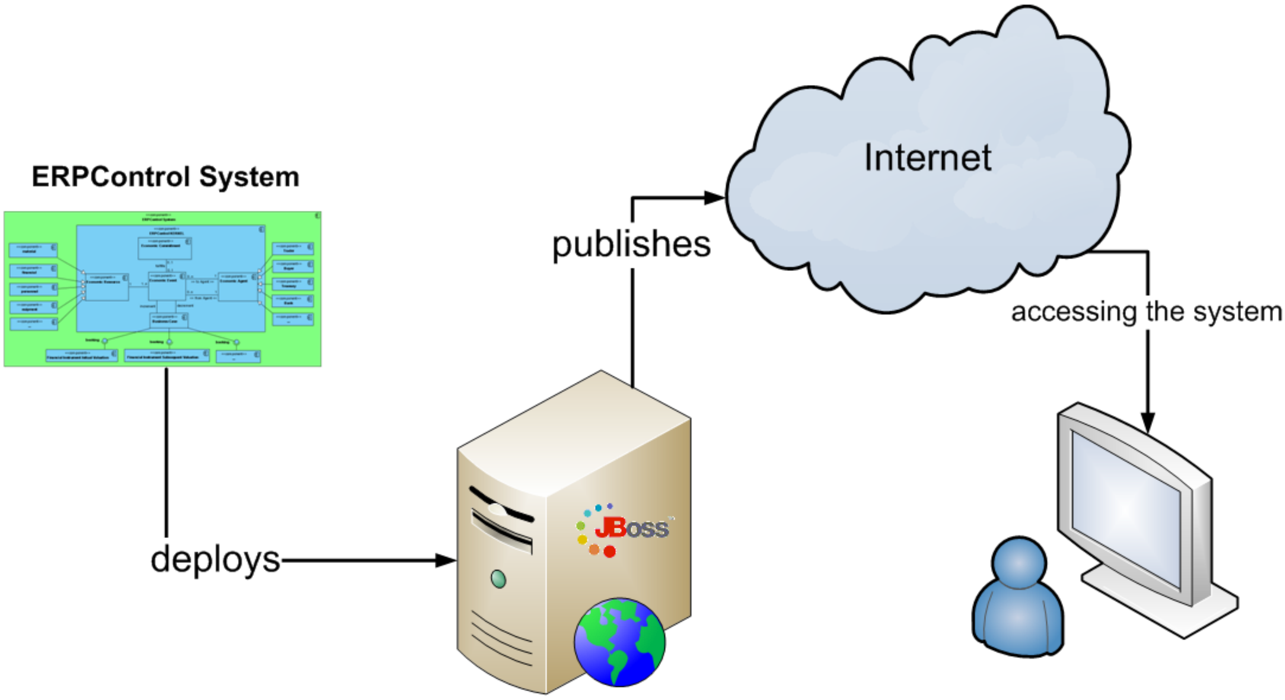


Figure 32: Distribution of the ERPControl system

Realized as a thin client application nearly all functionality of the ERPControl software is located on the server side. The biggest benefit of this division is maintaining the software as well as updating the components can be done very easily.
On the other hand, the amount of network traffic and needed server resources increases very fast which can lead to delays during user requests and that causes a bad user experience and also weakens the high quality of the system.

Problems like these can be solved with server replication. The load of traffic caused by a high amount of users is distributed on multiple equally configured servers. So the traffic load is shared by multiple machines which increase the performance of the system. The distribution of the components of the system is another possibility to increase the performance. For example the database, the REA Kernel or a package of various additional software modules could run on different servers.

Although the Java EE technology has a high consumption of resources it is a good choice to realize a huge system like this. Java provides good extensibility as well as the needed functionality to build a large scale distributed system.

4.3 Component Structuring

While the ERPControl system is growing more and more, the complexity of the structure also increases and threatens to become confusing. In software engineering we speak of the *"separation of concerns"* concept. This means all components dealing with different problems should be separated from each other. Applying this concept to the ERPControl system the software kernel should be encapsulated from the other components. The package structure of the system is organized as illustrated in figure 33.

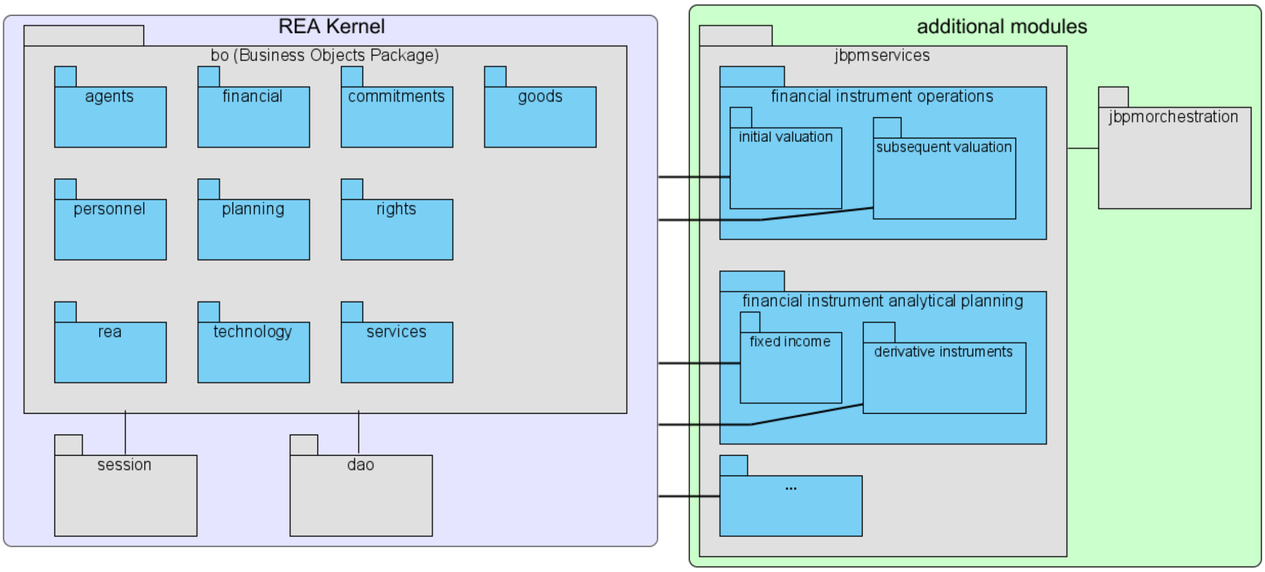


Figure 33: Package structure of the ERPControl system

Most components of the REA Kernel are tied together within the package *bo* which stands for business objects. The *bo* package contains all functions and data models that implement the extended REA model. The *session* package contains code for the user management of the software and the classes in the *dao* package are needed to access the database.

The classes within the REA Kernel are representing the core functions of the system. These packages should be separated from the other software modules to keep the complexity of the system structure as low as possible.
With a very high number of classes the complexity of the system quickly becomes unmanageable which causes a higher error rate.
For the further development of the ERPControl system, the REA Kernel should be stored within a single **J**ava **AR**chive (JAR) file which represents a library and can be imported by every Java class file. This ensures that no unintended changes at the REA Kernel are made by external developers and also the distribution of the core system would become much easier.

As illustrated in figure 33 additional software modules are connected with the existing REA Kernel and uses the specified interfaces to access the core functions of the system like booking of resource changes.
The above diagram displays the modules for initial and subsequent valuation of financial instruments as well as the analytical planning of fixed income and derivative instruments which is the implementation part of this thesis.

A well defined structuring of the different components of the software is one of the most important things to guarantee scalability, reusability and accuracy.

5. Software based Planning and Control of Financial Instruments

The software based planning and control of financial instruments is the core part of this thesis. The combination of information technology and business administration has a very high potential to control and plan various processes within a company or an organization in an optimized way.
Despite that, no perfect software solution for this exists and probably will never exist because of the large variety and nearly endless organizational structures and different business processes in every single organization.

The ERPControl system is an approach to create a new and innovative kind of management information system.
In this thesis I set the focus on financial instruments within a company. The upcoming sections will describe in detail the following business processes in the finance sector. The mathematical methods and theoretical approaches of the following valuation and planning processes are based on [IuFSA09].

- Initial valuation of fixed income financial instruments
- Subsequent valuation of fixed income financial instruments
- Analytical planning of fixed income financial instruments
- Analytical planning of financial options

The business process flow is the basis for each software module. The process modeling is done within the *JBoss Business Process Managing (jBPM)* language. It is an xml based language realized as a graphical modeling editor with different kinds of elements which I will introduce in the following sections.

A new process flow is created and started in annotating and calling a specific Java method with @CreateProcess. The name of a jBPM process is specified within the XML file of the specific business process:

```
<process-definition name="bp_calculationprocess">
</process-definition>
```

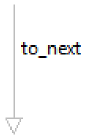
```
@CreateProcess(definition="bp_calculationprocess")
public void beginCalculationProcess(){}
```

In the following explanation of the jBPM elements the graphical symbol of a specific element is followed by the proper XML code.


```
<start-state name="start">
</start-state>
```

Figure 34: Start State in jBPM

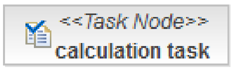
The *Start State* within a jBPM process marks the beginning of a process flow. When a new process flow is created the token points to the *Start State* and automatically goes to the first node specified by the outgoing transition. A token is a pointer to a specific state.




```
<transition to="next_node" name="to_next"></transition>
```

Figure 35: Transition in jBPM

A *Transition* determines which process element is next after the previous node is successfully terminated.




```
<task-node name="calculation task">
    <task name="calculate_pricing">
        <description>
            Pricing calculation
        </description>
        <assignment actor-id="#{actor.id}"/>
    </task>
</task-node>
```

Figure 36: Task Node in jBPM

A Task node in jBPM specifies a specific task that has to be processed by a specific actor in the context of the business process.

To start a task a specific Java method annotated with @StartTask has to be called.

```
@StartTask
public String beginPricingCalculation() {}
```

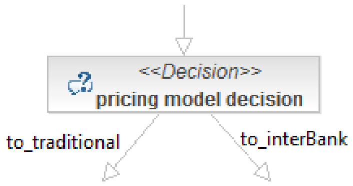
As return value the annotated method returns the URL of the next view component where the specific task is processed.
After a successful execution of the task a Java method annotated with @EndTask has to be called to signal the process manager that the processing of the task has successfully ended and the next task can be started.

```
@EndTask(transition="to_next")
public String endPricingCalculation() {}
```

The end method returns the URL of the task list.

In jBPM, every token can point to a specific actor, thereby creating a connection between a task node and an actor. The idea behind this task-actor relation in a token is that the business process manager will be waiting for some external trigger. So for example the process manager which controls the flow of the business process is waiting for a user input until the task can be terminated and the next task node can be processed. So the task list is a collection of tokens that refers to a specific actor.

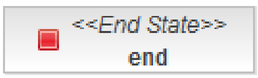
The XML code in figure 36 shows the specification of a task node with a specific task that is assigned to a specific actor specified by *actor.id*.
A task node can have multiple incoming transactions and multiple outgoing transactions. Which outgoing transaction is chosen can be specified by adding a transition attribute to the @EndTask annotation.




```xml
<decision name="pricing model decision">
    <handler class="PricingModelDecision.java"></handler>
    <transition to="traditional pricing" name="to_traditional"></transition>
    <transition to="interbank pricing" name="to_interBank"></transition>
</decision>
```

Figure 37: Decision Node in jBPM

A *Decision Node* specifies which transition will be the next based on the return value of a Java class defined as the handler for the decision node. A decision node has one or more incomings but should have at least two different outgoing transitions.




```xml
<end-state name="end">
</end-state>
```

Figure 38: Decision Node in jBPM

When reaching the *End State* of a jBPM process flow the process ends and the entered states have been successfully processed.

5.1 Operation Processes of Financial Instruments

The initial valuation process of fixed income financial instruments is specified as an operational process in the area of financing within the ERPControl system. Unlike analytical planning processes, operation processes result in a business transaction with an external agent and involve a change in the amount of resources within the company.

5.1.1 Initial valuation of Fixed Income Financial Instruments

Initial valuation of fixed income financial instruments also means borrowing money from a bank.

The illustration in figure 39 of the process as an UML activity diagram provides a view on the process flow.
After the process is started a trading agent has to be selected which usually will be a *Bank* in the case of borrowing money. The process is continued with specifying some necessary parameters of the fixed income financial instrument as the maturity, the IFRS category, or the pricing model.

Depending on the specified pricing model either the current interest rate curve or a user specified interest rate is used for the discounting of the cash flows in each period.
These parameters are needed to calculate the necessary data for the initial valuation of the defined loan type.
In the last step of the business process the determined results of the initial valuation are entered into the database and thereby available in the company's balance sheet.

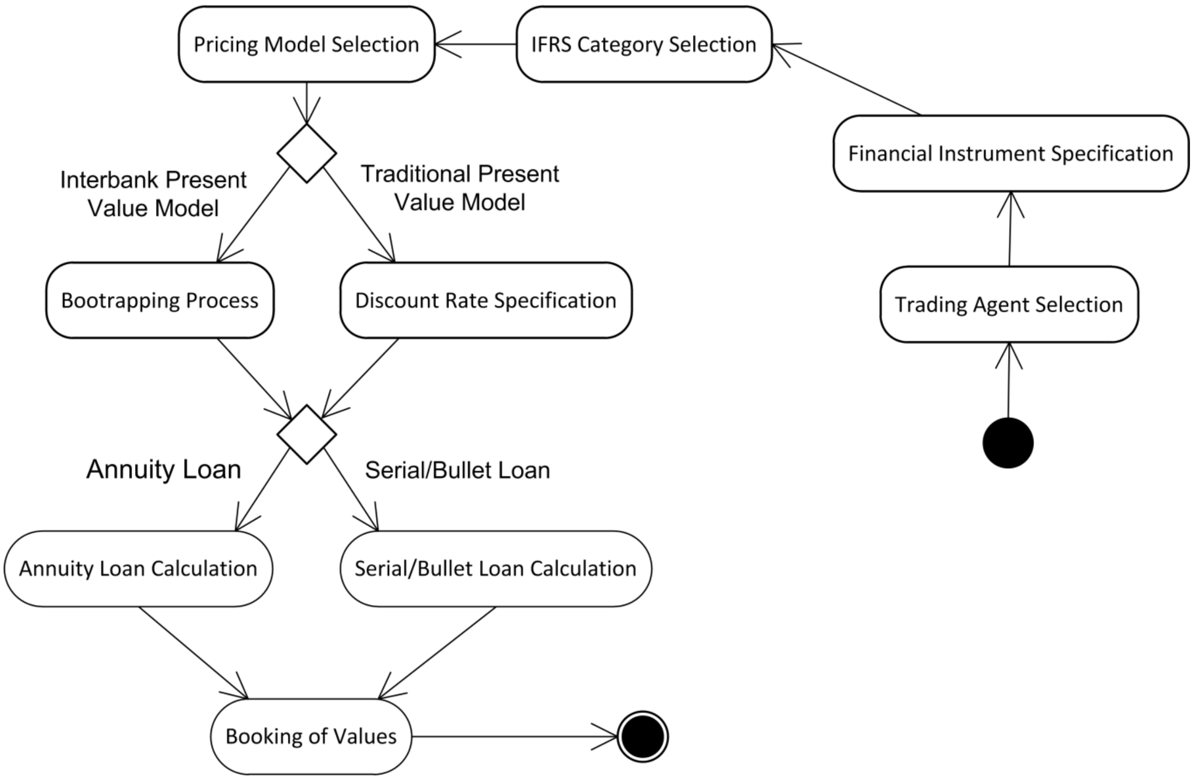


Figure 39: UML activity diagram of the initial valuation process

The business process model for the initial valuation is specified in figure 40.

As you can see in the illustration of the process model every task node has a *to_next* transition that specifies the flow to the next task node and a *cancel* transition that leads to the end node. So in every step of the task list the user can choose, either to enter the task and fulfill the needed user actions or to cancel to process.

The different steps of the process definition are described in detail in the next sections.

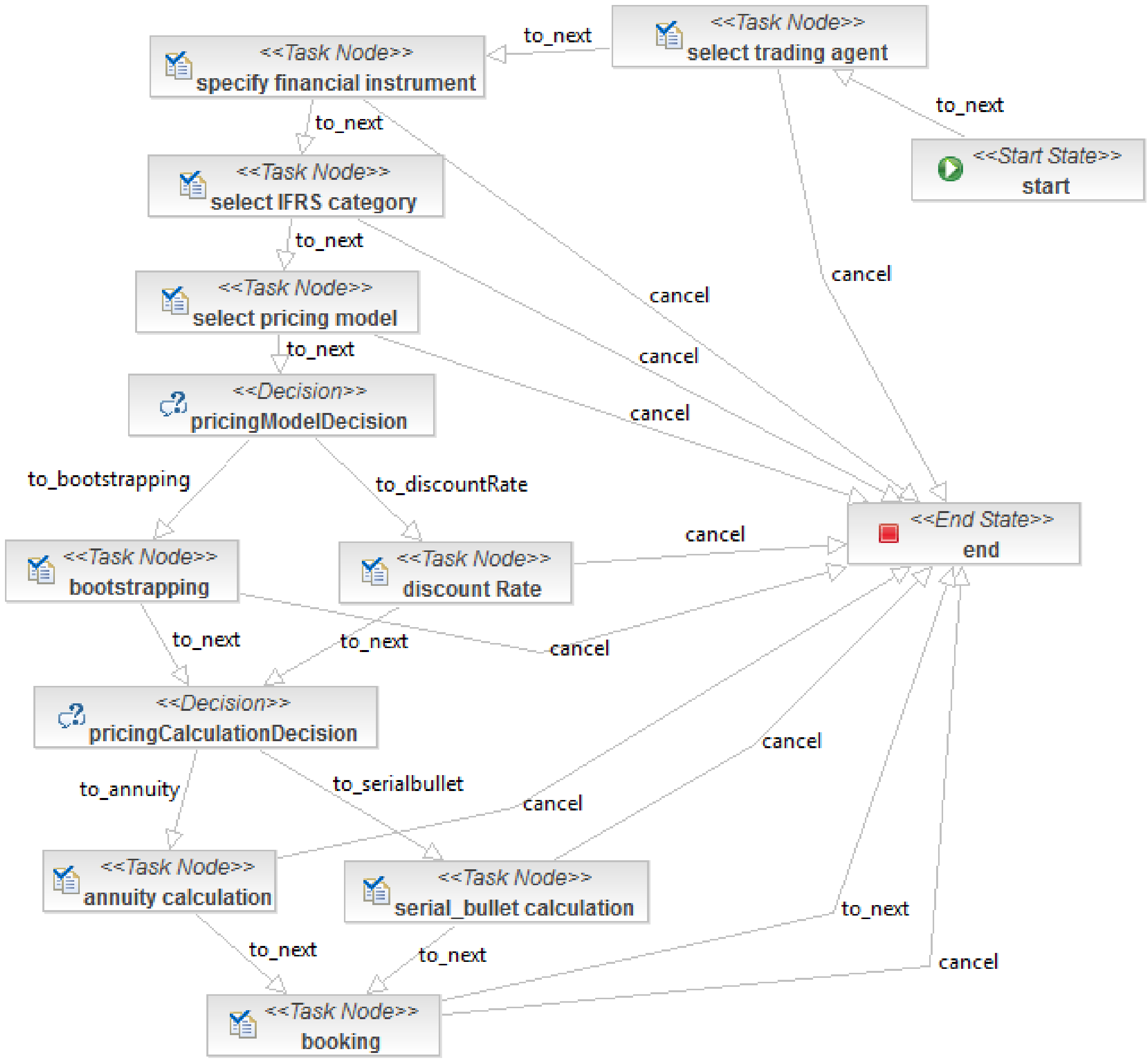


Figure 40: Process model for the initial valuation of fixed income financial instruments

The jBPM view is a very software-technical point of view on the process of an initial valuation of a fixed income instrument. The tasks and transitions are first of all needed to control the steps a user has to perform for the initial valuation.

The summarized steps are explained in detail in the upcoming sections.

5.1.1.1 Selection of a Trading Agent

The initial valuation of a fixed income financial instrument involves the interaction with an external agent, in most cases this will be a bank. So at the first task of the valuation a specific trading agent has to be chosen.

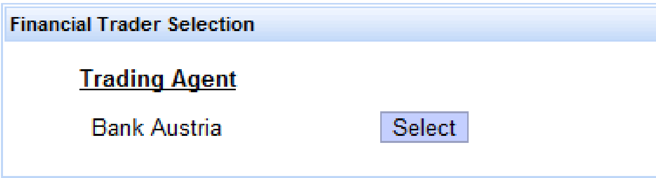


Figure 41: Selection of a trading agent

The selected trading agent is needed in the last task, the booking of the financial instrument, when a new business case instance is created.

5.1.1.2 Specification of the Financial Instrument

After the selection of a matching trading agent the next step in the business process is the specification of the desired financial instrument.

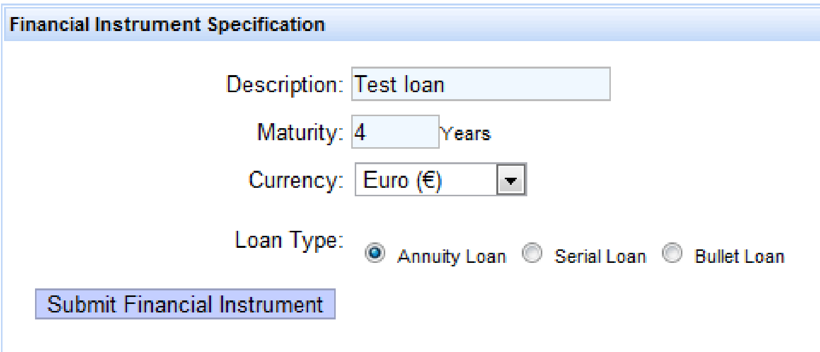


Figure 42: Specification of the financial instrument

To specify a fixed income financial instrument the user has to enter a description of the financial instrument and set the maturity of the instrument. As currency the user can choose between Euros and US Dollars.
Finally the loan type has to be chosen. The user is able to select between three different loan types, *Annuity Loan, Serial Loan* and *Bullet Loan.*

An annuity loan is characterized with an equal amount of cash flows over all periods. So over time the interest payments of this loan type are going down while the redemption payments are going up as illustrated in figure 43 for a 12 year annuity loan.

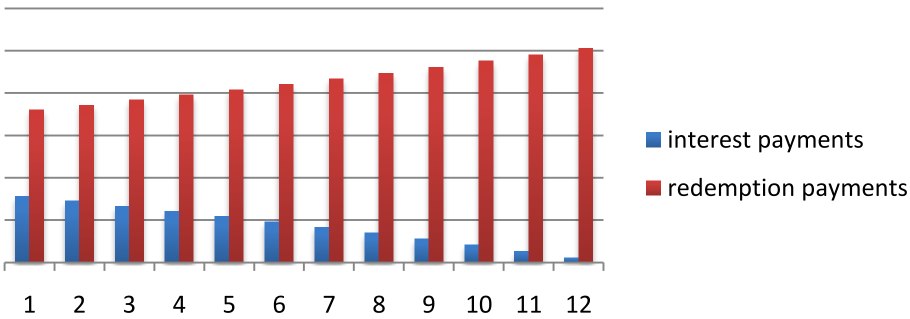


Figure 43: Annuity Loan

As you can see in figure 44 a serial loan has constant redemption payments and decreasing interest payments. This results in a different cash flow for every period.

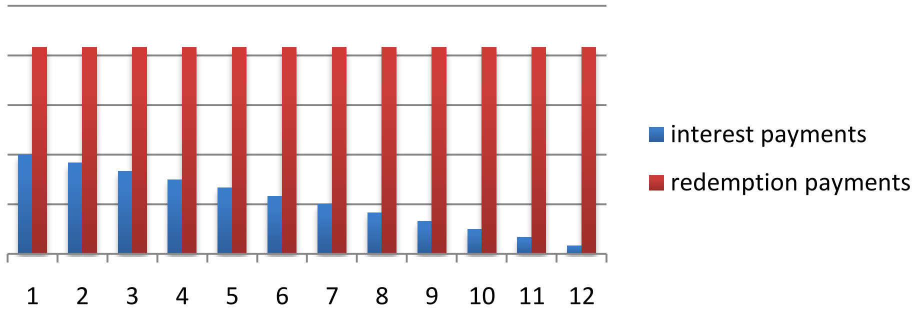


Figure 44: Serial Loan

A bullet loan is specified with constant interest payments over the whole maturity and a single redemption payment at the end paying back the complete financial liability.

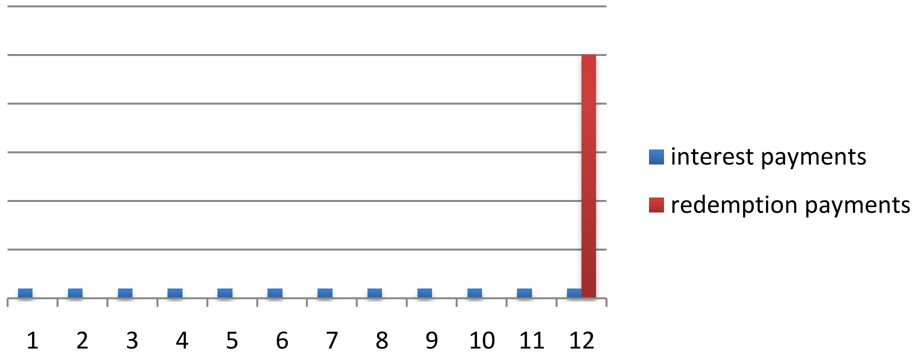


Figure 45: Bullet Loan

With the specified description of the financial instrument the user is able to identify the loan again in the subsequent valuation process.

5.1.1.3 IFRS Category Selection

Each financial instrument has to be assigned to a specific *IFRS (International Financial Reporting Standard)* category. For fixed income financial instruments there are four different IFRS categories, and one has to be selected to process the valuation.

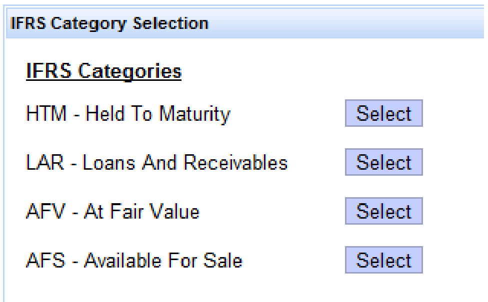


Figure 46: IFRS category selection

Held To Maturity (HTM) instruments are financial investments that are kept till the final due date. The subsequent valuation for HTM instruments is done with amortized costs of acquisition which are determined with the effective interest rate method. The resulting changes in value over time establish a financial income effect of gain and loss.

Loans And Receivables (LAR) categorized financial instruments are subsequently valuated with amortized costs of acquisition. Like in the HTM category the subsequently valuation is done by the effective interest rate method. The changes in value over time result in the operating statement which establishes a financial income effect of gain and loss.

At Fair Value through Profit and Loss (AFV) are financial instruments subsequently valuated at fair value. The changes in value over time results in a financial income effect of gain and loss. The subsequent valuation is based on the current interest curve.

Available For Sale (AFS) are financial instruments available for sale at any time and are subsequent valuated based on fair value. The changes in value over time till the moment of sale are entered in a revaluation reserve in the equity capital. The reserve is recorded in income at the moment of sale.

The description of the IFRS categories are based on [IuFSA09: p. 214,215] and internet reference [4].

The following table shows a summary of the different IFRS categories.

		financial income	
IFRS Category	**Subsequent valuation**	**effective**	**neutral**
HTM	amortized costs of acquisition	operating statement effect	
LAR	amortized costs of acquisition	operating statement effect	
AFV	fair value	operating statement effect	
AFS	fair value		reserve effect

Table 1: IFRS Categories

5.1.1.4 Pricing Model Selection

The next step in the initial valuation of a financial instrument is the selection of a pricing model. Here the user has two options, the *Traditional Present Value Model* or the *Inter Bank Present Value Model*. The difference between these two models in the ERPControl software is that the traditional model uses a constant user specified interest rate for the discounting in all periods. The interbank model uses the current interbank swap rates to do the discounting. Both models are used for the pricing of financial instruments within the software.

So for the *Traditional Present Value Model* the user just has to specify an interest rate for the discounting in all periods.

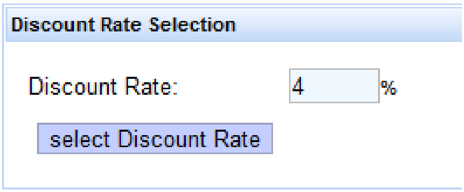


Figure 47: Specifying the Traditional Present Value Model

The pricing with the *Inter Bank Present Value Model* is done on the basis of the current interest rate curve. These rates are calculated from the current swap rates which the ERPControl software automatically retrieves from the webpage of the Austrian bank institution *Erste Bank.*

Here is the web URL:
http://produkte.erstegroup.com/CorporateClients/de/MarketsAndTrends/Fixed_Income/Kapitalmarktderivate

Based on the retrieved swap rate the interest rates are automatically calculated using the bootstrapping method which I will illustrate now.
To calculate the interest rates we start with the one year swap rate $R^S_{0,1}$ which equates the one year interest rate $R_{0,1}$.
On the basis of that the two year interest rate $R_{0,2}$ is calculated. To do this the two year discount factor $DF_{0,2}$ (2) is needed which is determined from the two year swap rate $R^S_{0,2}$ and the one year discount factor $DF_{0,1}$ as illustrated in (1) and (2).

(1) $$DF_{0,1} = (1 + R^S_{0,1})^{-T_{0,1}}$$

(2) $$DF_{0,2} = \frac{1 - R^S_{0,2} * DF_{0,1}}{R^S_{0,2} + 1}$$

The calculated discount factor $DF_{0,2}$ is now converted to the two year interest rate $R_{0,2}$ as illustrated in (3).

(3) $$R_{0,2} = \left(\frac{1}{DF_{0,2}}\right)^{\frac{1}{T_{0,2}}} - 1$$

This procedure is now repeated for a longer period of time. The interest rates for longer maturities ($R_{0,t}$) are little by little determined based on the corresponding swap rates (R^S_t) by solving the resulting equation for each demanded discount factor ($DF_{0,t}$) and the transformation into the proper interest rate ($R_{0,t}$).

The equations in (2) and (3) are based on the fact that the swap rates are par interest rates so that for a fixed income financial instrument the nominal value is equal to the present value. Equation (4) shows the transformation of the mathematical equation that results from equating the nominal value with the present value, which is solved for the discount factor with the longest maturity ($DF_{0,T}$).

(4)

$$\sum_{t=1}^{T} K_{0,t}^{S} * DF_{0,t} + NW_0 * DF_{0,T} = NW_0$$

$$\sum_{t=1}^{T} \left(\frac{K_{0,t}^{S}}{NW_0}\right) * DF_{0,t} + 1 * DF_{0,T} = 1$$

$$\sum_{t=1}^{T} \left(R_{0,t}^{S}\right) * DF_{0,t} + DF_{0,T} = 1$$

$$\sum_{t=1}^{T-1} R_{0,t}^{S} * DF_{0,t} + R_{0,T}^{S} * DF_{0,T} + DF_{0,T} = 1$$

$$DF_{0,T} = \frac{1 - \sum_{t=1}^{T-1} R_{0,t}^{S} * DF_{0,t}}{R_{0,t}^{S} + 1}$$

Now the calculated discount factors have to be transformed to interest rates. The function to convert the discount factors to interest rates is derived in (5).

(5)

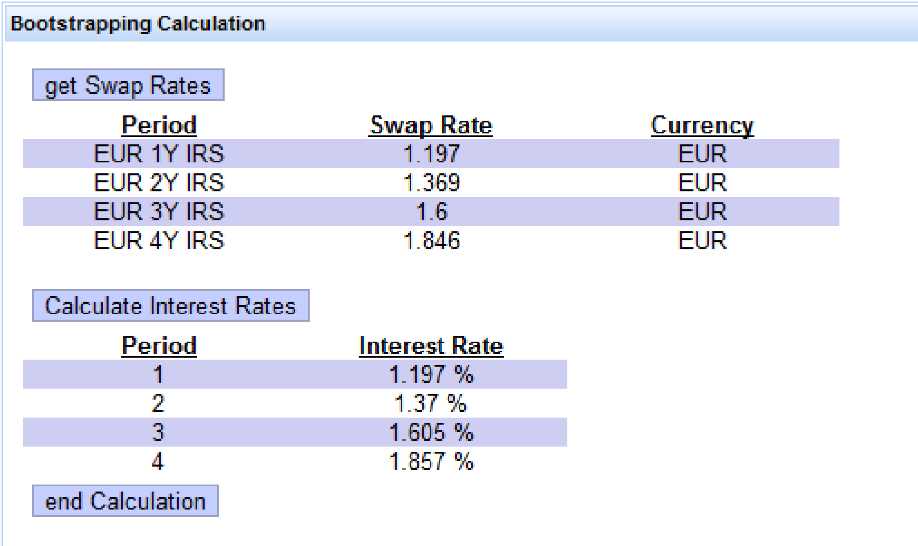
$$\frac{1}{\left(1 + R_{0,T}\right)^{T_{0,T}}} = DF_{0,T}$$

$$\frac{1}{DF_{0,T}} = \left(1 + R_{0,T}\right)^{T_{0,T}}$$

$$\left(\frac{1}{DF_{0,T}}\right)^{\frac{1}{T_{0,T}}} = 1 + R_{0,T}$$

$$R_{0,T} = \left(\frac{1}{DF_{0,T}}\right)^{\frac{1}{T_{0,T}}} - 1$$

This procedure is implemented in the *BootstrappingProcess.java* Session Bean in ERPControl and automatically returns the current interest rates. For example the Euro interest rates for 4 years as illustrated in figure 48.



Bootstrapping Calculation

get Swap Rates

Period	Swap Rate	Currency
EUR 1Y IRS	1.197	EUR
EUR 2Y IRS	1.369	EUR
EUR 3Y IRS	1.6	EUR
EUR 4Y IRS	1.846	EUR

Calculate Interest Rates

Period	Interest Rate
1	1.197 %
2	1.37 %
3	1.605 %
4	1.857 %

end Calculation

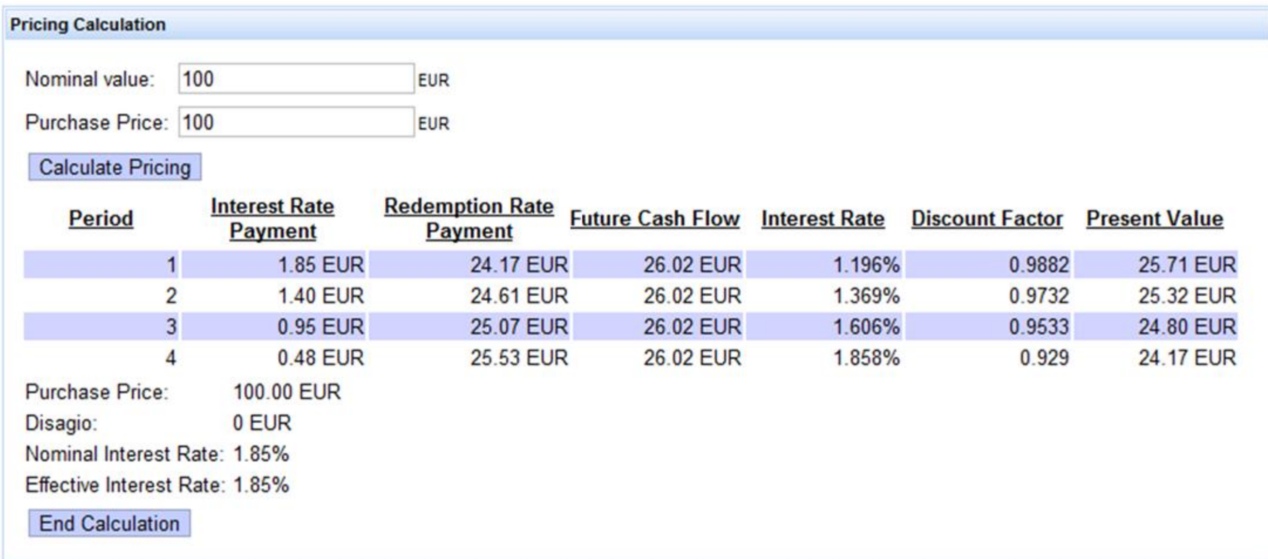
Figure 48: Bootstrapping process calculated with ERPControl

5.1.1.5 Calculation of Prices

The calculation of prices has to be done for three different types of loans as specified in the *Financial Instrument Specification* Task. The different calculation processes will be demonstrated in the upcoming pages.

5.1.1.5.1 Annuity Loan Pricing

Figure 49 shows the summary of the annuity loan calculation according to the *PricingCalculationAnnuity.java* service within the ERPControl system.



Pricing Calculation

Nominal value: 100 EUR

Purchase Price: 100 EUR

Calculate Pricing

Period	Interest Rate Payment	Redemption Rate Payment	Future Cash Flow	Interest Rate	Discount Factor	Present Value
1	1.85 EUR	24.17 EUR	26.02 EUR	1.196%	0.9882	25.71 EUR
2	1.40 EUR	24.61 EUR	26.02 EUR	1.369%	0.9732	25.32 EUR
3	0.95 EUR	25.07 EUR	26.02 EUR	1.606%	0.9533	24.80 EUR
4	0.48 EUR	25.53 EUR	26.02 EUR	1.858%	0.929	24.17 EUR

Purchase Price: 100.00 EUR

Disagio: 0 EUR

Nominal Interest Rate: 1.85%

Effective Interest Rate: 1.85%

End Calculation

Figure 49: Annuity Loan pricing calculation

As defined in 5.1.1.2 an annuity loan is characterized by constant cash flow rates. To start the calculation the user has to specify the *Nominal Value* and the *Purchase Price* of the loan. The nominal value is the basis for the calculation of the interest payments. The purchase price is the amount of money a customer receives when money is borrowed from a bank.

The constant payments (future cash flows) are also called annuities. One annuity is the sum of the interest payment and the redemption payment of a period. Thereby over all periods the amount of the interest payment is going down while the amount of a redemption payment is going up as illustrated in figure 43 and calculated in figure 49.

The discount factors are calculated based on the interest rate of the specific period. For example the discount factor of period 1 is calculated as illustrated in (6).

(6) $$\left(1+\left(\frac{1.196}{100}\right)\right)^{-1} = 0.9882$$

The equalization of nominal value and purchase price, which equates the present value, leads to a par-rating so that neither an Agio nor a Disagio is present and the payout is equal to the nominal value. Based on the present value of the loan the annuities are calculated as shown in (7).

(7)
$$PV_0 = \sum_{t=1}^{T} \frac{A}{\left(1+R_{0,t}\right)^{T_{0,t}}} = NV_0$$

$$\sum_{t=1}^{T} A * DF_{0,t} = A * \sum_{t=1}^{T} DF_{0,t} = NV_0$$

$$A = \frac{NV_0}{\sum_{t=1}^{T} DF_{0,t}} = \frac{NV_0}{APVF_0}$$

The sum of discount factors over all periods is also called annuity present value factor. Due to the fact that we are dealing with a par-rating here, the nominal interest rate equals the effective interest rate as you can see in figure 49. The calculation of the nominal interest rate is illustrated in (8).

(8) $$R_0^N = \frac{1-DF_{t,T}}{\sum_{t=1}^{T} DF_{0,t}} = R_0^E$$

The sum of discount factors is equal to the calculation in (9).

(9) $$APVF_0 = 0.9882 + 0.9732 + 0.9533 + 0.929 = 3.8437$$

Based on the calculated annuity present value factor the annuity for all periods is calculated as shown in (10).

(10) $$A = \frac{100}{3.8437} = 26.02$$

Applying the formula defined in (8) the calculation of the nominal interest rate is shown in (11).

(11) $$R_0^N = \frac{1 - 0.929}{3.8437} = 0.0185$$

Multiplied by 100 the nominal interest rate now equals 1.85% as shown in figure 49.

Now that we know the annuities as well as the nominal interest rate, the redemption payment and the interest payments can be calculated. The interest payments are calculated by the multiplication of the nominal interest rate with the nominal value reduced by the sum of redemption payments over the past periods.

So the interest payment in period 1 is:

(12) $$IP_1 = \frac{1.85}{100} * 100 = 1.85$$

Now that we know the interest payment in period 1 we can compute the redemption payment which is the interest payment subtracted from the annuity as in (13).

(13) $$RP_1 = 26.02 - 1.85 = 24.17$$

The nominal value is now reduced by the redemption payment of the first period, so the interest payment of period 2 is calculated based on the reduced nominal value.

(15) $$IP_2 = (100 - 24.17) * \frac{1.85}{100} = 1.40$$

Generalized the method to calculate an interest payment of a specific period x is defined in (16).

(16) $$IP_x = (NV_0 - \sum_{t=1}^{x} RP_t) * R_0^N$$

The redemption payment of period 2 is now again the annuity reduced by the interest payment of period 2. This procedure is now repeated for all periods as represented in figure 49.

The present value of a single period is the result of the discount factor multiplied by the cash flow of the specific period.

(17) $$PV_t = DF_t * CF_t$$

To demonstrate this, the present value of period one is calculated like this:

(18) $$0.9882 * 26.02 = 25.71$$

The purchase price is now the result of the sum of the present values over all periods.

(19)

$$PP_0 = \sum_{t=1}^{T} PV_t = 25.71 + 25.32 + 24.80 + 24.17 = 100$$

5.1.1.5.2 Serial Loan Pricing

Compared to the annuity loan a serial loan has constant redemption payments and variable cash flows over all periods.

Pricing Calculation

Nominal value: 100 EUR

Nominal interest Rate: 4.0 %

Calculate Pricing

Period	Interest Rate Payment	Redemption Rate Payment	Future Cash Flow	Interest Rate	Discount Factor	Present Value
1	4.00 EUR	25.00 EUR	29.00 EUR	1.196%	0.9882	28.66 EUR
2	3.00 EUR	25.00 EUR	28.00 EUR	1.369%	0.9731	27.25 EUR
3	2.00 EUR	25.00 EUR	27.00 EUR	1.606%	0.9533	25.74 EUR
4	1.00 EUR	25.00 EUR	26.00 EUR	1.858%	0.929	24.16 EUR

Purchase Price: 105.81 EUR

Agio: -5.81 EUR

Effective Interest Rate: 1.6012%

End Calculation

Figure 50: Serial Loan pricing calculation

While the redemption payments remain constant over time the interest rates are going down by the reduced nominal value. Unlike in an annuity loan here the nominal interest rate is specified by the user and the purchase price is the result of the pricing calculation. The cash flow in each period is the sum of the interest payment plus the redemption payment.

The interest payment is calculated by the multiplication of the nominal value reduced by the sum of redemption payments with the nominal interest rate as defined in (16). Also the present value of each period is calculated in the same way as in the annuity loan pricing method defined in (17).
In the calculation of the effective interest rate the (Dis-)Agio is considered, so unless the loan is par-rated the effective interest rate is different compared to the nominal interest rate.
The effective interest rate is calculated by the equation of the sum of the present values over all periods with the purchase price as illustrated in (20).

(20)

$$\sum_{t=1}^{T} \frac{C_t}{(1 + R_0^E)^{T_{0,t}}} = PP_0$$

The result of this equation for the calculation of an effective interest rate over multiple periods is a nonlinear equation which has to be solved numerically. The equation for the serial loan in figure 50 is illustrated in (21).

(21)

$$\frac{29}{(1+R_0^E)^1}+\frac{28}{(1+R_0^E)^2}+\frac{27}{(1+R_0^E)^3}+\frac{26}{(1+R_0^E)^4}=105.81$$

In the initial valuation software module the numerical equation to determine the effective interest rate is solved using the root finding algorithm bisection. Therefore the equation is transformed into the following:

(22)

$$\frac{29}{(1+R_0^E)^1}+\frac{28}{(1+R_0^E)^2}+\frac{27}{(1+R_0^E)^3}+\frac{26}{(1+R_0^E)^4}-105.81=0$$

Equation (22) is now solved using the bisection solver function of the Apache Math Commons library.

The purchase price in the current loan is not equal to the nominal value, so this loan is not par-rated. As defined in (19) the purchase price is the sum of the present values over all periods. Due to the fact that the purchase price is not equal to the nominal value we have to deal with an *Agio.* Agios or *Disagios* are calculated by subtracting the purchase price from the nominal value as defined in (23).

(23)

$$(D)A_0 = NV_0 - PP_0$$

We are speaking of a disagio if the result of this calculation is greater than 0 and of an agio if the result is smaller than 0.

5.1.1.5.3 Bullet Loan Pricing

The third and last type of a loan is the bullet loan where the total sum of debt is paid back at the last period. So the only payments that have to be made in all except the last period are the interest payments.

Pricing Calculation

Nominal value: 100 EUR

Nominal interest Rate: 4.0 %

Calculate Pricing

Period	Interest Rate Payment	Redemption Rate Payment	Future Cash Flow	Interest Rate	Discount Factor	Present Value
1	4.00 EUR	0 EUR	4.00 EUR	1.206%	0.988	3.96 EUR
2	4.00 EUR	0 EUR	4.00 EUR	1.381%	0.9729	3.90 EUR
3	4.00 EUR	0 EUR	4.00 EUR	1.603%	0.9534	3.82 EUR
4	4.00 EUR	100 EUR	104.00 EUR	1.848%	0.9293	96.65 EUR

Purchase Price: 108.33 EUR
Agio: -8.33 EUR
Effective Interest Rate: 1.8218%

End Calculation

Figure 51: Bullet Loan pricing calculation, interbank present value model

As illustrated in figure 51 the interest payments over all periods remain constant. This is the result of the fact that in a bullet loan calculation the debt is not reduced over time so the basis for the calculation of the interest payment remains the same.

All exemplified loans are priced with the interbank present value model. A loan priced with the traditional present value model is illustrated in figure 52.

Pricing Calculation

Nominal value: 100 EUR

Nominal interest Rate: 4.0 %

Calculate Pricing

Period	Interest Rate Payment	Redemption Rate Payment	Future Cash Flow	Interest Rate	Discount Factor	Present Value
1	4.00 EUR	0 EUR	4.00 EUR	4.0%	0.9615	3.85 EUR
2	4.00 EUR	0 EUR	4.00 EUR	4.0%	0.9245	3.70 EUR
3	4.00 EUR	0 EUR	4.00 EUR	4.0%	0.8889	3.56 EUR
4	4.00 EUR	100 EUR	104.00 EUR	4.0%	0.8548	88.89 EUR

Purchase Price: 100.00 EUR
Agio: 0.00 EUR
Effective Interest Rate: 3.9972%

End Calculation

Figure 52: Bullet Loan pricing calculation, traditional present value model

As you can see, the interest rate in the traditional present value model is set to a level of 4% over all periods. This causes a lower purchase price of the financial instrument. Also the effective interest rate is now at a level of 4%, the displayed number of 3.9972% is a result of the bisection algorithm because solving a nonlinear equation can only be done approximately.
Due to the fact that the effective interest rate is now equal to the nominal interest rate the loan is par-rated so the nominal value equals the purchase price.

The calculation of the purchase price, the (dis-)agio as well as the effective interest rate is done with the same procedure as shown in the serial loan pricing section.

5.1.1.6 Booking of Values

After the pricing calculation of the specific loan type is done the next and last step in the initial valuation business process is the booking of the value changes. Figure 53 shows the last screen of the initial valuation task list where a summary of the specific loan is displayed and the booking process can be executed.

Booking of Values

Task ID	Started at	Financial Instrument	Trading Agent	Maturity	Pricing Model	IFRS Category	Purchase Price		
1	Aug 4, 2010 11:22:32 PM	Test loan	Bank Austria	4	Inter Bank Present Value Model	Available For Sale	108.33 EUR	Book	Cancel

Figure 53: Booking screen for a fixed income financial instrument in the ERPControl system

The booking process is now accessing the REA Kernel of the software to create the appropriate economic events and to store the resulting data in the database.

As shown in figure 53 the purchase price of the specified loan is 108.33 Euros. The borrower gets this amount of money from the bank and gives the bank in exchange a promise to repay an equal amount of money. The database browser displays the economic events specified in the booking process. These events are combined to a business case object which is stored in the database. The process of storing the changes in value checks the sum of incoming and outgoing resources. The value restriction does not allow the sum of incoming resources to be different than the sum of outgoing resources.

description	eventType	quantity	price_currency
Bank -> Treasury (Cash)	INCREMENT	108.33	EUR
Treasury -> Bank (Financial Liability=Loan)	DECREMENT	-108.33	EUR

Figure 54: Economic events specified by the booking process of a loan

The increment event of the business case is the transfer of the amount of 108.33 EUR from the external agent bank to the internal agent treasury.

Figure 55: Increase event of the booking process, resource cash from Bank to Treasury

To fulfill the value restriction the decrement event is the transfer of a financial liability from the organization unit treasury to the bank.

Figure 56: Decrease event of the booking process, resource financial liability from Treasury to Bank

As illustrated in figure 55 and 56 the amount of incoming resources equals the amount of outgoing resources. So the changes in value can be successfully entered.

List of Resources

Class	Description	Quantity	UoM	Price	Value
Cash	EUR Cash	108.33	PCS	EUR 1.00	EUR 108.33
Cash	USD Cash	0.00	PCS	$ 1.00	$ 0.00
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	0.00	PCS	EUR 1.00	EUR 0.00
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	0.00	PCS	EUR 1.00	EUR 0.00
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
BulletLoan	Test loan	-108.33	PCS	EUR 1.00	EUR -108.33

Figure 57: Resource list with the entered value changes

Finally the resource list of the ERPControl system shows a Euro Cash of 108.33 Euros and a bullet loan with the amount of -108.33 Euros representing the financial liability.

5.2 Performance Management Processes of Financial Instruments

The subsequent valuation of financial instruments is considered as a financial management process within the performance management section of the ERPControl system. These kinds of processes are usually executed by a financial manager within a specific organization. Most of the financial management processes can be done automatically with a proper software support like implemented in ERPControl.

5.2.1 Subsequent Valuation of a Fixed Income Financial Instrument

After the initial valuation, financial instruments have to be subsequently valuated in every period. The procedure of the subsequent valuation depends on the IFRS category of the financial instrument. In ERPControl every financial instrument has a maturity and a current period which is increased by 1 year after each subsequent valuation process.
Right after the initial valuation of a financial instrument the current period is 0. At this version of the software the current period can be increased manually. If a financial instrument is at current period 1 or higher it can be subsequently valuated and the changes in value are entered and made persistent.

The illustration as an UML activity diagram in figure 58 provides a view on the process flow. In the first task of the subsequent valuation a summary over all fixed income financial instruments is presented to the user where the current state of each instrument is apparent.
In the second, and main step, of the process the revaluation of all instruments, in a current period greater than 0, is performed. The last step of the process makes the changes in value available in the balance sheet by entering the results into the database.

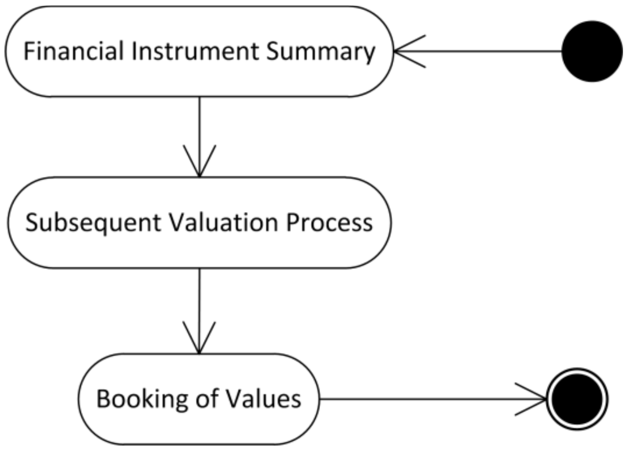


Figure 58: UML activity diagram of the subsequent valuation of fixed income financial instruments

Figure 59 shows the business process model of the subsequent valuation.

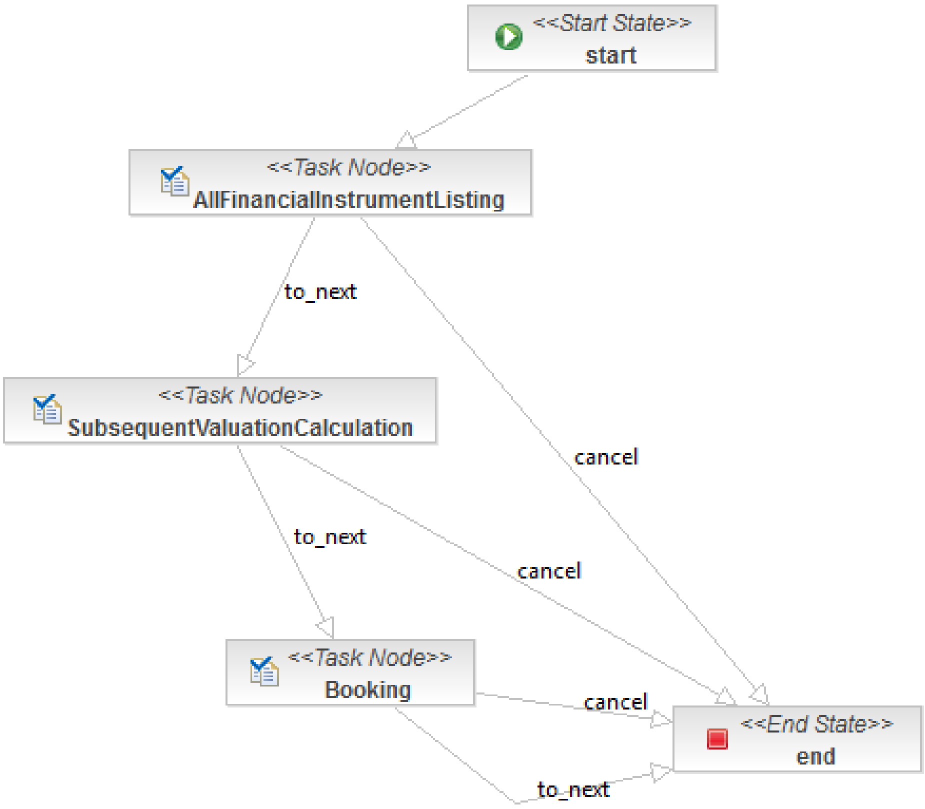


Figure 59: jBPM process of the subsequent valuation of fixed income financial instruments

The steps illustrated in the process model are explained in detail in the upcoming sections.

5.2.1.1 Financial Instrument Listing

When the process of the subsequent valuation is started, a list of all fixed income financial instruments currently stored in the database of the ERPControl system is presented to the user. All of the displayed loans are in period 0 and therefore have to be manually set to current period 1 to be subsequently valuated. As shown in figure 60 currently four fixed income financial instruments are stored within the ERPControl database.

List of all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Purchase Price	
AFS Loan	Available For Sale	4 Years	0	105.85 EUR	Increase Current Period
AFV Loan	At Fair Value	4 Years	0	100.00 EUR	Increase Current Period
HTM Loan	Held To Maturity	4 Years	0	110.42 USD	Increase Current Period
LAR Pricing	Loans And Receivables	4 Years	0	105.85 EUR	Increase Current Period

End Financial Instruments List

Figure 60: List of all fixed income financial instruments with current period 0

Three financial instruments have Euros as their currency and one loan is in US Dollars. Now the updated list of resources shows the sum of the loans of each currency as well as the appropriate financial liability.

List of Resources

Class	Description	Quantity	UoM	Price	Value
Cash	EUR Cash	311.70	PCS	EUR 1.00	EUR 311.70
Cash	USD Cash	110.42	PCS	$ 1.00	$ 110.42
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	0.00	PCS	EUR 1.00	EUR 0.00
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	0.00	PCS	EUR 1.00	EUR 0.00
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
SerialLoan	AFS Loan	-105.85	PCS	EUR 1.00	EUR -105.85
AnnuityLoan	AFV Loan	-100.00	PCS	EUR 1.00	EUR -100.00
BulletLoan	HTM Loan	-110.42	PCS	$ 1.00	$ -110.42
SerialLoan	LAR Pricing	-105.85	PCS	EUR 1.00	EUR -105.85

Figure 61: Resource list containing four fixed income financial instruments

To perform the process of the subsequent valuation all financial instruments are now manually set to current period 1. This has to be done only once for the remaining periods. The current period is increased automatically after booking the value changes.

List of all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Purchase Price
AFS Loan	Available For Sale	4 Years	1	105.85 EUR
AFV Loan	At Fair Value	4 Years	1	100.00 EUR
HTM Loan	Held To Maturity	4 Years	1	110.42 USD
LAR Pricing	Loans And Receivables	4 Years	1	105.85 EUR

End Financial Instruments List

Figure 62: List of fixed income financial instruments with current period at 1

The process of the subsequent valuation will be illustrated in detail for each IFRS category in the upcoming sections.

5.2.1.2 Held To Maturity Subsequent Valuation

Subsequent valuation of Held To Maturity financial instruments is based on the amortized costs of acquisition and is effectively entered in the operation statement. The pricing for the subsequent

valuation of HTM instruments is done with the effective interest rate which was determined during the initial valuation.
To clearly explain the process of the subsequent valuation I provide calculation tables containing the initial and subsequent valuation of the specific financial instrument.

	t=0	t=1	t=2	t=3	t=4	
NV_0	**100**					Nominal Value
NV_t		100	100	100	100	Reduced Nominal Value
R_t^N		4%	4%	4%	4%	Nominal Interest Rate
RP_t		0	0	0	100	Redemption Payment
IP_t		4	4	4	4	Interest Payment
Ct		4	4	4	104	Cash Flow
R_t		0.453%	0.675%	0.995%	1.340%	Interest Rate (USD)
$DF_{0,t}$		0.9955	0.9866	0.9707	0.9481	Discount Factor
PV_t		3.98	3.95	3.88	98.61	Present Value
PP	**110.42**					Purchase Price
$(D)A_0$	**-10.42**					(Dis-)Agio
R_0^E	**1.304%**					Effective Interest Rate
PV_{EIRt}		3.95	3.95	3.95	102.66	Effective Interest Rate Present Value
$\sum SVPV_t$		110.56	106.61	102.66	0.00	Sum of subsequent valuated present values
$PWPV_t$	110.42	110.56	106.61	102.66	0.00	Pathwise Present Value
PV_{BRPt}		110.56	106.61	102.66	100.00	Present Value before Redemption Payment
$(D)AD_t$		0.14	-3.95	-3.95	-2.66	(Dis-)Agio Dissolution
FS_t		4.14	0.05	0.05	1.34	Financial Success
SR_t		3.75%	0.05%	0.05%	1.30%	Financial Success Rate

Table 2: HTM initial and subsequent valuation after period 1

Table 2 shows the initial and subsequent valuation of a HTM bullet loan. The blue cells are the start values, and the green cells are the calculation of the subsequent valuation.
The subsequent valuation of a HTM loan is calculated based on the effective interest rate. So the present values of the subsequent valuation are calculated as defined in (24).

(24)

$$PV_{EIRt} = \frac{C_t}{(1 + R_0^E)}$$

So for example the effective interest rate present value of period 1 is calculated as shown in (25).

(25)

$$PV_{EIRt} = \frac{4}{(1 + 0.01304)} = 3.95$$

The path-wise present value is the result of the sum of the present values of all remaining periods. For example the path-wise present value of period 1 is the sum of the present values of the periods 2, 3 and 4.

(26)

$$PWPV_1 = 3.95 + 3.95 + 102.66 = 110.56$$

So the path-wise present value of period 1 equals 110.56 US Dollars. The calculation for all other path-wise present values can be performed equally as defined in (27).

(27)

$$PWPV_t = \sum_{t+1}^{T} PV_{EIRt}$$

The present value before redemption payment is calculated by adding the redemption payment of the specific period to the path-wise present value.

(28)

$$PV_{BRPt} = PWPV_t + RP_t$$

The calculation in (29) exemplifies the determination of the present value before redemption payment of period 1. Due to the fact that the redemption payment in period 1 is 0 the present value before redemption payment equals the path-wise present value.

(29)

$$PV_{BRP1} = 110.56 + 0 = 110.56$$

After the calculation of all path-wise present values and present values before redemption payment the (dis-)agio dissolution can be calculated. To determine the (dis-)agio dissolution the path-wise present value is subtracted from the present value before redemption payment of the following period.

(30)

$$(D)AD_t = PV_{BRPt} - PWPV_{t-1}$$

To determine the (dis-)agio dissolution of the first period the purchase price of the financial instrument is subtracted from the path-wise present value of period 1. In this case the result is 0.14 US Dollar as defined in (31).

(31)

$$(D)AD_1 = 110.56 - 110.42 = 0.14$$

After the determination of the (dis-)agio dissolution the financial success of the period can be calculated. In the case of an HTM financial instrument the financial success is the result of the interest payment plus the (dis-)agio dissolution of a specific period as illustrated in (32).

(32)

$$FS_t = IP_t + (D)AD_t$$

The last step of the subsequent valuation of a fixed income financial instrument is the determination of the financial success rate. The financial success rate is calculated by dividing the financial success of a specific period by the path-wise present value of the previous period.

(33)

$$FSR_t = \frac{FS_t}{PWPV_{t-1}}$$

To demonstrate this, the calculation of the financial success rate of period 1 is illustrated in (34).

(34)

$$FSR_2 = \frac{4.14}{110.42} = 0.0375 = 3.75\%$$

In the ERPControl system the subsequent valuation is always done for only the current period of the financial instrument. After the subsequent valuation of a specific period a summary of the calculated values of this period is presented to the user as illustrated in figure 63.

Financial Instrument Subsequent Valuation Calculation

Valuate all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
HTM Loan	HTM	4 Years	1	4.0%	1.3043%	4.00 USD	110.56 USD	110.42 USD	110.56 USD	0.14 USD	4.14 USD	3.7493%	USD

Over all financial success (EUR): 0 EUR
Over all financial success (USD): 4.14 USD
Average financial success rate: 3.7493%

End Valuation Calculation

Figure 63: Subsequent valuation of a HTM bullet loan in period 1

In the period summary the path-wise present value as well as the path-wise present value of the previous period (t-1) are displayed to make it clear to the user how the (dis-)agio dissolution is calculated.

The last column represents the revaluation reserve which is only applied for Available For Sale instruments. In the valuation process for all other financial instruments this column is left blank.

5.2.1.3 Loans and Receivables Subsequent Valuation

The subsequent valuation of Loans and Receivables categorized financial instruments works in the same way as for HTM instruments. Here the calculation of the present value in the subsequent valuation is done with the effective interest rate method. Table 3 shows a 4 year LAR serial loan.

	t=0	t=1	t=2	t=3	t=4	
NV_0	100					Nominal Value
NV_t		100	75	50	25	Reduced Nominal Value
R_t^N		4%	4%	4%	4%	Nominal Interest Rate
RP_t		25	25	25	25	Redemption Payment
IP_t		4	3	2	1	Interest Payment
C_t		29	28	27	26	Cash Flow
R_t		1.224%	1.391%	1.589%	1.816%	Interest Rate (EUR)
$DF_{0,t}$		0.9879	0.9727	0.9538	0.9305	Discount Factor
PV_t		28.65	27.24	25.75	24.19	Present Value
PP	105.85					Purchase Price
$(D)A_0$	-5.85					(Dis-)Agio
R_0^E	1.585%					Effective Interest Rate
PV_{EIRt}		28.55	27.56	26.58	25.59	Effective Interest Rate Present Value
$\sum SVPV_t$		79.74	52.17	25.59	0	Sum of subsequently valuated present values
$PWPV_t$	105.85	79.74	52.17	25.59	0.00	Pathwise Present Value
PV_{BRPt}		104.74	77.17	50.59	25.00	Present Value before Redemption Payment
$(D)AD_t$		-1.1	-2.57	-1.58	-0.59	(Dis-)Agio Dissolution
FS_t		2.89	0.43	0.42	0.41	Financial Success
SR_t		2.73%	0.54%	0.81%	1.60%	Financial Success Rate

Table 3: LAR initial and subsequent valuation after period 1

In contrast to the previous HTM bullet loan this loan is a serial loan, so the difference between the path-wise present value and the present value before redemption payment is clearly visible in every period.

Figure 64 illustrates all periods valuated with the ERPControl system.

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
LAR Loan	LAR	4 Years	1	4.0%	1.5854%	29.00 EUR	79.74 EUR	105.85 EUR	104.74 EUR	-1.11 EUR	2.89 EUR	2.7263%	EUR
LAR Loan	LAR	4 Years	2	4.0%	1.5854%	28.00 EUR	52.17 EUR	79.74 EUR	77.17 EUR	-2.57 EUR	0.43 EUR	0.5428%	EUR
LAR Loan	LAR	4 Years	3	4.0%	1.5854%	27.00 EUR	25.59 EUR	52.17 EUR	50.59 EUR	-1.58 EUR	0.42 EUR	0.8131%	EUR
LAR Loan	LAR	4 Years	4	4.0%	1.5854%	26.00 EUR	0.00 EUR	25.59 EUR	25.00 EUR	-0.59 EUR	0.41 EUR	1.6021%	EUR

Figure 64: All periods of the subsequent valuation of a LAR serial loan by the ERPControl system

For presentation purposes figure 64 shows the subsequent valuation of all periods at once. In a normal case the subsequent valuation is processed only for the current period.

5.2.1.4 At Fair Value Subsequent Valuation

In contrast to the subsequent valuation of HTM and LAR instruments, At Fair Value instruments are valuated based on the fair value of the financial instrument. The changes in value are effectively entered in the operation statement.
Instead of the subsequent valuation in the form of the amortized costs of acquisition which are determined based on the effective interest rate method, the revaluation of AFV-instruments is based on the future cash flow. The determined values over time have now a stochastic nature. The development of the values depends on the current interest rate curve.

Due to that a new discount factor for the subsequent valuation of period 1 is calculated based on the current interest rate as defined in (35).

(35)

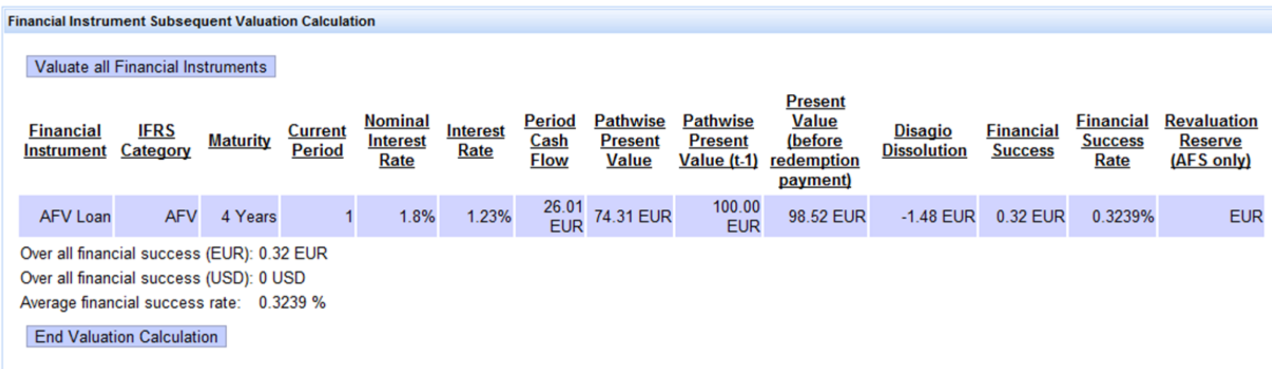
$$DF_{t,t+1} = \left(1 + R_{t,t+1}\right)^{-(T_t)}$$

Table 4 shows the initial and subsequent valuation of an AFV annuity loan.

	t=0	t=1	t=2	t=3	t=4	
NV_0	100					Nominal Value
NV_t		100	75.79	51.15	26.07	Reduced Nominal Value
R_t^N		1.80%	1.80%	1.80%	1.80%	Nominal Interest Rate
RP_t		24.21	24.64	25.08	25.54	Redemption Payment
IP_t		1.8	1.36	0.92	0.47	Interest Payment
C_t		26.01	26.01	26.01	26.01	Cash Flow
R_t		1.231%	1.389%	1.586%	1.809%	Interest Rate (EUR)
$DF_{0,t}$		0.9878	0.9728	0.9539	0.9308	Discount Factor
PV_t		25.69	25.30	24.81	24.21	Present Value
PP	100.0					Purchase Price
$(D)A_0$	0.0					(Dis-)Agio
R_0^E	1.80%					Effective Interest Rate
R_t		**1.230%**	1.388%	1.586%	1.82%	new interest rate curve (EUR)
$DF_{t,t+1}$		**0.9878**	0.9728	0.9539	0.9304	new discount factor
PV_{EIRt}		**25.69**	25.30	24.80	24.20	new Present Value
$\sum SVPV_t$		**74.31**	49.00	24.20	0.00	Sum of subsequently valuated present values
$PWPV_t$	100.0	**74.31**	49.00	24.20	0.00	Pathwise Present Value
PV_{BRPt}		**98.52**	73.64	49.28	25.54	Present Value before Redemption Payment
$(D)AD_t$		**-1.48**	-0.66	0.28	1.34	(Dis-)Agio Dissolution
FS_t		**0.32**	0.71	1.20	1.81	Financial Success
SR_t		**0.32%**	0.95%	2.45%	7.48%	Financial Success Rate

Table 4: AFV initial and subsequent valuation after period 1

The calculation presented in table 4 represents the determination of the subsequent valuation for period 1. Although the other periods are calculated now, their values will change again during the next valuation because the interest rate curve will change. Because of that these periods are marked orange as visible in table 4.


Financial Instrument Subsequent Valuation Calculation

Valuate all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
AFV Loan	AFV	4 Years	1	1.8%	1.23%	26.01 EUR	74.31 EUR	100.00 EUR	98.52 EUR	-1.48 EUR	0.32 EUR	0.3239%	EUR

Over all financial success (EUR): 0.32 EUR
Over all financial success (USD): 0 USD
Average financial success rate: 0.3239 %

End Valuation Calculation

Figure 65: Subsequent valuation of an AFV annuity loan for period 1 by the ERPControl system

As mentioned before, in the ERPControl software the subsequent valuation is always determined for the current period. After the changes in values are entered the current period is automatically increased by one. Applied in a real company the subsequent valuation and the proper booking events would be done completely automatically after every year.

5.2.1.5 Available For Sale Subsequent Valuation

Available For Sale categorized financial instruments are subsequently valuated based on the fair value. The periodical changes in value are entered directly to the equity as revaluation reserve. At the moment of sale the revaluation reserve is entered income effective.
This procedure affects the financial success of each period because in this case the financial success only consists of the interest payment of the specific period. Table 5 illustrates the initial and subsequent valuation of a 4 year AFS serial loan.

	t=0	t=1	t=2	t=3	t=4	
NV_0	100					Nominal Value
NV_t		100	75	50	25	Reduced Nominal Value
R_t^N		4%	4%	4%	4%	Nominal Interest Rate
RP_t		25	25	25	25	Redemption Payment
IP_t		4	3	2	1	Interest Payment
Ct		29	28	27	26	Cash Flow
R_t		1.230%	1.385%	1.589%	1.809%	Interest Rate (EUR)
$DF_{0,t}$		0.9878	0.9729	0.9538	0.9308	Discount Factor
PV_t		28.65	27.24	25.75	24.20	Present Value
PP	105.85					Purchase Price
$(D)A_0$	-5.85					(Dis-)Agio
R_0^E	1.585%					Effective Interest Rate
R_t		**1.230%**	1.389%	1.59%	1.81%	new interest rate curve
$DF_{0,t}$		**0.9878**	0.9728	0.9538	0.9307	new discount factor
PV_{EIRt}		**28.65**	27.24	25.75	24.20	Effective Interest Rate Present Value
$\sum SVPV_t$		**77.19**	49.95	24.20	0.00	Sum of subsequently valuated present value
$PWPV_t$	105.85	**77.19**	49.95	24.20	0.00	Pathwise Present Value
PV_{BRPt}		**102.19**	74.95	49.20	25.00	Present Value before Redemption Payment
$(D)AD_t$		**-3.66**	-2.24	-0.75	0.80	(Dis-)Agio Dissolution
FS_t		**4.00**	3.00	2.00	1.00	Financial Success
$REVRES_t$					-5.85	Revaluation Reserve
SRt		**3.78%**	3.89%	4.00%	-20.01%	Financial Success Rate

Table 5: AFS initial and subsequent valuation after period 1

As mentioned previously the subsequent valuation of AFS instruments depends on the current interest rate curve. Due to that, in every period the financial instrument has to be revaluated. Table 5 illustrates the subsequent valuation for period 1. All the other periods are marked in a different color because they have to be revaluated in the future. The revaluation reserve shows an amount of -5.85 Euros which is the sum of the (dis-)agio dissolutions over all periods. Figure 66 shows the subsequent valuation summary for period 1 calculated by the ERPControl software. Here the revaluation reserve has an amount of -3.66 Euros because the valuation is done only for the first period.

Financial Instrument Subsequent Valuation Calculation

Valuate all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
AFS Loan	AFS	4 Years	1	4.0%	1.23%	29.00 EUR	77.19 EUR	105.85 EUR	102.19 EUR	-3.66 EUR	4.00 EUR	3.7789%	-3.66 EUR

Over all financial success (EUR): 4.00 EUR
Over all financial success (USD): 0 USD
Average financial success rate: 3.7789 %

End Valuation Calculation

Figure 66: Subsequent valuation of an AFS serial loan for period 1 by the ERPControl system

To illustrate the revaluation after period one is passed, table 6 shows the revaluation of the financial instrument and the changes in values.

	t=0	t=1	t=2	t=3	t=4	
NV_0	100					Nominal Value
NV_t		100	75	50	25	Reduced Nominal Value
R_t^N		4%	4%	4%	4%	Nominal Interest Rate
RP_t		25	25	25	25	RedemptionPayment
IP_t		4	3	2	1	Interest Payment
Ct		29	28	27	26	Cash Flow
R_t		1.230%	1.385%	1.589%	1.809%	Interest Rate
$DF_{0,t}$		0.9878	0.9729	0.9538	0.9308	Discount Factor
PV_t		28.65	27.24	25.75	24.20	Present Value
PP	105.85					Purchase Price
$(D)A_0$	-5.85					(Dis-)Agio
R_0^E	1.585%					Effective Interest Rate
R_t		1.230%	**1.450%**	1.68%	2.00%	new interest rate curve
$DF_{0,t}$		0.9878	**0.9716**	0.9514	0.9240	new discount factor
PV_{EIRt}		28.65	**27.21**	25.69	24.02	Effective Interest Rate Present Value
$\sum SVPV_t$		77.19	**49.71**	24.02	0.00	Sum of subsequent valuated present value
$PWPV_t$	105.85	77.19	**49.71**	24.02	0.00	Pathwise Present Value
PV_{BRPt}		102.19	**74.71**	49.02	25.00	Present Value before Redemption Payment
$(D)AD_t$		-3.66	**-2.21**	-0.69	0.98	(Dis-)Agio Dissolution
FS_t		4.00	**3.00**	2.00	1.00	Financial Success
$REVRES_t$					-5.58	Revaluation Reserve
SR_t		3.78%	**3.90%**	4.02%	-20.15%	Financial Success Rate

Table 6: AFS initial and subsequent valuation after period 2

The calculation in table 6 presents the revaluation of the financial instrument after period 2. The interest rates in the table 6 example are going up, and despite that the revaluation reserve did not change a lot because some periods have a negative and some a positive (dis-)agio dissolution and this neutralizes the change of the revaluation reserve.
The values in period 1 did not change despite the new interest rate curve because they already have been entered into the database. Because of that period 1 is marked in different colors.

The next step in the subsequent valuation business process is the booking of the changes in value caused by the revaluation of the financial instrument.

5.2.1.6 Booking of the Subsequent Valuation

The values determined in the subsequent valuation process have to be entered in the resource list in each period. With each booking activity the financial liability is reduced by a specific amount. After the revaluation in each period the redemption payment, interest payment and (dis-)agio dissolution have to be entered. In the case of an AFS instrument the revaluation reserve has to be booked income effective in the last period.

To demonstrate the booking process I virtually bought four different kinds of loans in the ERPControl system. So the resource list now has the status shown in figure 67. These loans are different when compared to the loans in the previous section.

List of Resources

Class	Description	Quantity	UoM	Price	Value
Cash	EUR Cash	425.21	PCS	EUR 1.00	EUR 425.21
Cash	USD Cash	0.00	PCS	$ 1.00	$ 0.00
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	0.00	PCS	EUR 1.00	EUR 0.00
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	0.00	PCS	EUR 1.00	EUR 0.00
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
AnnuityLoan	HTM Loan	-105.00	PCS	EUR 1.00	EUR -105.00
SerialLoan	LAR Loan	-105.86	PCS	EUR 1.00	EUR -105.86
BulletLoan	AFV Loan	-108.49	PCS	EUR 1.00	EUR -108.49
SerialLoan	AFS Loan	-105.86	PCS	EUR 1.00	EUR -105.86

Figure 67: Resource list containing 4 different kinds of loans as well as the proper cash

The resource list shows four loans each with a different IFRS category. The sum of the cash of these loans is visible at the top of the resource list. During the term of the loans the company can work with the amount of 425.21 Euros and, for example, try to make some good investments.

All listed loans are at current period 0 at the moment. During the first subsequent valuation the loans will be set to current period one and the appropriate values will be calculated. To illustrate how much money these four types of loans will cost the company no other cash will be entered to the treasury during the term of these loans.

The first subsequent valuation is shown in figure 68.

Financial Instrument Subsequent Valuation Calculation

Valuate all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
HTM Loan	HTM	4 Years	1	1.8%	1.8%	27.30 EUR	80.45 EUR	105.00 EUR	105.95 EUR	0.95 EUR	2.75 EUR	2.6208%	EUR
LAR Loan	LAR	4 Years	1	4.0%	1.5815%	29.00 EUR	79.74 EUR	105.86 EUR	104.74 EUR	-1.12 EUR	2.88 EUR	2.7195%	EUR
AFV Loan	AFV	4 Years	1	4.0%	1.23%	4.00 EUR	104.51 EUR	108.49 EUR	104.51 EUR	-3.98 EUR	0.02 EUR	0.0217%	EUR
AFS Loan	AFS	4 Years	1	4.0%	1.23%	29.00 EUR	77.20 EUR	105.86 EUR	102.20 EUR	-3.66 EUR	4.00 EUR	3.7785%	-3.66 EUR

Over all financial success (EUR): 9.65 EUR
Over all financial success (USD): 0 USD
Average financial success rate: 2.9403 %

End Valuation Calculation

Figure 68: Subsequent valuation of period 1

After the process of the subsequent valuation is successfully executed the booking screen with a summary of the financial success over all instruments is presented to the user.

Financial Instrument Subsequent Valuation Booking

Over all financial success (EUR): 9.65 EUR
Over all financial success (USD): 0.00 USD
Average financial success rate: 2.9403 %

Book All

Figure 69: Booking screen

After the user activates the *Book All* button the appropriate changes in value are entered and the resource list now shows an updated amount of resources.

To make it clear and understandable what happens within the REA Kernel when the changes in value are entered, I will present a table for each loan that represents the booking rates that are made in each period. These tables will be updated after each period until the debt is completely repaid.

Table 7 shows the booking activities for the 4 year HTM Annuity Loan. In period 0 an amount of 105.00 Euros was borrowed from a bank which represents an inflow of the resource cash for the treasury. Simultaneously and outflow of the same amount of money happened which represents

the debt. This procedure was defined in detail in section 5.1.1.6 and illustrated in figure 55 and figure 56.
As mentioned before an annuity loan has constant cash flows over all periods. So in this case every period a sum of 27.30 Euros have to be paid to the bank. The table below shows a redemption payment of 25.5 Euros and an interest payment of 1.8 Euros in period 1 which are equal to a sum 27.30 Euros.

4 Year HTM Annuity Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
0	105		-105	borrowing money
1	-25.5		25.5	redemption payment
1	-1.8	1.8		interest payment
1		0.95	-0.95	(dis-)agio dissolution
current Level	**77.7**	**2.75**	**-80.45**	

Table 7: Booking activities for the HTM Loan from period 0-1

So in period 1 the bank receives 25.5 Euros of redemption payment and 1.8 Euros of interest payment. This is paid from the treasury which is reduced by a sum of 27.30 Euros. These activities in REA ontology are illustrated in figure 70-75.

Figure 70: Decrease event redemption payment of resource cash from Treasury to Bank

Figure 71: Increase event redemption payment of resource financial liability from Bank to Treasury

Due to the fact that the financial liability is represented by a negative quantity of the resource loan, the debt is reduced by an increase event.

Figure 72: Decrease event interest payment of resource cash from Treasury to Bank

Figure 73: Increase event interest payment of resource expense account from Bank to Treasury

In the software model of REA everything is represented as a resource. So also an expense account and a financial liability are considered as a resource within the ERPControl system.

The last booking activity for the HTM Loan in period 1 is the booking of the (dis-)agio dissolution. Depending on the interest rates of the revaluation, the (dis-)agio dissolution either reduces (negative (dis-)agio dissolution) or increases (positive (dis-)agio dissolution) the financial liability. In the case of period 1 we are confronted with a positive (dis-)agio dissolution so the debt is increased by the (dis-)agio dissolution in the negative direction. The resource flows mapped to the REA ontology are illustrated in figure 74 and 75.

Figure 74: Decrease event (dis-)agio dissolution of resource financial liability from Treasury to Bank

Figure 75: Increase event (dis-)agio dissolution of resource expense account from Bank to Treasury

The booking procedures illustrated in figure 70-75 work similarly for all other types of loans. I will refer to these illustrations when the booking activities for the other loans are explained.

This flow of resources represents the REA perspective of booking activities which differs from the traditional approach of debit and credit. The ERPControl software works in the same way as defined in the figures above. The created and persisted economic events after the booking of the changes in values look similar to figures 70-75.

description	eventType	quantity	price_currency
Bank -> Treasury (Loan)	INCREMENT	25.50	EUR
Treasury -> Bank (Cash)	DECREMENT	-25.50	EUR
Treasury -> Bank (Cash)	DECREMENT	-1.80	EUR
Bank -> Treasury (Expense Account)	INCREMENT	1.80	EUR
Treasury -> Bank (Loan)	DECREMENT	-0.95	EUR
Bank -> Treasury (Expense Account)	INCREMENT	0.95	EUR

Figure 76: Economic Events within the ERPControl system for the booking of the subsequent valuation of the HTM Loan

Similar to the booking activities of the HTM Loan are the bookings for the LAR Loan. The difference is that the LAR Loan is a serial loan. In this case the redemption payments are constant over all periods. The booking activities and the appropriate economic events are shown in table 8 and figure 77.

4 Year LAR Serial Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
0	105.86		-105.86	borrowing money
1	-25		25	redemption payment
1	-4	4		interest payment
1		-1.12	1.12	(dis-)agio dissolution
current Level	**76.86**	**2.88**	**-79.74**	

Table 8: Booking activities for the LAR Loan from period 0-1

As shown in figure 68 the LAR Loan has a negative (dis-)agio dissolution of -1.12 Euros in period 1. So in this case the debt is reduced by the (dis-)agio dissolution and not increased as in the case of the previously considered HTM Loan.

description	eventType	quantity	price_currency
Bank -> Treasury (Loan)	INCREMENT	25.00	EUR
Treasury -> Bank (Cash)	DECREMENT	-25.00	EUR
Treasury -> Bank (Cash)	DECREMENT	-4.00	EUR
Bank -> Treasury (Expense Account)	INCREMENT	4.00	EUR
Treasury -> Bank (Expense Account)	DECREMENT	-1.12	EUR
Bank -> Treasury (Loan)	INCREMENT	1.12	EUR

Figure 77: Economic events within the ERPControl system for the booking of the subsequent valuation of the LAR Loan

The 4 Year AFV Loan is a bullet loan. This means the complete debt is paid back in the last period so the redemption payments in the previous periods equal 0. This type of loan also has constant interest rates over all periods because the nominal value, which is the basis for the interest payment calculation, is not reduced.

The booking activities are again similar to the activities defined for the HTM Loan above. Table 9 shows the resource flows for periods 0-1 of the AFV Loan.

4 Year AFV Bullet Loan Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
0	108.49		-108.49	borrowing money
1	0		0	redemption payment
1	-4	4		interest payment
1		-3.98	3.98	(dis-)agio dissolution
current Level	**104.49**	**0.02**	**-104.51**	

Table 9: Booking activities for the AFVLoan from period 0-1

The list of economic events illustrated in figure 78 shows no redemption payment event. This is because the redemption payment is 0, so this causes no value changes, and for that no economic events have to be executed by the ERPControl software.

description	eventType	quantity	price_currency
Bank -> Treasury (Expense Account)	INCREMENT	4.00	EUR
Treasury -> Bank (Cash)	DECREMENT	-4.00	EUR
Bank -> Treasury (Loan)	INCREMENT	3.98	EUR
Treasury -> Bank (Expense Account)	DECREMENT	-3.98	EUR

Figure 78: Economic events within the ERPControl system for the booking of the subsequent valuation of the AFV Loan

In contrast to the bookings of the previous loans, the (dis-)agio dissolution of the AFS Loan is entered to the revaluation reserve as equity. At the last period the revaluation reserve is booked back to the expense account. The economic events for the booking of the (dis-)agio dissolution to the revaluation reserve is illustrated in figure 79 and 80.

Figure 79: Decrease event (dis-)agio dissolution of resource revaluation reserve from Treasury to Bank

Figure 80: Increase event (dis-)agio dissolution of resource financial liability from Bank to Treasury

The booking activities for the AFS Loan are summarized in table 10. In this booking procedure an additional kind of resource joined the business case. As described above for the expense account, the financial liability and also the revaluation reserve are considered as a resource within the ERPControl system.

4 Year AFS Serial Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	Revaluation Reserve	
0	105.86		-105.86		borrowing money
1	-25		25		redemption payment
1	-4	4			interest payment
1			3.66	-3.66	(dis-)agio dissolution
current Level	**76.86**	**4**	**-77.2**	**-3.66**	

Table 10: Booking activities for the AFS Loan from period 0-1

The last two entries in the list of economic events illustrated in figure 81 show the resource flow of the (dis-)agio dissolution to the revaluation reserve with an amount of 3.66 Euros.

description	eventType	quantity	price_currency
Treasury -> Bank (Cash)	DECREMENT	-25.00	EUR
Bank -> Treasury (Loan)	INCREMENT	25.00	EUR
Bank -> Treasury (Expense Account)	INCREMENT	4.00	EUR
Treasury -> Bank (Cash)	DECREMENT	-4.00	EUR
Treasury -> Bank (Revaluation Reserve Account)	DECREMENT	-3.66	EUR
Bank -> Treasury (Loan)	INCREMENT	3.66	EUR

Figure 81: Economic events within the ERPControl system for the booking of the subsequent valuation of the AFS Loan

After the booking of these 4 types of loans the resource list is updated and shows the changes in value. The amount of cash in the treasury now equals 335.91 Euros. This corresponds to the sum of cash over all financial instruments after the booking activities for period 1.

(36)

$$Level\ of\ EUR\ Cash = 77.7 + 76.86 + 104.49 + 76.86 = 335.91\ Euros$$

The current level of the expense account now equals the sum of the financial success over all financial instruments of 9.65 Euros as defined in (37).

(37)

$$Level\ of\ Expense\ Account = 2.75 + 2.88 + 0.02 + 4.00 = 9.65\ Euros$$

Figure 82 shows the updated resource list after storing the changes in value, caused by the booking activities, in the database.

List of Resources

Class	Description	Quantity	UoM	Price	Value
Cash	EUR Cash	335.91	PCS	EUR 1.00	EUR 335.91
Cash	USD Cash	0.00	PCS	$ 1.00	$ 0.00
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	9.65	PCS	EUR 1.00	EUR 9.65
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	-3.66	PCS	EUR 1.00	EUR -3.66
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
AnnuityLoan	HTM Loan	-80.45	PCS	EUR 1.00	EUR -80.45
SerialLoan	LAR Loan	-79.74	PCS	EUR 1.00	EUR -79.74
BulletLoan	AFV Loan	-104.51	PCS	EUR 1.00	EUR -104.51
SerialLoan	AFS Loan	-77.20	PCS	EUR 1.00	EUR -77.20

Figure 82: Updated resource list after booking changes in value after subsequent valuation for period 1

The procedure of entering the changes in value after the revaluation in each period works similarly to the procedures in period 1. So I will skip the detailed illustration of periods 2 and 3. Nevertheless the booking tables of each financial instrument will contain the activities over all periods.

Figure 83 shows the summary of the subsequent valuation of the 4 different loans in current period 4.

Financial Instrument Subsequent Valuation Calculation

Valuate all Financial Instruments

Financial Instrument	IFRS Category	Maturity	Current Period	Nominal Interest Rate	Interest Rate	Period Cash Flow	Pathwise Present Value	Pathwise Present Value (t-1)	Present Value (before redemption payment)	Disagio Dissolution	Financial Success	Financial Success Rate	Revaluation Reserve (AFS only)
HTM Loan	HTM	4 Years	4	1.8%	1.8%	27.30 EUR	0.00 EUR	26.82 EUR	26.91 EUR	0.09 EUR	0.49 EUR	1.8269%	EUR
LAR Loan	LAR	4 Years	4	4.0%	1.5815%	26.00 EUR	0.00 EUR	25.60 EUR	25.00 EUR	-0.60 EUR	0.40 EUR	1.5624%	EUR
AFV Loan	AFV	4 Years	4	4.0%	1.817%	104.00 EUR	0.00 EUR	96.77 EUR	100.00 EUR	3.23 EUR	7.23 EUR	7.4713%	EUR
AFS Loan	AFS	4 Years	4	4.0%	1.817%	26.00 EUR	0.00 EUR	24.19 EUR	25.00 EUR	0.81 EUR	1.00 EUR	4.1339%	-5.86 EUR

Overall financial success (EUR): 9.12 EUR
Overall financial success (USD): 0 USD
Average financial success rate: 4.2053 %

End Valuation Calculation

Figure 83: Subsequent valuation of period 4

4 Year HTM Annuity Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
0	105		-105	borrowing money
1	-25.5		25.5	redemption payment
1	-1.8	1.8		interest payment
1		0.95	-0.95	(dis-)agio dissolution
2	-25.96		25.96	redemption payment
2	-1.34	1.34		interest payment
2		-0.86	0.86	(dis-)agio dissolution
3	-26.43		26.43	redemption payment
3	-0.87	0.87		interest payment
3		-0.38	0.38	(dis-)agio dissolution
4	-26.91		26.91	redemption payment
4	-0.4	0.4		interest payment
4		0.09	-0.09	(dis-)agio dissolution
current Level	**-4.21**	**4.21**	**0.00**	

Table 11: Booking activities for the HTMLoan from period 0-4

Table 11 shows the booking activities of the HTM Loan for the complete term of this financial instrument. So after 4 periods the complete debt has been repaid to the bank and the resource HTM Loan of the type annuity loan which represents the financial liability is now at a level of 0.00 Euros. The expense account shows a level of 4.21 Euros which are equal to the costs the borrowing procedure this loan caused for the company.

Table 12 shows the booking activities over 4 years for the LAR Serial Loan. In contrast to the HTM Loan, the redemption payments remained constant over all periods and the interest payments are decreasing because of the reduced nominal value over time. After 4 periods the complete debt was amortized, which you can see at the level of 0.00 Euros of financial liability.

4 Year LAR Serial Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
eti0	105.86		-105.86	borrowing money
1	-25		25	redemption payment
1	-4	4		interest payment
1		-1.12	1.12	(dis-)agio dissolution
2	-25		25	redemption payment
2	-3	3		interest payment
2		-2.57	2.57	(dis-)agio dissolution
3	-25		25	redemption payment
3	-2	2		interest payment
3		-1.57	1.57	(dis-)agio dissolution
4	-25		25	redemption payment
4	-1	1		interest payment
4		-0.6	0.6	(dis-)agio dissolution
current Level	**-4.14**	**4.14**	**0.00**	

Table 12: Booking activities for the LAR Loan from period 0-4

The AFV Bullet Loan illustrated in table 13 shows a redemption payment of 100 Euros at the fourth period. This results in an expense account with a level of 7.51 Euros which makes this loan the most expensive one of the 4 compared loans.

4 Year AFV Bullet Loan Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	
0	108.49		-108.49	borrowing money
1	0		0	redemption payment
1	-4	4		interest payment
1		-3.98	3.98	(dis-)agio dissolution
2	0		0	redemption payment
2	-4	4		interest payment
2		-3.92	3.92	(dis-)agio dissolution
3	0		0	redemption payment
3	-4	4		interest payment
3		-3.82	3.82	(dis-)agio dissolution
4	-100		100	redemption payment
4	-4	4		interest payment
4		3.23	-3.23	(dis-)agio dissolution
current Level	**-7.51**	**7.51**	**0.00**	

Table 13: Booking activities for the AFV Loan from period 0-4

The last of these 4 loans is represented in table 14. Also the debt of the AFS Serial Loan is amortized after 4 periods. Compared to the other loans this loan has an additional booking activity in the last period, the booking of the revaluation reserve to the expense account which reduces the liability for the borrower of the loan in this case. Figure 84 and 85 show the decrease event of the revaluation reserve and the increase event of the expense account which results in a reduced liability for the borrower of the loan.

Figure 84: Decrease event revaluation reserve of resource expense account from Treasury to Bank

Figure 85: Increase event revaluation reserve of resource revaluation reserve from Bank to Treasury

At the end of the booking activities in period 4 the AFS Serial Loan in table 14 shows a debt of 0.00 Euros and also a revaluation reserve of 0.00 Euros. The complete cost of this financial instrument for the borrower equals 4.14 Euros.

4 Year AFS Serial Loan

Period	Treasury	Expense Account	Loan (Financial Liability)	Revaluation Reserve	
0	105.86		-105.86		borrowing money
1	-25		25		redemption payment
1	-4	4			interest payment
1			3.66	-3.66	(dis-)agio dissolution
2	-25		25		redemption payment
2	-3	3			interest payment
2			2.26	-2.26	(dis-)agio dissolution
3	-25		25		redemption payment
3	-2	2			interest payment
3			0.75	-0.75	(dis-)agio dissolution
4	-25		25		redemption payment
4	-1	1			interest payment
4			-0.81	0.81	(dis-)agio dissolution
4		-5.86		5.86	revaluation reserve
current Level	**-4.14**	**4.14**	**0.00**	**0.00**	

Table 14: Booking activities for the AFSLoan from period 0-4

After the successful subsequent valuation and booking of the four different kinds of loans the debt of all loans equals 0.00 Euros. That means all financial liabilities are amortized after the fourth and last period.

The expense account shows a level of 20 Euros. This represents the sum of all costs of the financial instruments that have to be paid to the bank.

(38)

$$final\ level\ of\ Expense\ Account = 4.21 + 4.14 + 7.51 + 4.14 = 20.00\ Euros$$

So the cheapest loans for the borrower are the LAR and AFS Serial Loans. The most expensive loan was the AFV Bullet Loan.

At the beginning of the booking activities of the subsequent valuation process we considered a treasury with a level of 0.00 Euros. The money in the expense account that has to be paid to the bank for borrowing the money was taken from the cash resource of the treasury. This assumption now causes a level of -20.00 Euros of the resource cash in the treasury.

The resource list in figure 86 now shows the final level of the four loans borrowed in period 0 as well as the amount of EUR Cash and the EUR Expense.

Class	Description	Quantity	UoM	Price	Value
Cash	EUR Cash	-20.00	PCS	EUR 1.00	EUR -20.00
Cash	USD Cash	0.00	PCS	$ 1.00	$ 0.00
InternalCurrencyUnit	Internal Currency Unit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	EUR Profit	0.00	PCS	EUR 1.00	EUR 0.00
RevenueAccount	USD Profit	0.00	PCS	$ 1.00	$ 0.00
ExpenseAccount	EUR Expense	20.00	PCS	EUR 1.00	EUR 20.00
ExpenseAccount	USD Expense	0.00	PCS	$ 1.00	$ 0.00
RevaluationReserveAccount	EUR Revaluation Reserve	0.00	PCS	EUR 1.00	EUR 0.00
RevaluationReserveAccount	USD Revaluation Reserve	0.00	PCS	$ 1.00	$ 0.00
ValueAddedTax	Tax on sales	0.00	PCS	EUR 1.00	EUR 0.00
ValueAddedTax	Tax on investments	0.00	PCS	EUR 1.00	EUR 0.00
AnnuityLoan	HTM Loan	0.00	PCS	EUR 1.00	EUR 0.00
SerialLoan	LAR Loan	0.00	PCS	EUR 1.00	EUR 0.00
BulletLoan	AFV Loan	0.00	PCS	EUR 1.00	EUR 0.00
SerialLoan	AFS Loan	0.00	PCS	EUR 1.00	EUR 0.00

List of Resources

Figure 86: Resource List after the revaluation and booking in period 4

5.3 Analytical Planning of Financial Instruments

The analytical planning section treats the future development of financial instruments. On the basis of various mathematical models the prospective values of financial instruments are estimated. Based on the Vasicek Model the future development of loans is estimated by creating a binomial tree where every path represents a potential future interest rate curve and the appropriate development of the periodic discounted cash flow for the specific loan.
Another analytical planning tool is the planning and pricing of financial options based on the Cox Ross Rubinstein as well as the Black and Black-Scholes Models. Unlike the previously introduced business processes the analytical planning processes do not result in a booking process. This means no changes in values are entered into the database after these processes. These software based planning tools will be illustrated in detail in the upcoming sections.

5.3.1 Analytical Planning of Fixed Income Financial Instruments

The analytical planning of fixed income financial instruments can be done for all 4 different types of IFRS categorized loans. Thereby HTM and LAR categorized instruments have only one single path because they are revaluated based on the effective interest rate which does not change over time. AFV and AFS instruments are revaluated based on the current interest curve, so they have multiple paths of the future development. The process of this analytical planning process is illustrated in the UML activity diagram in figure 87.

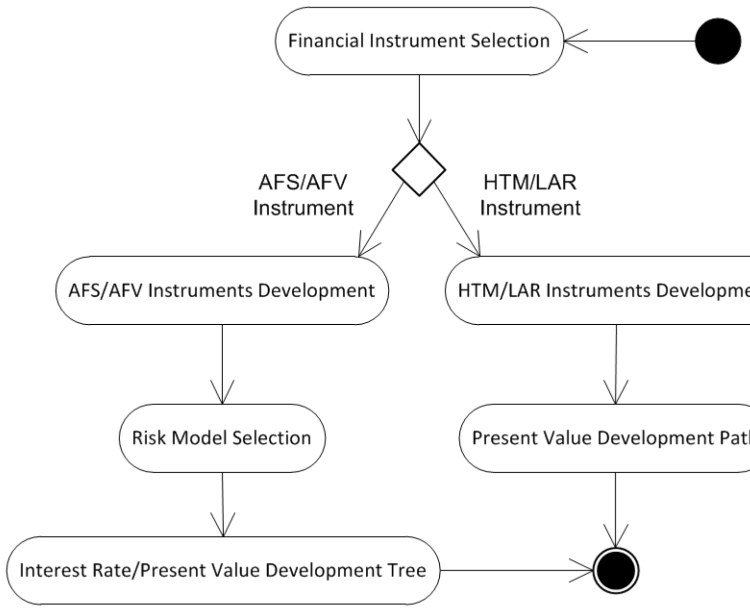


Figure 87: UML activity diagram of the analytical planning of fixed income financial instruments process

After the selection of a specific financial instrument to perform the analytical planning process, the system distinguishes between AFS/AFV and HTM/LAR instruments as illustrated in the UML activity diagram of the process as well as in figure 88. Before the interest rate and present value tree for AFS or AFV categorized instruments is created, a specific risk model which represents a mathematical model for the determination of interest rate development has to be specified. The development of HTM and LAR categorized instruments follows a straight path so no risk model has to be specified here. The appropriate business process for the software model of the analytical planning of fixed income instruments is displayed in figure 88.

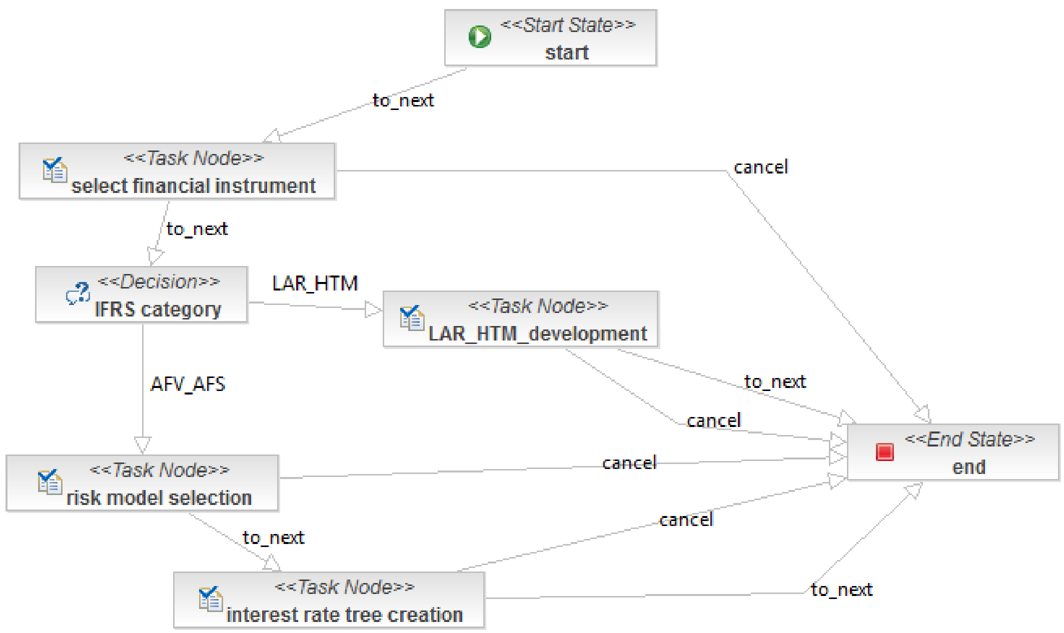


Figure 88: Business process of the analytical planning of fixed income financial instruments

5.3.1.1 Financial Instrument Selection

The first step of the analytical planning process of fixed income financial instruments is the selection of the financial instrument. Here a list of all available fixed income instruments is presented to the user as shown in figure 89. Depending on the current period of the financial instrument the displayed tree will be longer or shorter. So for an instrument with current period 0 all future paths are displayed.

List of fixed income Financial Instruments

Financial Instrument	Price	Currency	IFRS Category	Maturity	Current Period	
AFS Loan	105.84	EUR	Available For Sale	4 Years	0	Select
HTM Loan	105.00	EUR	Held To Maturity	4 Years	0	Select

Figure 89: Selection of a fixed income financial instrument for the analytical planning process

The listed financial instruments were created before in the initial valuation process. The displayed instruments were not subsequently valuated until now because they are both in current period 0.

5.3.1.2 Risk Model Selection

The risk model is the theoretical model which represents the basis for the planning of the future development of the financial instrument. The planning approach is only an estimation of the future. There will always be a specific uncertainty because not even the best software tools and the most precise mathematical models are able to predict future events with a reliability of 100%.
The step of the risk model selection has only be done for AFS and AFV instruments. As mentioned above HTM and LAR instruments are revaluated based on the effective interest rate over all periods. Due to that they result only in a single path, so there is no uncertainty about the future development of this instrument.

When an AFS or AFV instrument has been selected the screen shown in figure 90 is presented to the user.

Risk Model Selection

Risk Models	
Vasicek Model	Select

Figure 90: Selection of the risk model

The current state of implementation of the ERPControl system offers only one risk model, the Vasicek Model, for the analytical planning of fixed income financial instruments.

5.3.1.3 Interest Rate Tree Creation

After the selection of an AFS or AFV instrument the last and main step of the analytical planning process is the creation of the interest rate tree based on the Vasicek Model.

The start screen of the interest rate tree creation step shows multiple factors which are needed for the creation of the tree.

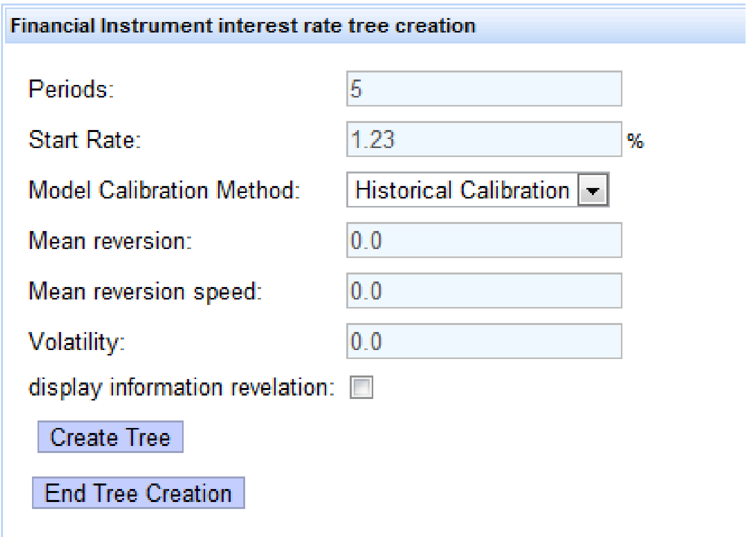


Figure 91: Interest Rate Tree specification

The number of periods specifies the size of the tree. So for a 4 year instrument the tree has a size of 5 for periods 0, 1, 2, 3 and 4. Only the prospective periods are modeled in the tree so the number of paths will be $2^4 = 16$.
The start rate is the interest rate of the starting period of the tree calculated on the basis of the current interest rate curve.

5.3.1.3.1 Vasicek Model

As mentioned above, the subsequent valuation of financial instruments of the IFRS category *At Fair Value* and *Available For Sale* depends on the future development of the interest curve.
To estimate the future development of the interest curve various mathematical models are available. One of the first of these models was the Vasicek Model introduced in 1977 by the Czech mathematician Oldrich Alfons Vasicek.

The mathematical definition of the Vasicek Model is the equation set forth in (39).

(39)

$$dr_t = \lambda(\mu - r_t)\, dt + \sigma dW_t$$

In the model the various factors are specified as follows:

r_t…the interest rate of period t

dr_t…the interest rate difference between two periods

λ…the mean reversion speed

μ…the mean reversion

σ…the volatility

dW_t…is a Wiener Process, to simplify the model we estimate $dW_t \sim 1$

To create the annualized interest rate binomial tree the rates of the future periods are calculated based on the Vasicek Model in the following way as defined in [BjEr10: p. 16].

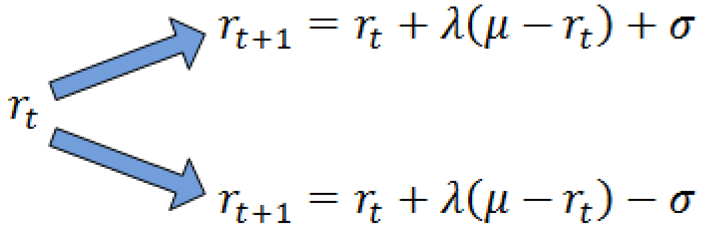


Figure 92: Vasicek Interest Tree Model

In the interest tree model the interest rate of the upcoming period can either go up or down. In the ERPControl software the binary interest rate tree is visualized using dynamically generated customized HTML tables.

Before an interest curve can be estimated the Vasicek Model has to be calibrated. This means the factors μ the mean reversion, λ the mean reversion speed and σ the volatility have to be determinated based on various approaches. The three different ways to calibrate the Vasicek Model are introduced in the following.

5.3.1.3.2 Calibration Methods

Historical Calibration

The most common method to calibrate the Vasicek Model is the historical calibration. Here the factors mean reversion, mean reversion speed and volatility are calculated based on a time series of interest rates.

Various statistical methods like *least squares, maximum likelihood* or *generalized method of moments* can be applied to determine the factors μ, λ and σ. The class

VasicekHistoricalCalibration.java uses the maximum likelihood method to calculate the values. This method is applied as explained in the internet reference [1].

The maximum likelihood is applied in calculating the factors from the interest rates defined in (40).

(40)

$$r_x = \sum_{i=1}^{n} r_{i-1} \qquad r_y = \sum_{i=1}^{n} r_i \qquad r_{xx} = \sum_{i=1}^{n} r_{i-1}^2 \qquad r_{yy} = \sum_{i=1}^{n} r_i^2 \qquad r_{xy} = \sum_{i=1}^{n} r_{i-1} r_i$$

These factors are needed to determine the Vasicek factors as illustrated in the formulas (41) – (43). In (42) δ is the time step which is 1 for 1 year in this case.

(41)

$$\mu = \frac{r_y r_{xx} - r_x r_{xy}}{n\left(r_{xx} - r_{xy}\right) - \left(r_x^2 - r_x r_y\right)}$$

(42)

$$\lambda = -\frac{1}{\delta} ln \frac{r_{xy} - \mu r_x - \mu r_y + n\mu^2}{r_{xx} - 2\mu r_x + n\mu^2}$$

(43)

$$\alpha = e^{-\lambda\delta}$$

$$\widehat{\sigma^2} = \frac{1}{n}\left[r_{yy} - 2\alpha r_{xy} + \alpha^2 r_{xx} - 2\mu(1-\alpha)\left(r_y - \alpha r_x\right) + n\mu^2(1-\alpha)^2\right]$$

$$\sigma^2 = \widehat{\sigma^2}\frac{2\lambda}{1-\alpha^2}$$

The drawback of the historical calibration is that up- and downturns, for example as a consequence of various historical political decisions or random historical events, are influencing the determined factors. So the key point of the historical calibration of the Vasicek model is the used time series of interest rates.

In the package

```
at.ac.vut.reamis.erp.jbpmservices.dcps.financialinstrument.fixedIncome.subsequen
tValuation.Planing
```

of the ERPControl system the file `rates.data` is located which contains the series of historical interest rates, calculated from a swap rate series between 2001 and 2007 provided by the Austrian National Bank at the following URL:

http://www.swap-rates.com/historic/EURO/2001-2007_Euro.xls

Users of the ERPControl system are able to edit the rates in this file to manipulate the results of the historical calibration.

The historical calibration on the basis of the mentioned time series leads to the following results:

$\sigma = 0.11597437854652676$
$\lambda = 0.011793870826849472$
$\mu = 2.968051394082052$

Implied Calibration

Besides the historical calibration of the Vasicek Model, the implied calibration is an alternative way to calculate the required factors mean reversion, mean reversion speed and volatility. The implied calibration compares the current market price with the Vasicek model price. The current market price is calculated with the model in (44) where r_t is the current interest rate and t is the current period.

(44)

$$P(r_t, t) = e^{-r_t * t}$$

This current market price is now equalized with the following Vasicek model price as illustrated in (45).

(45)

$$P(r_{to}, t, T, \lambda, \mu, \sigma) =$$

$$e^{\left(\mu - \frac{\sigma^2}{2*\lambda^2}\right)*\left(\frac{1}{\lambda}*\left(1-e^{-\lambda*(T-t)}\right)-T+t\right)-\left(\frac{\sigma^2}{4*\lambda}\right)*\left(\frac{1}{\lambda}*\left(1-e^{-\lambda*(T-t)}\right)\right)^2-\frac{1}{\lambda}*\left(1-e^{-\lambda*(T-t)}\right)*r_{to}}$$

Here r_{to} is considered as the overnight rate. To simplify this case we assume that $r_t \sim r_{to}$. In (45) t is the starting period which is usually 0 and T is the current period. For three unknowns λ, μ and σ we need at least three equations to solve this system of equations. To demonstrate this nonlinear system of equations we take a look at the following interest rates:

Period 1: $r_1 = 1.3\%$
Period 2: $r_2 = 1.52\%$
Period 3: $r_3 = 1.79\%$

For these values the system of equations would be specified as defined in (46).

(46)

$$f_1 = -1.3 * 1 = \left(\mu - \frac{\sigma^2}{2*\lambda^2}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(1-0)}\right) - 1 + 0\right) - \left(\frac{\sigma^2}{4*\lambda}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(1-0)}\right)\right)^2 - \frac{1}{\lambda} * \left(1 - e^{-\lambda*(1-0)}\right) * 1.3$$

$$f_2 = -1.52 * 2 = \left(\mu - \frac{\sigma^2}{2*\lambda^2}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(2-0)}\right) - 2 + 0\right) - \left(\frac{\sigma^2}{4*\lambda}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(2-0)}\right)\right)^2 - \frac{1}{\lambda} * \left(1 - e^{-\lambda*(2-0)}\right) * 1.52$$

$$f_3 = -1.79 * 3 = \left(\mu - \frac{\sigma^2}{2*\lambda^2}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(3-0)}\right) - 3 + 0\right) - \left(\frac{\sigma^2}{4*\lambda}\right) * \left(\frac{1}{\lambda} * \left(1 - e^{-\lambda*(3-0)}\right)\right)^2 - \frac{1}{\lambda} * \left(1 - e^{-\lambda*(3-0)}\right) * 1.79$$

As mentioned above we are dealing here with a nonlinear system of equations. I chose the Newton-Raphson Method to solve the system numerically. The unknowns are approximated by iterating through the model defined in (47).

(47)

$$\overrightarrow{x_{n+1}} = \overrightarrow{x_n} - (J(x_n))^{-1} * \overrightarrow{f(x_n)}$$

The vector $\overrightarrow{x_n}$ represents the start values for **λ**, μ and σ. To apply the Newton-Raphson method the derivation of each equation by each unknown is needed to build the Jacobian matrix $J(x_n)$. So a system of three equations and three unknowns results in a 3x3 matrix. The resulting inverse Jacobian matrix $(J(x_n))^{-1}$ is multiplied by a vector of the function values of the above equations $\overrightarrow{f(x_n)}$.
This calculation leads to the first result value of the iteration represented by the vector $\overrightarrow{x_{n+1}}$.
The iteration process is now repeated until the system converges.

The Java class VasicekImpliedCalibration.java computes the iteration values in running a loop over the model illustrated in (48) till the system converges.

(48)

$$\begin{pmatrix} \sigma_{n+1} \\ \lambda_{n+1} \\ \mu_{n+1} \end{pmatrix} = \begin{pmatrix} \sigma_n \\ \lambda_n \\ \mu_n \end{pmatrix} - x_{step} * \begin{bmatrix} \frac{df1}{d\sigma} & \frac{df1}{d\lambda} & \frac{df1}{d\mu} \\ \frac{df2}{d\sigma} & \frac{df2}{d\lambda} & \frac{df2}{d\mu} \\ \frac{df3}{d\sigma} & \frac{df3}{d\lambda} & \frac{df3}{d\mu} \end{bmatrix}^{-1} * \begin{pmatrix} f_1(\sigma_n, \lambda_n, \mu_n) \\ f_2(\sigma_n, \lambda_n, \mu_n) \\ f_3(\sigma_n, \lambda_n, \mu_n) \end{pmatrix}$$

Depending on the function values the creation of the inverse matrix could become impossible because the matrix is singular.
Also the starting values have to be chosen carefully otherwise the numerical system will not converge. To ensure a valid outcome of the numerical solution of the system, the implementation algorithm of the calibration varies the factor x_{step} defined in (48). Thereby the step size of the iteration is increased or decreased this helps to achieve better results. This is also called *Damped Newton Method.*

Another way to improve the results of the numerical solution is the use of previous results as starting values. Therefore valid results of a successful iteration of the system are stored in a file and loaded again as start values.

For the equations in (46) the algorithm with the starting values $\sigma = 0.5,\ \lambda = 0.05,\ \mu = 1.0$ leads after 14 passes to the result:

$\sigma = 0.339725801981555533$

$\lambda = 0.236505258653831 96$

$\mu = 1.12007236181365$

These values are returned to the InterestTreeCreator class and the binomial interest rate tree is created.

Expert Calibration

The last alternative to calibrate the Vasicek Model is to ask economic experts to estimate the factors μ, **λ** and σ. The advantage of this method is that an economic expert is able to consider past, current and perhaps near future developments. No mathematical method is able to do this. On the other hand, even the best expert is not able to know what will occur in the future and exactly how interest rates will develop.

5.3.1.3.3 Interest Rate Tree Illustration

After the successful calibration of the Vasicek Model the tree can be created and looks as illustrated in figure 93. The calibration factors are stored in the database after the first calibration. So the next time the user wants to create the tree the calibration factors are loaded automatically.

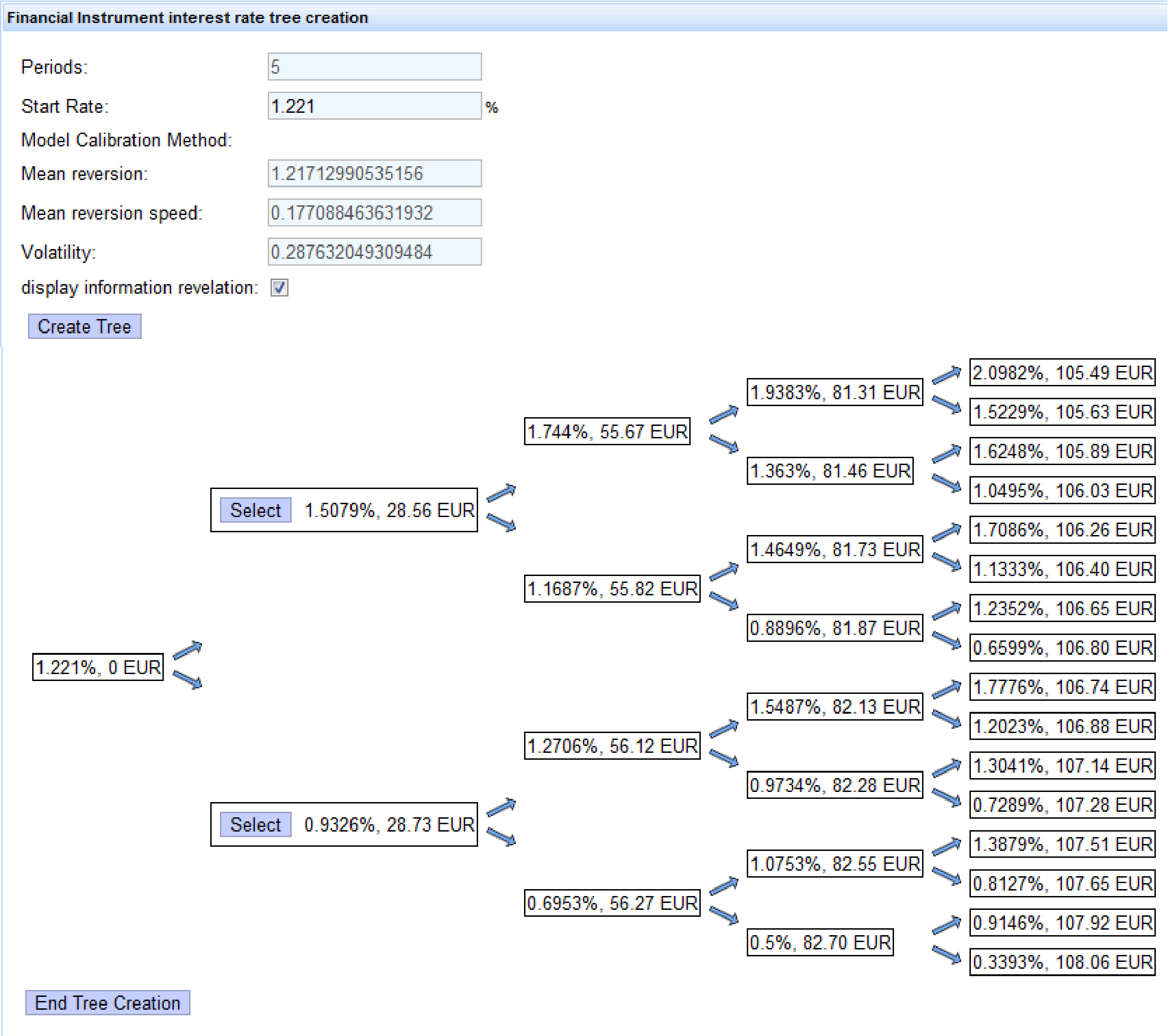


Figure 93: Interest Rate Tree

As shown in figure 93, I chose the implied calibration for the Vasicek Model to create the tree. The result for the mean reversion is 1.217 which represents the direction in which all rates are pulled. The mean reversion speed is 0.177 which is the speed of how fast the rates of the tree are pulled to the mean reversion. The volatility is 0.288 which represents the average amount of how much an interest rate rises or falls during a period.

To demonstrate this procedure the following calculation is carried out. As you can see in figure 93 the start rate is 1.221 and the mean reversion is 1.217, which is a little below the start rate.
This means the different rates of the tree are pulled downwards. To prove that, consider the calculations in (49) and (50).

(49)

$$1.221 - 0.9326 = 0.2884$$

(50)

$$1.5079 - 1.221 = 0.2869$$

In calculation (49) above I subtract the decreasing rate of period 1, 0.9326, from the start rate and get a result of 0.2884. Calculation (50) subtracts the start value from the increasing rate of period 1, 1.5079, which leads to a result of 0.2869. If you compare the results of these calculations, the difference of the decreasing rate and the start rate is higher than the difference between the start rate and the increasing rate. This demonstrates that the rates are pulled in the direction of the mean reversion which is lower than the start rate.

The tree does not only contain various interest rate paths it also contains the discounted cash flow of each period of the financial instrument. So besides the different interest rate curves, the created tree also shows a present value distribution.
Depending on the calibration values of the Vasicek Model the expected present value over all periods equals approximately the purchase price of the financial instrument. To illustrate that, the expectation value is calculated in (51).

(51)

$$\frac{105.49 + 105.63 + 105.89 + 106.03 + 106.26 + 106.4 + 106.65 + 106.8 + 106.74 + 106.88 + 107.14 + 107.28 + 107.51 + 107.65 + 107.92 + 108.06}{16}$$
$$= 106.77$$

The purchase price of the financial instrument as listed in figure 89 is 105.84. The result of the expectation value calculated in (51) equals 106.77. The deviation of the expectation value from the real purchase price is caused by the calibration factors of the Vasicek Model. As illustrated in (49) and (50) the interest rates in the tree are pulled downwards. This causes lower interest rates and therefore a higher present value over all periods.

The tree at figure 94 is now expert calibrated. As you can see, the mean reversion as well as the mean reversion speed, also called drift, and the volatility are much higher than the factors in figure 93.

(52)

$$1.222 - 1.0774 = 0.1446$$

(53)

$$2.0776 - 1.222 = 0.8556$$

The calculations in (52) and (53) now show a strong upwards movement of the interest rates in the tree. This causes higher interest rates over all periods which in turn result in a lower present value as calculated in (54).

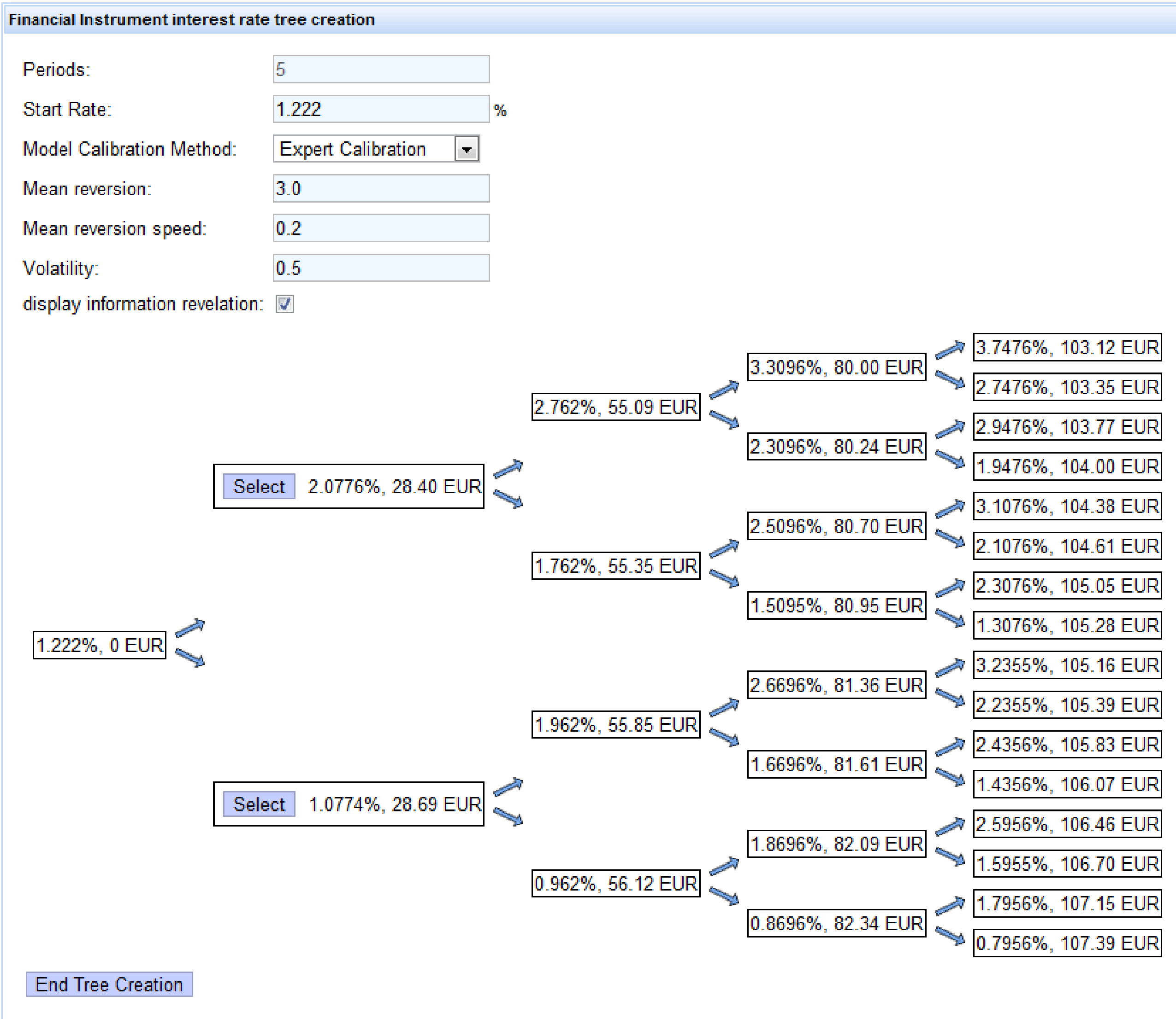


Figure 94: Interest Rate Tree

(54)

$$\frac{103.12 + 103.35 + 103.77 + 104 + 104.38 + 104.61 + 105.05 + 105.28 + 105.16 + 105.39 + 105.83 + 106.07 + 106.46 + 106.7 + 107.15 + 107.39}{16}$$

$$= 105.233$$

The calculation in (54) now shows an expectation value that is lower than the purchase price of 105.84. As mentioned above this effect is caused by the different calibration factors of the interest rate tree.

The interest rates in the tree are directly calculated with the Vasicek Model as illustrated in figure 92. The discounting of the cash flows in each period is calculated with the interest rate over all previous periods as defined in (55).

(55)

$$R_{0,T} = \left(\prod_{t=1}^{T}(1 + R_{t-1,t})\right)^{\frac{1}{T}} - 1$$

To demonstrate the method in (55), the calculation of the discounted cash flow 55.09 in figure 94, which is the increasing path in period 1, is illustrated in (56) and (57).

(56)

$$R_{0,2} = \left((1 + R_{0,1}) * (1 + R_{1,2})\right)^{\frac{1}{2}} - 1 = \left((1 + 0.020776) * (1 + 0.02762)\right)^{\frac{1}{2}} - 1 = 0.0241923 = 2.42\%$$

The cash flow of the AFS Loan in period 1 is 29.00 Euros and 28.00 Euros in period 2. The discounting illustrated in (57) yields the result of 55.09 which is the sum of discounted cash flow of the current period plus the discounted cash flow of the previous periods like displayed in the tree.

(57)

$$PV_T = \sum_{t=0}^{T} CF_t * (1 + R_{0,t})^{-t} = 29 * (1 + 0.020776)^{-1} + 28 * (1 + 0.0241923)^{-2} = 28.40 + 26.69 = 55.09$$

The value of 28.40 Euros is the discounted cash flow of period 1 as you can see in figure 94. Due to the fact that it is the first period the discounting is done with the Vasicek rate as there are no previous interest rates.
The calculation of the periodic interest rates and the discounting process of the cash flows are done similarly in all periods as illustrated in (56) and (57).

5.3.1.3.4 Path Simulation

Another feature of the interest rate tree is the simulation of the information revelation over time. In binomial trees like this, the interest rates in each period can either rise or fall. This means there are different interest rate curves for every path of the tree. By clicking on the *Select* button, displayed on a specific node, the part of the tree which was not chosen disappears. So in every period more information is revealed till only a single path of the tree is visible. This process is illustrated in the figures 95 – 99.

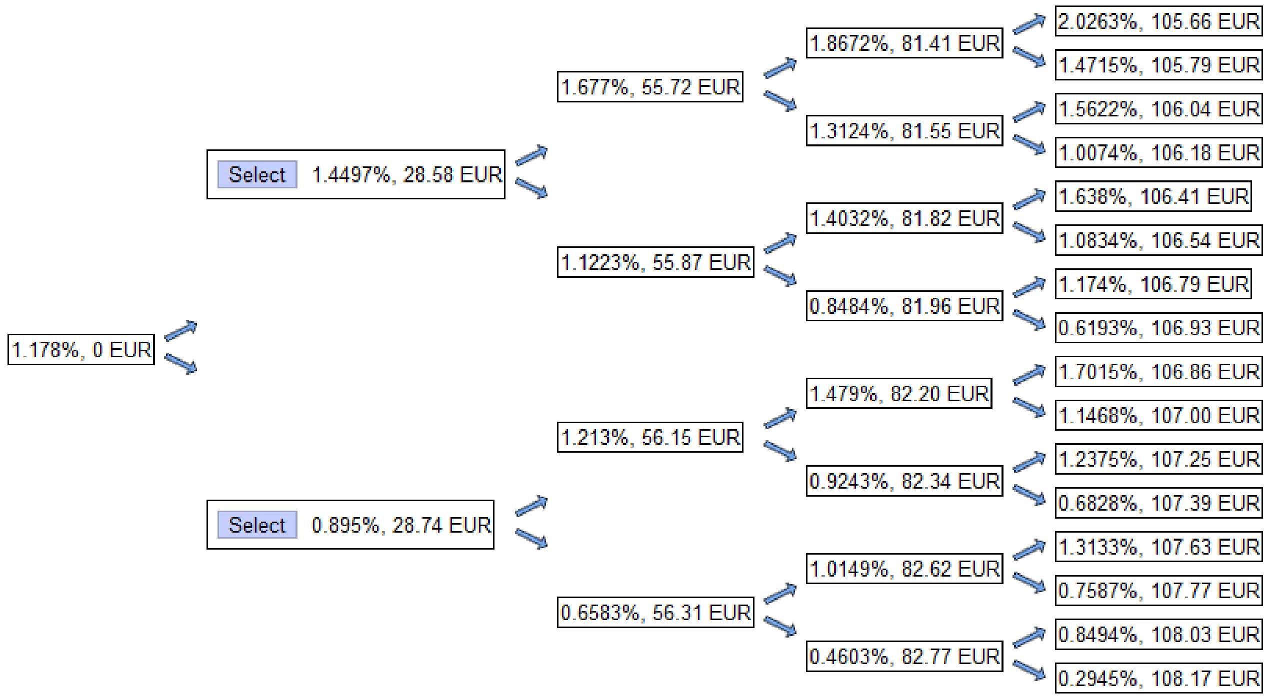


Figure 95: Interest Rate Tree (period 0)

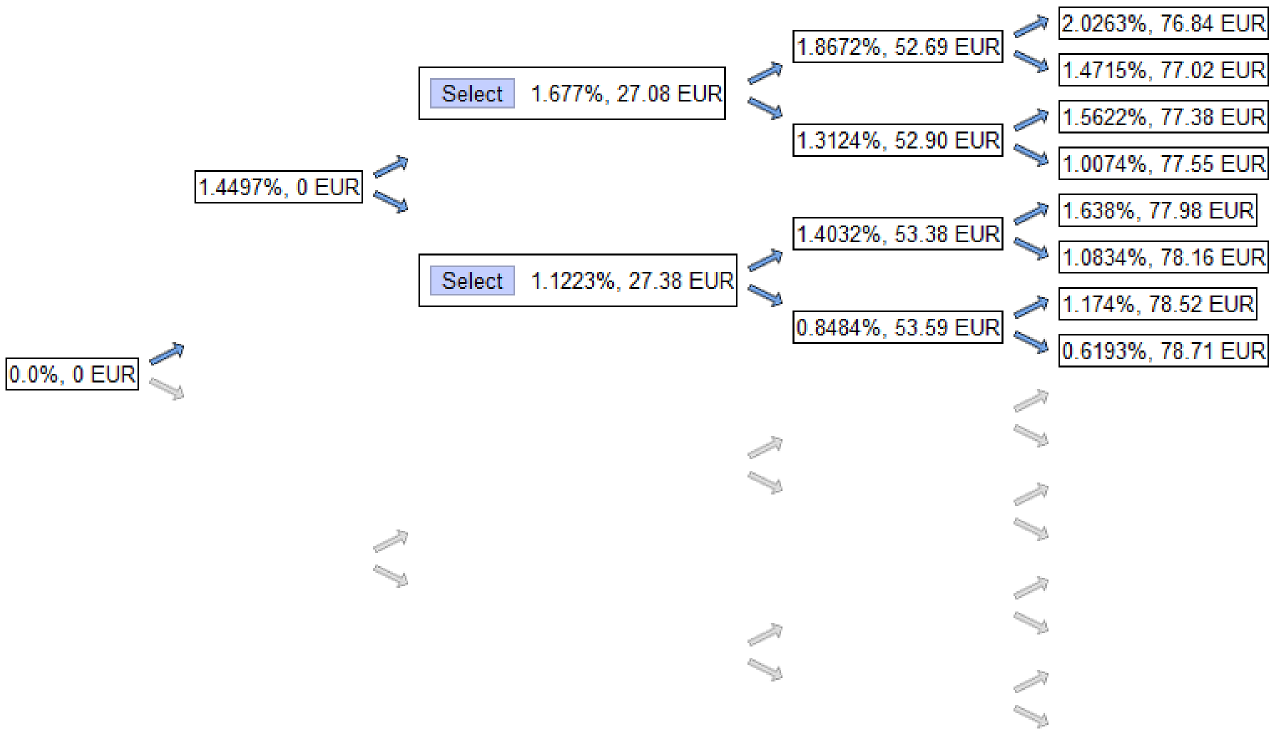


Figure 96: Interest Rate Tree (period 1)

After the information revelation in a period, the sum of the discounted cash flow over all periods is reduced by the discounted cash flow of this period. So at the end, a single path with a debt of 0 Euros results from this process. This happens because after a period the debt is reduced by the cash flow from the borrower to the bank.

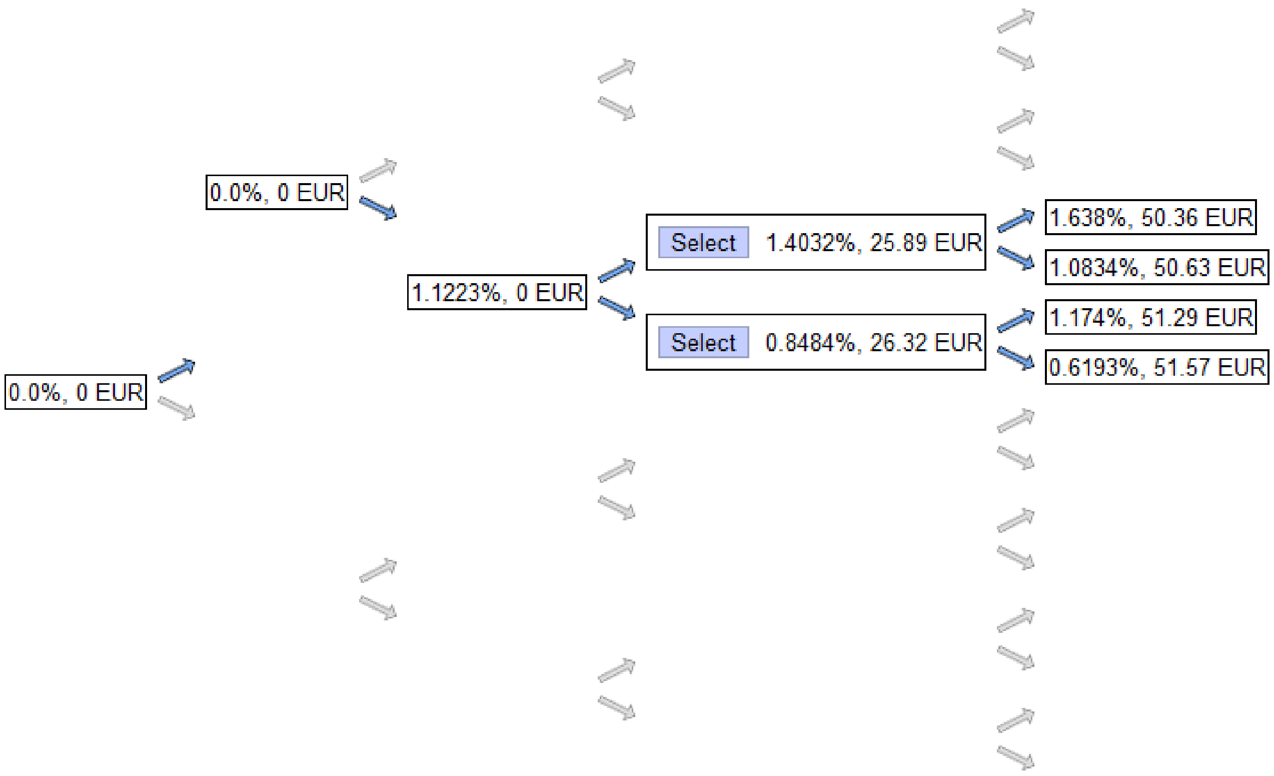


Figure 97: Interest Rate Tree (period 2)

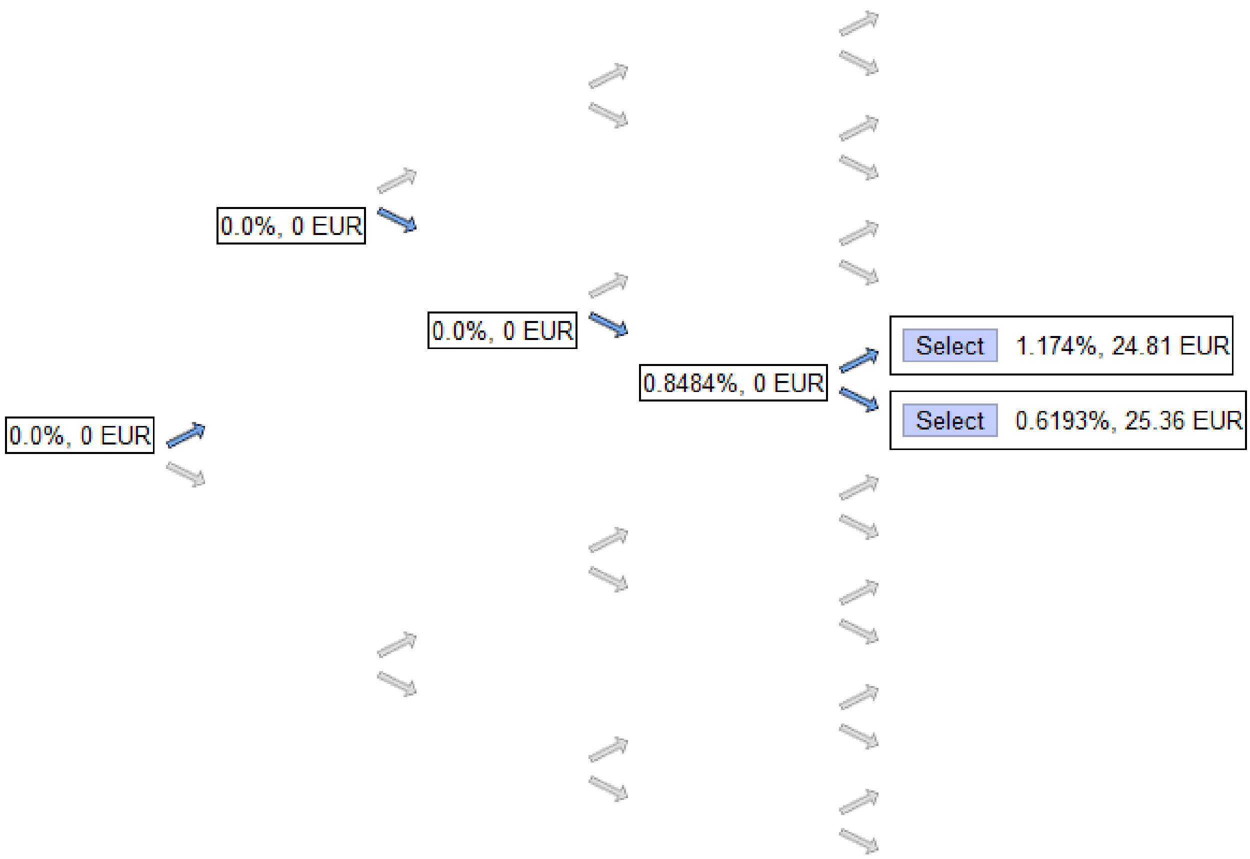


Figure 98: Interest Rate Tree (period 3)

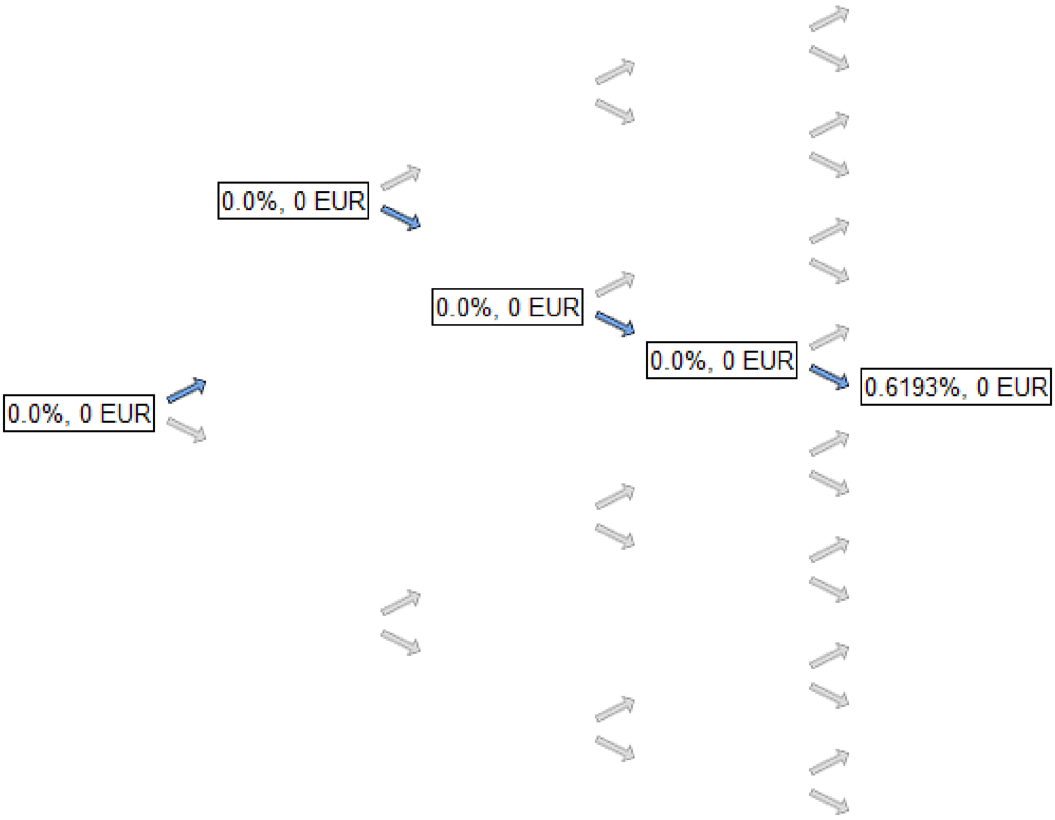


Figure 99: Interest Rate Tree (period 4)

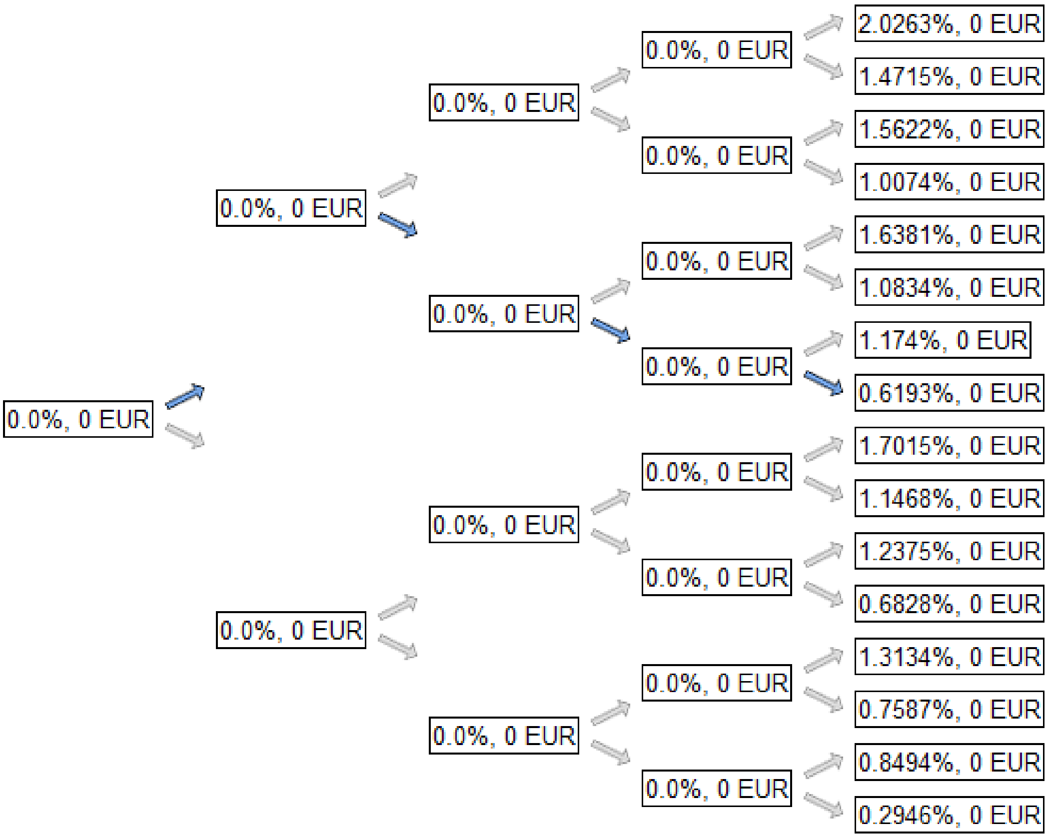


Figure 100: Interest Rate Tree (period 4), alternative presentation form

In the simulated path above, the interest rate curve rises in period 1 and then falls three times. After the information revelation is done the cash flows of the previous tree nodes are set to 0 because they are already paid. The interest rate of the last revealed period remains because it is the basis for the interest rates of the next period calculated by the Vasicek Model. All other interest rates prior to that are set to 0.0% because they have no influence on the future development of the interest curve.

As an alternative to displaying only the single resulting path of the tree is that all possible paths are displayed during the information revelation process, and all nodes of the tree are visible over all periods. In this case the resulting path is highlighted as illustrated in figure 100.

5.3.1.3.5 Tree Illustration in Advanced Periods

After the subsequent valuation of a financial instrument, as defined in section 5.2, an information revelation took place. That means a specific path was entered as illustrated in figures 95-99. In this case a shorter tree is rendered in the ERPControl system because previous periods are no longer influencing the future development of the financial instrument.
Figure 101 shows the same financial instrument as displayed above after the subsequent valuation in period 1.

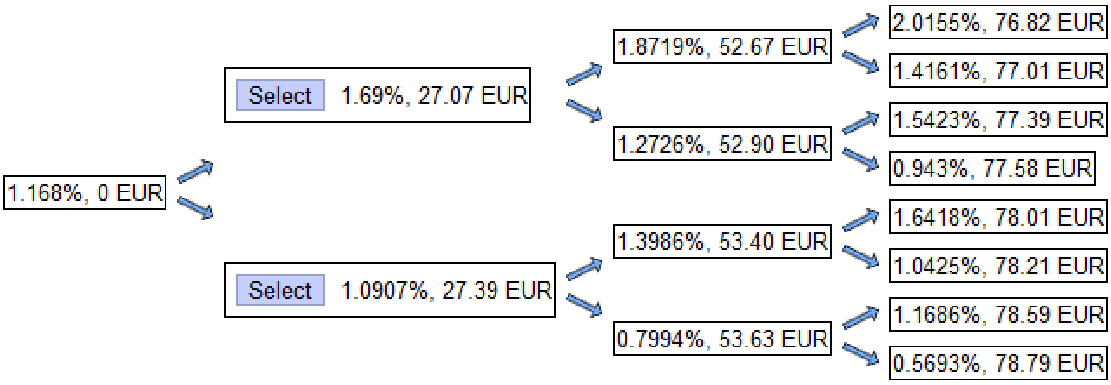


Figure 101: Interest rate tree after subsequent valuation in period 1

As you can see, the sum of the present values is now reduced by the discounted cash flow of period 1 because it has already been repaid.

5.3.1.3.6 Tree Creation Algorithm

The interest rate tree is displayed by dynamically creating HTML code. The basis for the rendering of the tree is an HTML Table in the shape of a binomial tree. An example with visible borders of a binomial HTML Table is displayed in figure 102.

<table>
<tr><td rowspan="8">1</td><td rowspan="4">2</td><td rowspan="2">3</td><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td rowspan="2">6</td><td>7</td></tr>
<tr><td>8</td></tr>
<tr><td rowspan="4">9</td><td rowspan="2">10</td><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td rowspan="2">13</td><td>14</td></tr>
<tr><td>15</td></tr>
</table>

Figure 102: Binomial HTML Table with rendered borders

The dynamically created HTML code has to contain the interest rates calculated with the Vasicek Model as well as the discounted cash flow of each period. The calculated values represent the content of the tree.
The data structure to store the values after the calculation is a two dimensional Array consisting of an Array List with an Array structure in every entry. A two dimensional Array for a three year maturity instrument is illustrated in figure 103 containing the numbers of the cells as defined in 102.

So the algorithm of the tree creation has, put simply, three main steps:

- Calculating the Vasicek interest rates
- Discounting the cash flow on the basis of the Vasicek interest rates
- Creating the HTML code for the binomial table structures with the interest rates and present values as cell content

The creation of the HTML code partly happens within the Java Session Bean and partly in the Java Server Face with the usage of <forEach> tags. The creation of the HTML code cannot be done completely within the session bean because JSF does not allow injecting of all tags and attributes that are necessary to render a binomial HTML table.

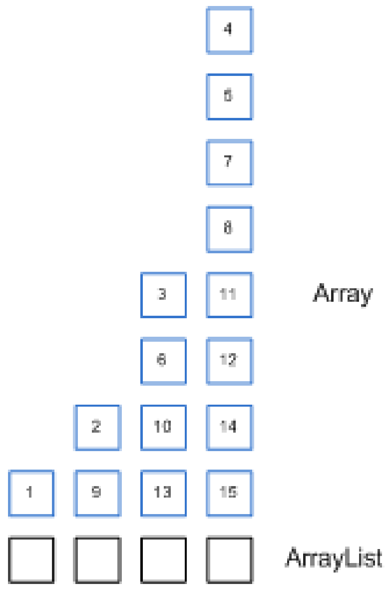


Figure 103: Data structure of the financial instrument development tree

For the illustration of the information revelation a separate algorithm checks every cell to determine whether it has to be rendered or not and adapts the content of the specific cell appropriately.

5.3.1.4 LAR and HTM Development

The subsequent valuation of *Loans and Receivables* as well as *Held To Maturity* categorized financial instruments are valuated based on the effective interest rate. So in this case the interest rates are not changing over the term of the financial instrument. Due to that the development of these instruments follows a straight path. In the ERPControl software this straight path is illustrated as displayed in figure 104.

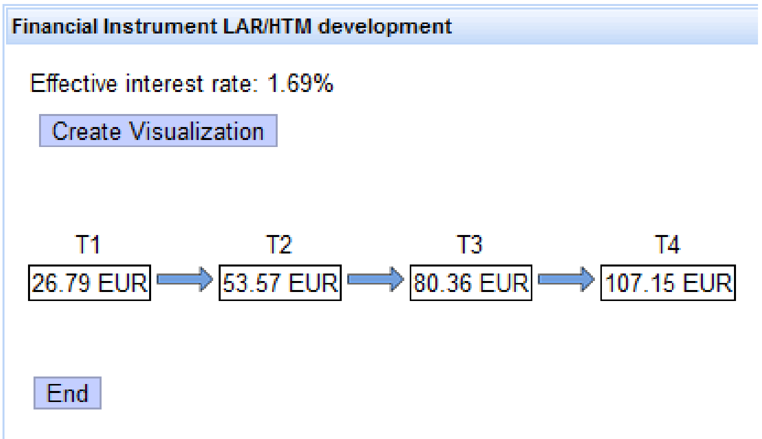


Figure 104: Path of an HTM categorized financial instrument

Figure 104 shows the visualization of the HTM categorized financial instrument as listed in figure 89. The HTM Loan is classified as an annuity loan with a constant cash flow of 27.24 Euros in every period.
The discounting of the cash flow in each period is done on the basis of the effective interest rate as shown in (58).

(58)

$$PV_t = CF_t * \frac{1}{(1 + R_0^E)} = 27.24 * \frac{1}{1.0169} = 26.787 = PV_1$$

The process of the subsequent valuation for HTM and LAR instruments results in a constant present value over all periods for annuity loans. The calculation of the complete sum of the present values over all periods, as shown in figure 104, is illustrated in (59).

(59)

$$\sum_{t=1}^{4} PV_t = 26.787 + 26.787 + 26.787 + 26.787 = 107.148$$

As you can see, the result of the calculation in (59) equals the sum of the present values over all four periods as demonstrated in figure 104.

Similar to the illustration in section 5.3.1.3.5, the development path is shorter and the sum of cash flows is reduced by the repaid parts after the subsequent valuation of the instrument. Figure 105 shows the visualization of the HTM Loan instrument after the booking of the changes in value in period 2.

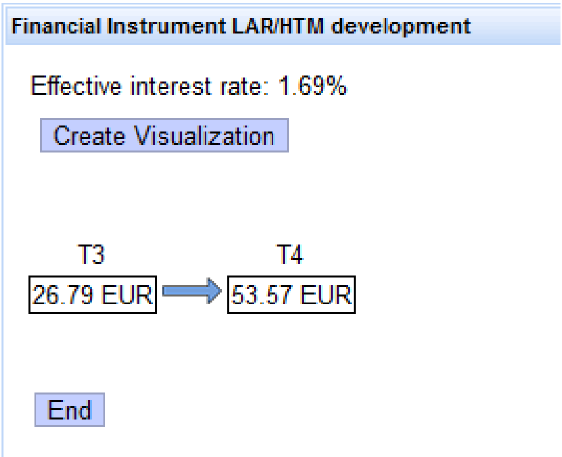


Figure 105: Remaining path of an HTM categorized financial instrument in current period 3

5.3.2 Analytical Planning of Financial Options

An option is a financial instrument that gives its owner the right, but not the obligation, to trade a specific asset. Options are derivative instruments, so their fair price derives from the value of another asset, called the underlying. In the ERPControl software the underlying is either a stock or a forward. A forward specifies a future contract between two parties to buy or sell an asset.
A call is an option to buy something and a put is an option to sell something.
The specified price for which the underlying asset may be traded is called the strike price. The process of activating and thereby trading the underlying at the agreed-upon price is referred to as exercising it. If the option is not exercised by the expiration date it becomes worthless.

There are various kinds of options like European Options, American Options, Bermuda Options or Vanilla Options, to name a few examples.
The option valuation module in the ERPControl system is able to evaluate the theoretical value of European and American Options according to various mathematical models. Table 15 shows which option types are valuated according to which mathematical model.

	Cox, Ross, Rubinstein Model	Black-Scholes Model	Black Model
European Stock Call	x	x	(x)
European Stock Put	x	x	(x)
European Forward Call	x		x
European Forward Put	x		x
American Stock Call	x		
American Stock Put	x		
American Forward Call	x		
American Forward Put	x		

Table 15: Mathematical model for the valuation of financial option instruments

The difference between European and American options is that European options can only be exercised on expiration. In contrast to that, American options can be exercised on any trading day on or before expiration. The Black and the Black-Scholes Models are not able to determine the value of options that may be exercised at any point before the expiration. So the application of these models is only possible for European options.
The option pricing tool in the ERPControl system is able to determine the value of *Plain Vanilla Options* which are European or American Put- or Call-Options. The option valuation process based on the CRR Model is done according to [HEG06] and the valuation process based on the Black and the Black-Scholes Model is performed according to [ESF02].

To summarize the process of option trading, the buyer of an option has the right, but not the obligation to buy (Call-Option) or sell (Put-Option) a specified quantity of an asset for a predetermined price (Strike Price).
The seller of an option receives the buying price of the option, and this is the stock price for a stock underlying and the forward price for a forward underlying. The seller is obligated to sell or buy the underlying at the predetermined price.

Figure 106 illustrates the UML activity diagram of the analytical planning process of financial options. After the specification of the necessary parameters of the financial option instrument, risk models have to be selected for the valuation of the option according to the option type as defined in table 15. The next process step contains the price tree creation which is needed by the CRR model. In the last step the value of the option is determined according to the specified risk models.

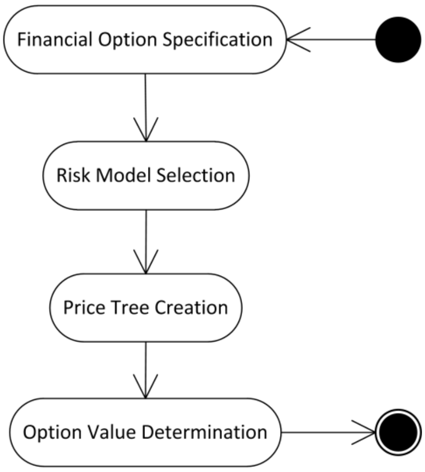


Figure 106: UML activity diagram of the valuation of Financial Options process

The evaluation of financial options within the ERPControl system follows the business process model illustrated in figure 107.

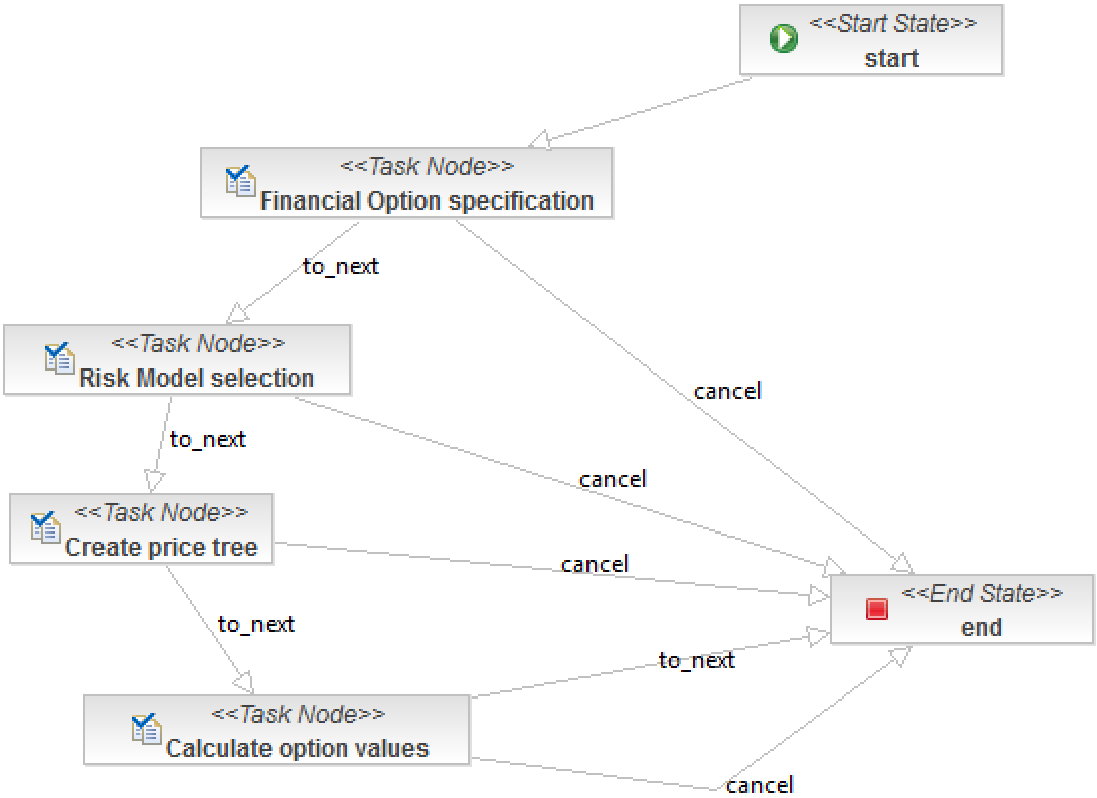


Figure 107: Business process model of the valuation of financial options

As illustrated in table 15 the valuation of financial options within the ERPControl system is done by the CRR (Cox, Ross, Rubinstein) Model, the Black Model and the Black-Scholes Model. The valuation with the CRR Model is based on the pricing tree for the maturity of the financial option. The value of the option is found by a standard backward induction of the price tree. So the CRR Model is a numerical way to determine an option value.
The Black and Black-Scholes Models determine the value of an option analytically. Because these models do not consider exercising the option before expiration, only European options can be evaluated with the Black and the Black-Scholes Model.

5.3.2.1 Financial Option Specification

The first task of the valuation process is the specification of a financial option. Figure 108 shows the form to enter the appropriate data of the financial option.

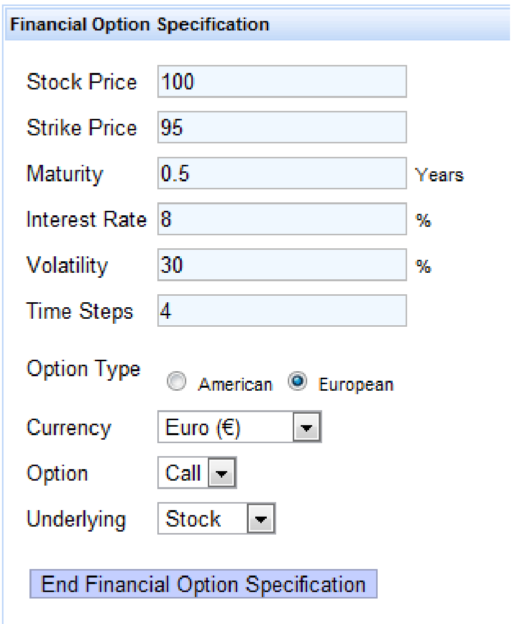


Figure 108: Financial option specification, European Stock Call Option

In figure 108 above a European Stock Call Option is specified. The various attributes of the financial option are explained in the following:

- **Stock Price/Forward Price (S/F):** the current market price of the underlying asset
- **Strike Price (X):** the predetermined price to buy or sell a specific quantity of the underlying asset
- **Maturity (T):** the amount of time until expiration
- **Interest Rate (r):** determining the costs of interest payments of holding a position in the underlying asset
- **Volatility (σ):** estimation of the future volatility of the underlying asset's price over the life time of the option

- **Time Steps (n):** the number of periods in the price tree
- **Option Type:** American or European option
- **Currency:** the currency of the option, Euro or US Dollar
- **Option:** Call- or Put-Option
- **Underlying:** Stock or Forward

So in the example presented in figure 108, a European Call Option with a strike price of 95 Euros, a maturity of ½ year, an interest rate of 8% and a volatility of 30%, is purchased for a stock price of 100 Euros.

In the following steps the determination of the option value according to various mathematical models is illustrated.

5.3.2.2 Risk Model Selection

Like any other analytical planning process, the financial option valuation process also is based on various risk models. In this case the CRR Model, the Black Model and the Black-Scholes Model represent the risk models.
Figure 109 shows the selection possibilities for the valuation of a European Stock Option.

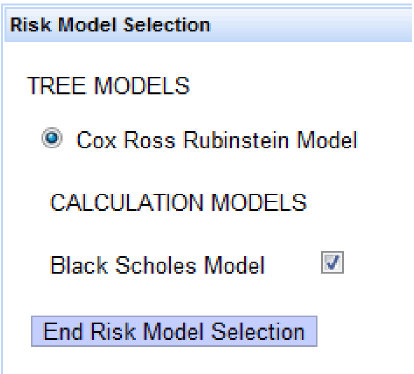


Figure 109: Risk model selection for the valuation of a European Stock Option

As you can see in figure 109 the Cox, Ross, Rubinstein and the Black-Scholes Models can be selected for the valuation of a European Stock Option. In the case of a European Forward Option, the Black Model instead of the Black-Scholes Model is used for determination of the value. So the ERPControl software ascertains that only European Stock Options are valuated with the Black-Scholes Model and European Forward Options are evaluated with the Black Model. The Black Model is actually an extension of the Black-Scholes Model to valuate forward options. (60) defines the method to transform the spot price into the appropriate forward price.

(60)

$$F = S * e^{r*T}$$

(61)

$$S = F * e^{-r*T}$$

The method in (61) defines the transfer of the forward price back into the spot price. In the ERPControl system stock options are only valuated with the Black-Scholes Model and forward options are only valuated with the Black Model. The Black Model can also be used to determine the value of European Stock Options, therefore the transformation into the spot price defined in (61) has to be considered, the result is the same like the calculation according to the Black-Scholes Model. In (60) and (61) T is the forward maturity of a forward option.
American Options can only be processed with the CRR Model as defined in table 15.

5.3.2.3 Price Tree Creation

The creation of the price tree is necessary for the calculation of the option value based on the Cox, Ross, Rubinstein Model. The price of the option in each node of the tree is equal to (62).

(62)

$$x\left(su^i d^{j-i}\right), \quad i = 0, 1, \dots, j$$

In (62), u and d stand for up and down jump size that the option price can take at each time step Δt. The up and down factors are defined in (64) and (65), and Δt is the time step which is defined in (61) as the maturity divided by the number of time steps.

(63)

$$\Delta t = \frac{T}{n}$$

(64)

$$u = e^{\sigma\sqrt{\Delta t}}$$

(65)

$$d = e^{-\sigma\sqrt{\Delta t}}$$

The volatility of the financial option is represented by σ. Based on the up and down factors the probability of the stock or forward price increasing at the next time step is determined as defined in (66).

(66)

$$p = \frac{e^{r*\Delta t} - d}{u - d}$$

The probability of the price of going down must be $1 - p$ since the probability of going either up or down equals unity, and r represents the interest rate as shown in figure 108. The up and down jump size and the up and down probability are chosen to match the first two moments of the stock price distribution (mean and variance). This ensures that the binomial tree will be a discretization of the geometric brownian motion. The resulting price tree visualized by the ERPControl software is illustrated in figure110.

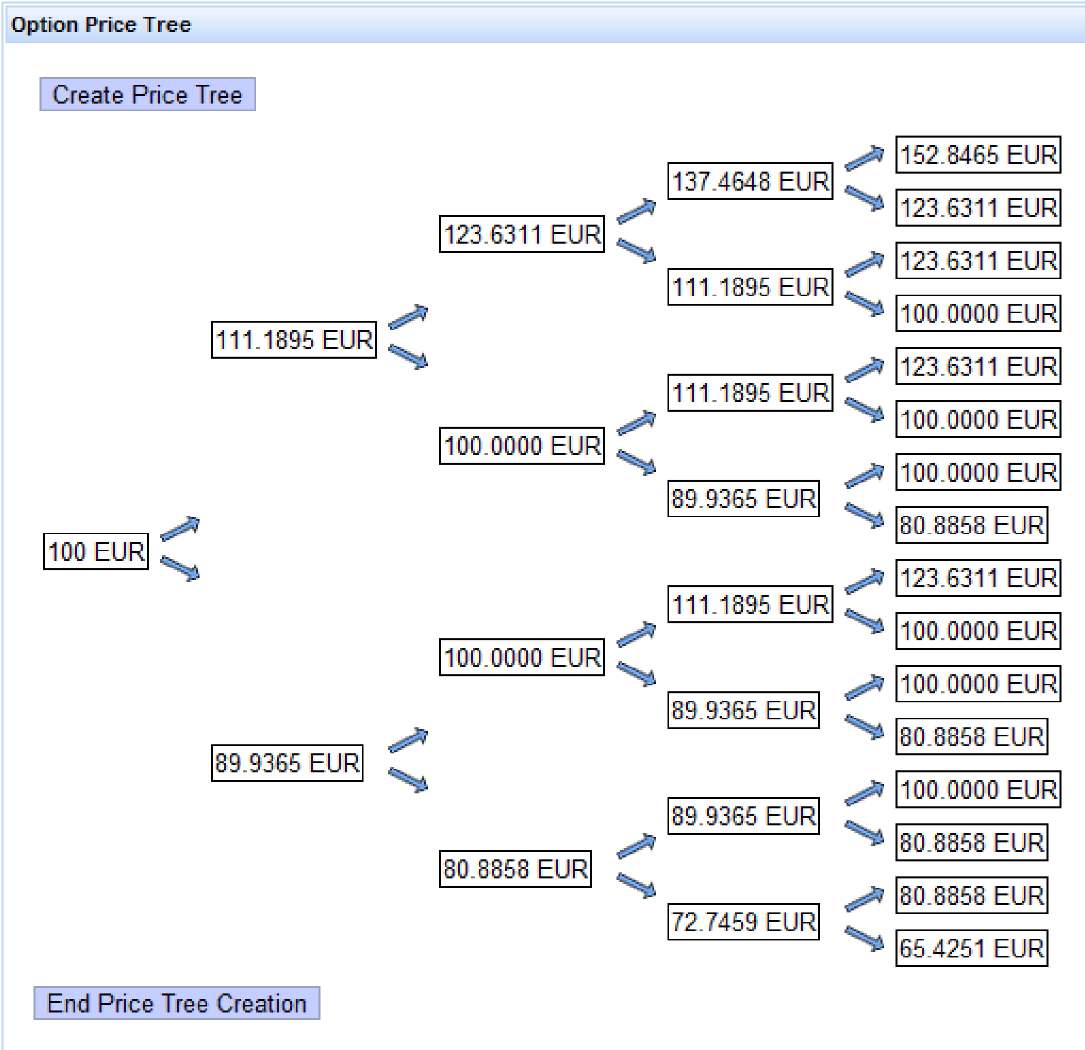


Figure 110: Price Tree of the European Stock Call Option

The prices in each period are calculated by multiplying the stock or forward price in each node of the tree with the up and down factors.
To exemplify this procedure in (67) and (68) the up and down jump sizes are calculated as defined in (64) and (65).

(67)

$$u = e^{0.3*\sqrt{\frac{0.5}{4}}} = 1.111895$$

(68)

$$d = e^{-0.3*\sqrt{\frac{0.5}{4}}} = 0.899365$$

So the increasing and decreasing prices in the first time step of the pricing are determined as illustrated in (69) and (70).

(69)

$$x(su) = s * u = 100 * 1.111895 = 111.1895$$

(70)

$$x(sd) = s * d = 100 * 0.899365 = 89.9365$$

The calculation of the following nodes in the pricing tree is done similarly. So the price in a node in the tree is the basis for the calculation of the price in the next node.

5.3.2.4 Option Value Calculation

The last step in this business process is the calculation process of the option value which depends on the specified option. In the next sections I will explain the determination process of the option value for the European Stock Call Option as shown in figure 108, for a European Forward Put Option, for an American Forward Call Option and for an American Stock Put Option.

5.3.2.4.1 Value Calculation of a European Stock Call Option

The determination of the value of a European Stock Call Option is done based on the CRR and the Black-Scholes Models. The calculation of the option value based on the CRR Model is done by a backward induction of the price tree illustrated in figure 110.

To perform the backward induction, first of all the value of the final nodes, also called leaf nodes, has to be determined as defined in (71).

(71)

$$P_{finalNode}^{Call} = max\left[\left(x(s_{ij}) - X\right), 0\right]$$

The value of each final node for a call option is the maximum of the price of the specific final node minus the strike price of the option or 0. For example the value of the final node of the first path in the option tree is determined as shown in (72).

(72)

$$P_{finalNode}^{Call} = max[(152.8465 - 95), 0] = 57.8465$$

The option value tree determined by the ERPControl software is illustrated in figure 111.

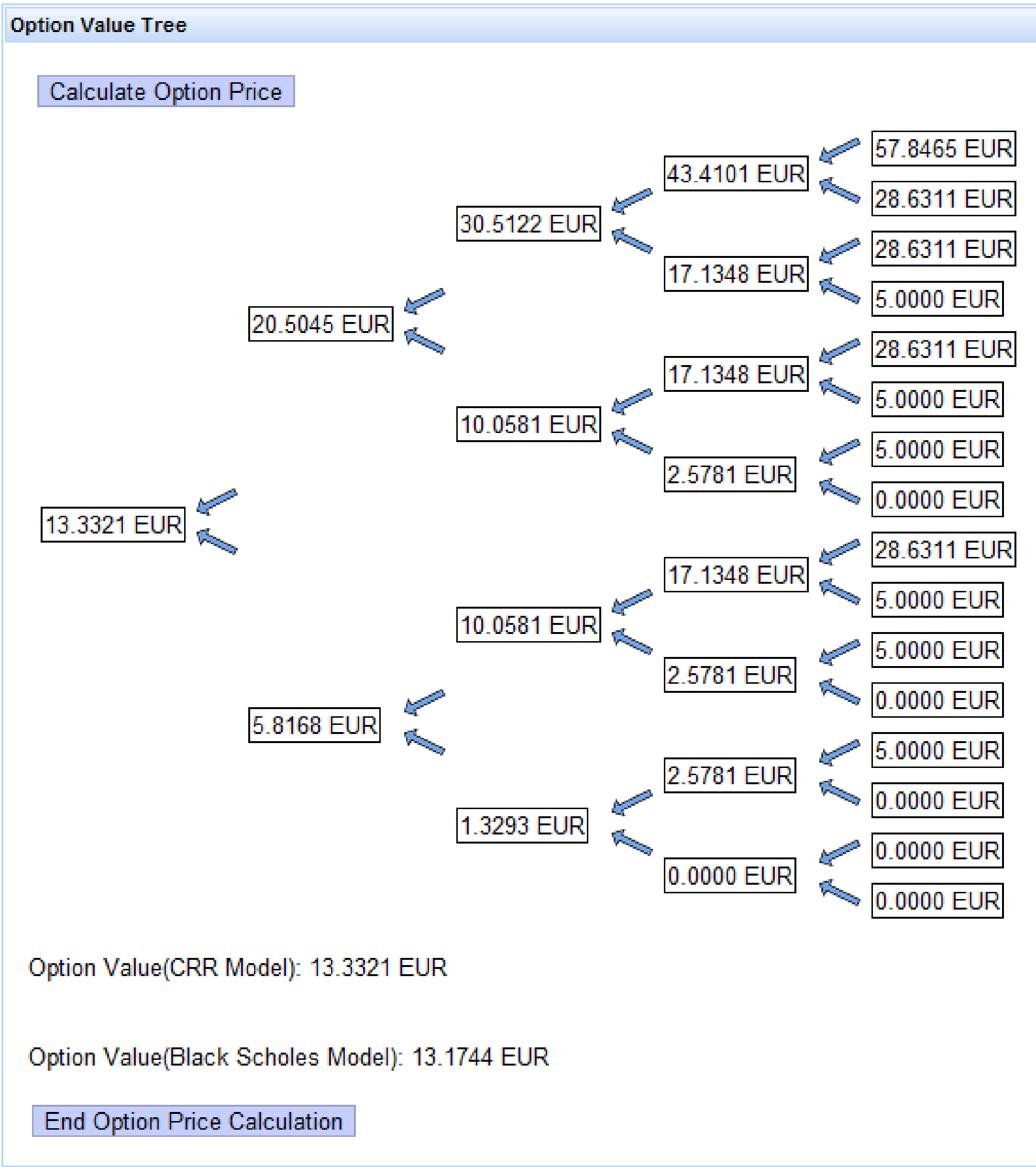


Figure 111: Option Value Tree of a European Stock Call Option

After the determination of the final node values as defined in (71) and illustrated in figure 111, the value of every node in the tree is determined by backward induction. The value calculation in each node for European Call Options is specified in (73).

(73)

$$P_{i,j}^{European} = max\left[0, e^{-r*\Delta t}\left(p * P_{j+1,i+1} + (1-p) * P_{j+1,i}\right)\right]$$

In (73), the price of a node in the tree is the maximum of 0 or the probability of an increasing price times the price of the first child node of the current node plus the probability of a decreasing price times the price of the second child node of the current node. The determination of the price for a specific node is shown in figure 112.

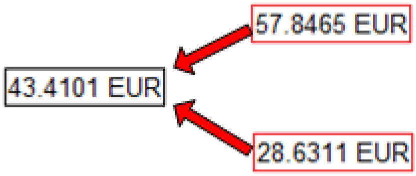


Figure 112: Value calculation for a specific node

The calculation in figure 112 is done according to the method defined in (73). To determine the value of the node, first of all the probability factor has to be calculated as shown in (74).

(74)

$$p = \frac{e^{0.08*0.125} - 0.899365}{1.111895 - 0.899365} = 0.520798$$

After the determination of the probability of an increasing price, the calculation of the node price shown in figure 112 is illustrated in (75).

(75)

$$P_{4,4}^{European} = max[0, e^{-0.08*0.125} * (0.520798 * 57.8465 + (1 - 0.520798) * 28.6311)] = 43.4101$$

After the calculation of the values for all tree nodes, similar to the process shown in (75), the root node of the binomial tree contains the value of 13.3321 Euros of the European Call Stock Option.

The index $P_{4,4}$ describes the position of the node in the tree. Commonly written the position of a node is $x(su^i d^{j-i})$ where $i = 0, 1, \dots, j$. So $P_{4,4}$ means an increase of the price in 4 time steps, so $i = 4$, and a decrease of the price in 0 time steps, so $j - i = 0 \rightarrow j = 4$.

Another way to determine the value of a stock option is the calculation according to the Black-Scholes Model as defined in (76).

(76)

$$P_{BS}^{Call} = S * N(x) - X * e^{(-r*T)} * N(x - \sigma * \sqrt{T})$$

$$x = \frac{ln\left(\frac{S}{X}\right) + \left(r + \frac{\sigma^2}{2}\right) * T}{\sigma * \sqrt{T}}$$

In the Black-Scholes Model above, N(x) represents the normal distribution at position x. The determination of the stock call option value of the instrument defined in figure 108 is illustrated in (77).

(77)

$$x = \frac{ln\left(\frac{100}{95}\right) + \left(0.08 + \frac{0.3^2}{2}\right) * 0.5}{0.3 * \sqrt{0.5}} = 0.536427$$

$$P_{BS}^{Call} = 100 * N(0.536427) - 95 * e^{-0.08*0.5} * N\left(0.536427 - 0.3 * \sqrt{0.5}\right) = 13.1744$$

As you can see the option value according to the Black-Scholes Model in (77) equals 13.1744 Euros. The valuation of the option according to the Black or the Black-Scholes Model is an exact determination of the option value. The determination according to the CRR Model is only an approximation of the exact value of the option. This causes the difference between the CRR determined option value of 13.3321 Euros and the Black-Scholes determined value of 13.1744 Euros. As presented in table 15 the European Stock Option valuation can be done with the Black-Scholes as well as the Black Model, the results of both models are the same.

The model specified in (76) is used for the value determination of a European Stock Call Option. For the sake of completeness, (78) illustrates the theoretical mathematical approach according to the Black-Scholes Model for the value determination of European Stock Put Options. The calculation of the values works similarly.

(78)

$$P_{BS}^{Put} = X * e^{(-r*T)} * N\left(-x + \sigma * \sqrt{T}\right) - S * N(-x)$$

$$x = \frac{ln\left(\frac{S}{X}\right) + \left(r + \frac{\sigma^2}{2}\right) * T}{\sigma * \sqrt{T}}$$

The valuation of European Put Options according to the CRR Model will be illustrated in the next section.

5.3.2.4.2 Value Calculation of a European Forward Put Option

A put option is based on the sale of a specified asset. Unlike European Stock Options, the determination of a forward option value is made using the Black Model in addition to the CRR Model.
Compared to a call option, there are also some differences in the value determination for a put option based on the CRR Model which will be illustrated in the upcoming pages.

A forward is a derivative categorized as an unconditional forward contract where the buyer and the seller of the contract agree at the point of time t = 0 to substitute the underlying for the forward

price at the point of time t = T. At the settlement date the buyer receives the underlying object and pays the forward price respectively the seller delivers the underlying and receives the forward price.
Now a European Forward Put Option is specified in the ERPControl software as shown in figure 113. To show the difference between call and put values, the following put option has the same attributes as the call option discussed previously.

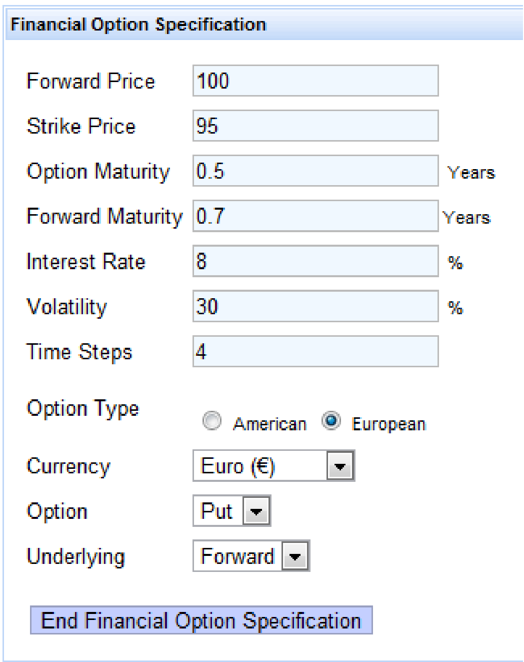


Figure 113: Financial option specification, European Forward Put Option

The specified option in figure 113 is now a European Forward Put Option, because of that the *Forward Price* as well as the *Forward Maturity* has to be entered. The forward maturity always has to be longer than the option maturity.

As mentioned above options with a forward as underlying are valuated using the Black Model. Because of that the risk model selection only provides the CRR and that Black Models as selection possibilities.

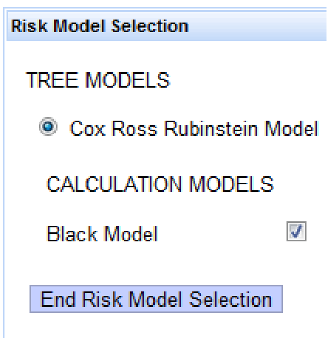


Figure 114: Risk model selection for the valuation of a European Forward Option

The creation of the price tree in figure 115 is now done in two steps. First the spot price tree is created as illustrated in section 5.3.2.3. Hereby the specified forward price in figure 113 is transformed into the appropriate spot price like defined in (61). After that, the spot prices in each cell of the tree are transformed into the appropriate forward prices according to the method defined in (80). These two steps are performed in one tree in the ERPControl software. The price tree of the European Forward Put Option is illustrated in figure 115.

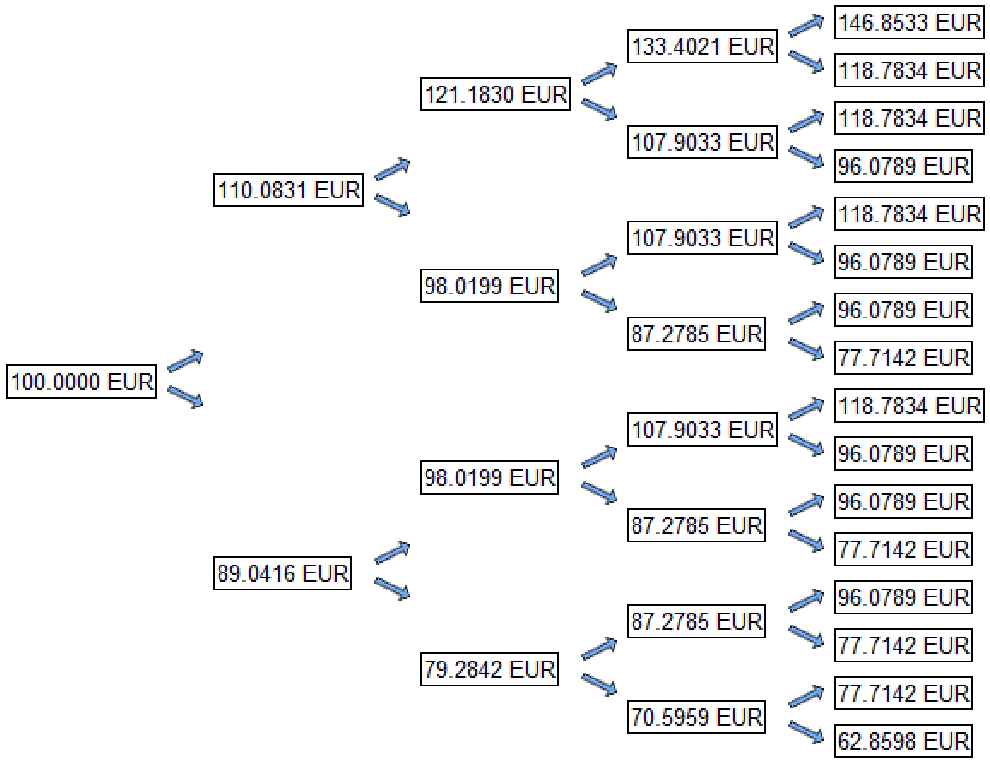


Figure 115: Price Tree of the European Forward Put Option

To clarify the forward price tree creation, consider calculations (79) and (80). The calculation in (79) transforms the specified forward price into the appropriate spot price.

(79)

$$x(s_{i,j}) = 100 * e^{-0.08*0.7} = 94.5539$$

(80)

$$x(s_{i,j}) = (94.5539 * 1.111895) * e^{0.08*\left((0.7-0.5)+0.5*\frac{3}{4}\right)} = 110.0831$$

In (80) the forward price of the first up going tree node is calculated on the basis if the determined spot price in (79). As specified in figure 113, 0.7 is the forward maturity, 0.5 is the option maturity and 0.08 is the interest rate. The forward maturity always has to be longer than the option maturity, so in this case the forward term is 0.2 years longer than the option term. In (80), $\frac{3}{4}$ specifies the remaining periods divided by the complete amount of periods in the tree.

The determination of the forward put option value according to the Cox, Ross, Rubinstein Model also differs from the previous procedure at the point of the value calculation of the final nodes of the option value tree.
In contrast to the calculation for a call option, the value of a final node for a put option is the maximum of the subtraction of the node price from the strike price or 0, as illustrated in (81).

(81)

$$P_{finalNode}^{Put} = max[(X - x(s_{ij})), 0]$$

So the value of the bottom final node of the forward call option is determined as shown in (82).

(82)

$$P_{finalNode}^{Put} = max[(95 - 62.8598), 0] = 32.1403$$

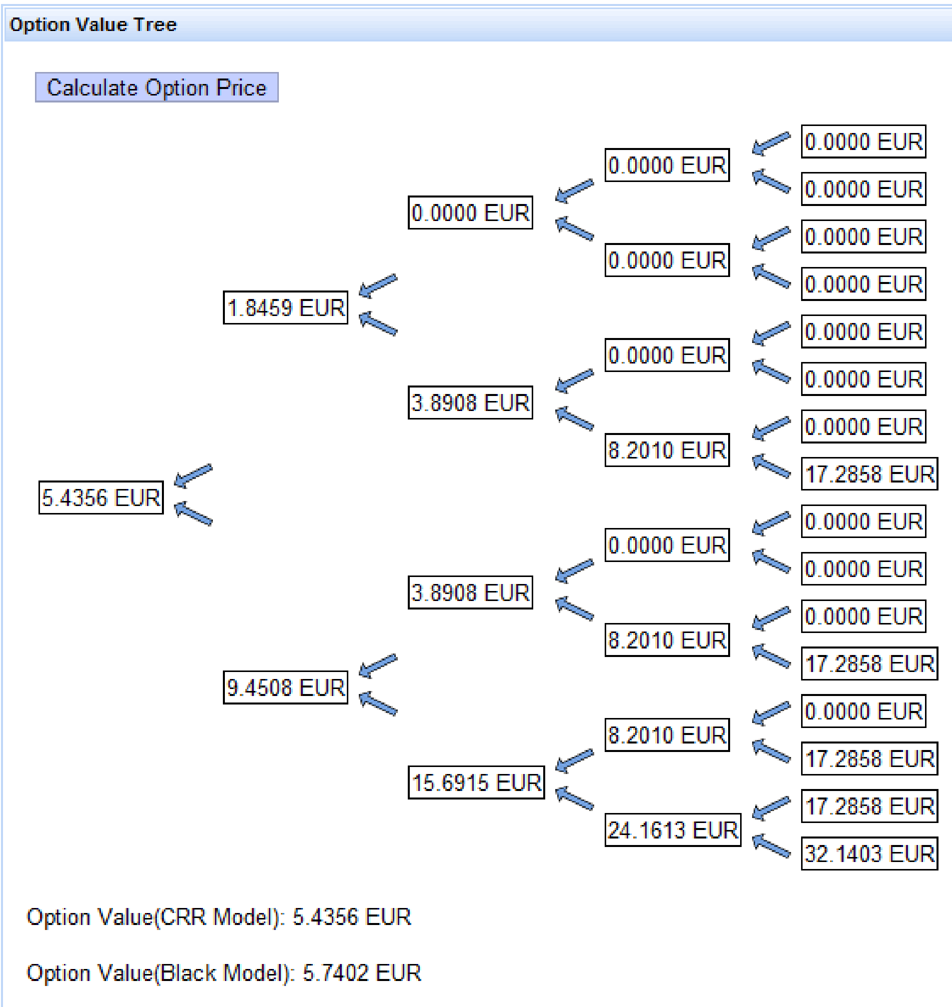


Figure 116: Option value tree of a European Forward Put Option

The backward induction of the final node values to the root node which represents the value of the option is done similarly to the method defined in (73). This process leads to an option value of 5.4356 Euro.

As shown in table 15 an alternative way to determine the value of a European Put Option is the Black Model as defined in (83).

(83)

$$P_B^{Put} = \frac{X * N\left(-x + \sigma * \sqrt{T}\right) - F * N(-x)}{e^{r*T}}$$

$$x = \frac{ln\left(\frac{F}{X}\right) + \frac{\sigma^2 * T}{2}}{\sigma * \sqrt{T}}$$

Variable F in (83) represents the future price of the European Forward Option, and N(x) is again the normal distribution on position x. The determination of the option value according to the Black Model with a result of 5.7402 Euros is shown in (83).

(84)

$$x = \frac{ln\left(\frac{100}{95}\right) + \frac{0.3^2 * 0.5}{2}}{0.3 * \sqrt{0.5}} = 0.347865$$

$$P_B^{Put} = \frac{95 * N\left(-0.347865 + 0.3 * \sqrt{0.5}\right) - 100 * N(-0.347865)}{e^{0.08*0.5}} = 5.7402$$

As you can see in figure 116 the CRR determined value and the Black Model determined value are differing from each other. Contrary to the pricing of a stock underlying, the analytical solution according to the Black Model is only an approximation of the numerical solution according to the CRR Model. This is because the Black Model, specified in (83) does not incorporate the forward maturity.

The Black Model for the determination of a European Forward Call Option is illustrated in (85). The Black Model for the valuation of forward calls differ from the Black Model for forward put options, but the calculation of the value works similarly as the calculation in (84).

(85)

$$P_B^{Call} = \frac{F * N(x) - X * N\left(x - \sigma * \sqrt{T}\right)}{e^{r*T}}$$

$$x = \frac{ln\left(\frac{F}{X}\right) + \frac{\sigma^2 * T}{2}}{\sigma * \sqrt{T}}$$

5.3.2.4.3 Value Calculation of an American Forward Call Option

As explained at the beginning of section 5.3.2 American Options differ from European Options in the way that they can be exercised on any trading day on or before expiration. Due to that, it is not possible to valuate American Options with the Black or the Black-Scholes Models because these models only consider options which are exercised at the time of expiration.
So the value of American Options can only be determined according to the Cox, Ross, Rubinstein Model. The CRR valuation process of American Options differs from the valuation process of European Options. The valuation process will be demonstrated in detail in the upcoming pages.
First of all an American Forward Call Option is specified in the ERPControl system as presented in figure 117.

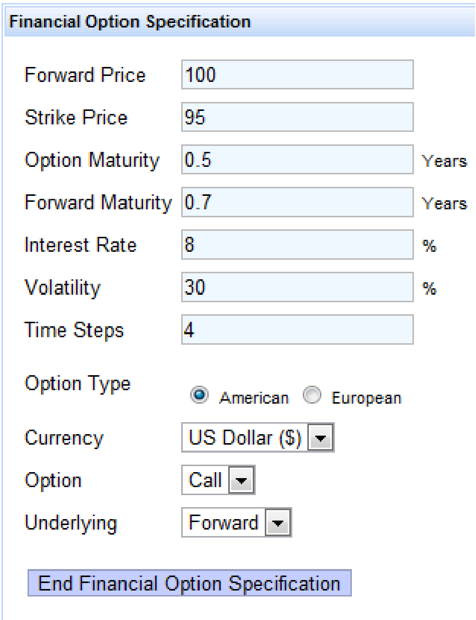


Figure 117: Specification of an American Forward Call Option in the ERPControl system

The specified financial option has the same attributes as the previously discussed European Options, so it is easy to compare these two types of options.

As mentioned before the valuation of American Options cannot be done with the Black or the Black-Scholes Models so the only selection possibility for a risk model is the Cox, Ross, Rubinstein Model as shown in Figure 118.

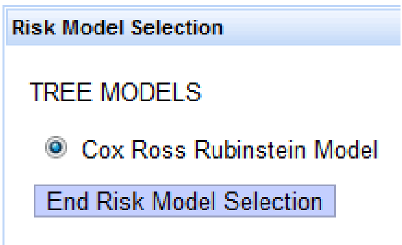


Figure 118: Risk Model selection for an American Option

The creation of the forward price tree for an American Forward Option is done in the same way as for a European Forward Option discussed in the previous section. So the price tree for this option looks exactly the same as illustrated for the European Forward Option in figure 115.

The main difference for the valuation of American Options is the backward induction for the node values of the tree.

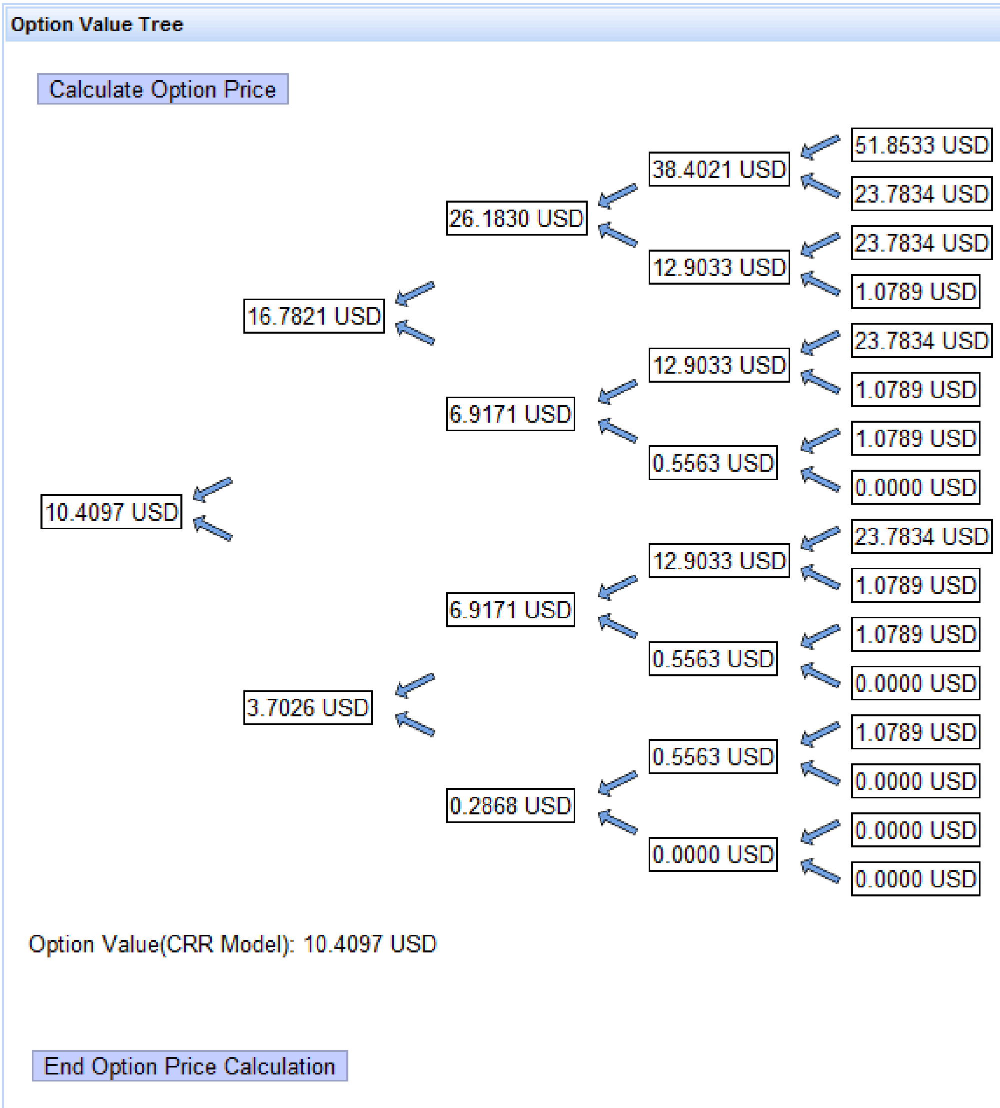


Figure 119: Option value tree for an American Forward Call Option

Figure 119 shows the valuation tree for the American Forward Call Option. To determine the option value of 10.4097 US Dollars first of all the values of the final nodes have to be calculated. This is done in the same way as specified in (71).
To make this procedure clear, (86) shows the determination of the final node value of the bottom final node of the tree.

(86)

$$P_{finalNode}^{Call} = max[(62.8598 - 95), 0] = 0$$

After calculation of the final node values, the values of the remaining nodes are determined as defined in (87).

(87)

$$P_{j,i}^{AmericanCall} = max\left[x\left(su^i d^{j-i}\right) - X,\ e^{-r*\Delta t} * \left(p * P_{j+1,i+1} + (1-p) * P_{j+1,i}\right)\right]$$

As mentioned before an American Call Option may be exercised at any point of time. This causes the difference $x(su^i d^{j-i}) - X$ in the method above compared to a European Option as defined in (73).

To demonstrate this procedure the value of the node displayed in figure 120 is determined in (88).

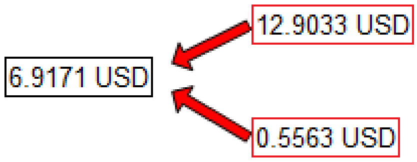


Figure 120: Value calculation for a specific node

(88)

$$P_{2,1}^{AmericanCall} = \max[98.0199 - 95,\ e^{-0.08*0.125} * (0.520798 * 12.9033 + 0.479202 * 0.5563)]$$

$$P_{2,1}^{AmericanCall} = \max[3.0199, 6.9171] = 6.9171$$

The probability as calculated in (74) is the same for this tree because the option was specified with the same attributes as the option in section 5.3.2.4.1, and $x\left(su^1 d^{2-1}\right)$ equals the price of 98.0199 at the node of the price tree where starting at the root node the price goes up one time and then down one time as illustrated in figure 115.

This procedure is performed for every node in the tree until the root node is reached which shows the value of the option as 10.4097 US Dollars.

5.3.2.4.4 Value Calculation of an American Stock Put Option

The main difference between the value determination of an American Call Option and an American Put Option is the process of the backward induction of the value tree. The difference is illustrated in (89) and discussed in the upcoming pages.

(89)

$$P_{j,i}^{AmericanPut} = max\left[X - x\left(su^i d^{j-i}\right), \; e^{-r*\Delta t} * \left(p * P_{j+1,i+1} + (1-p) * P_{j+1,i}\right)\right]$$

As shown in (89) in the first part of the method the price of a specific node is now subtracted from the strike price of the option.
The specified attributes of the American Stock Put Option are the same as in the examples above, and the CRR Model is the only available risk model.

The price tree creation procedure is done in the same way as explained in section 5.3.2.3. The tree for this option created by the ERPControl system is illustrated in figure 121.

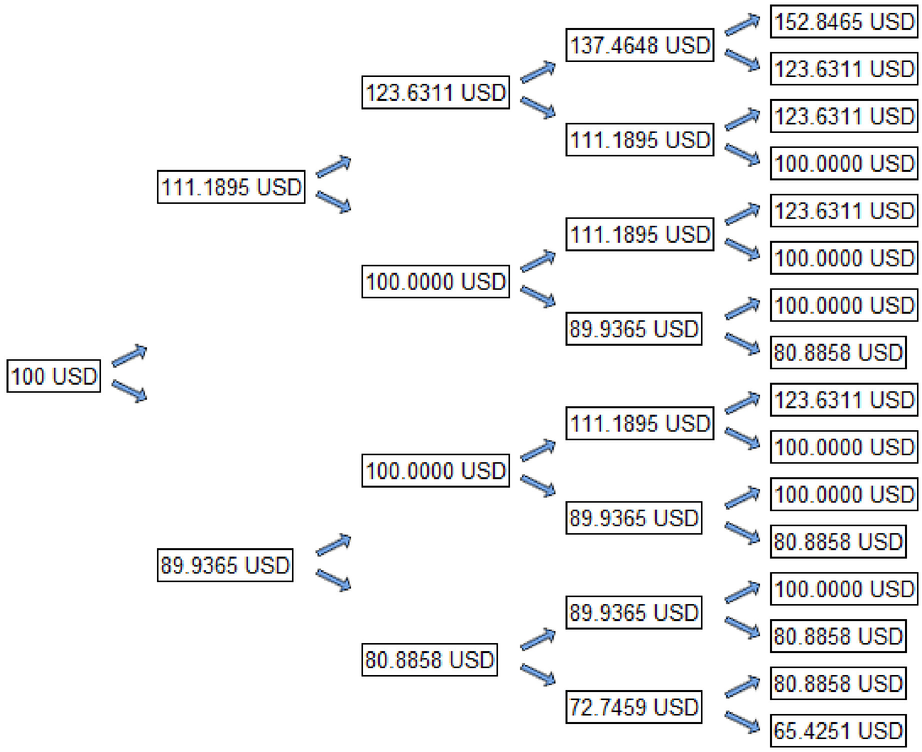


Figure 121: Price Tree of an American Stock Put Option

Processing the values of the final nodes is done in the same way as for European Put Options as defined in (81). The calculation of the top final node in the value tree is shown in (90).

(90)

$$P_{finalNode}^{Put} = max[(95 - 152.8465), 0] = 0$$

Again this procedure is done for all final nodes in the tree. The calculation of the values of the remaining nodes according to the method defined in (88) is demonstrated in (91) for the node displayed in figure 122.

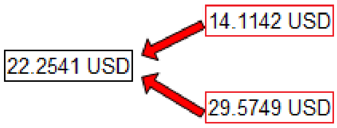


Figure 122: Value calculation for a specific node

(91)

$$P_{3,0}^{AmericanPut} = \max[95 - 72.7459,\ e^{-0.08*0.125} * (0.520798 * 14.1142 + 0.479202 * 29.5749)]$$

$$P_{3,0}^{AmericanPut} = \max[22.2541, 21.3088] = 22.2541$$

So the value of the node determined in (91) equals the subtraction of the node $x\left(su^0 d^{3-0}\right)$ in the price tree from the strike price of the financial option. The probability of a price to increase or decrease is the same as determined in (74).

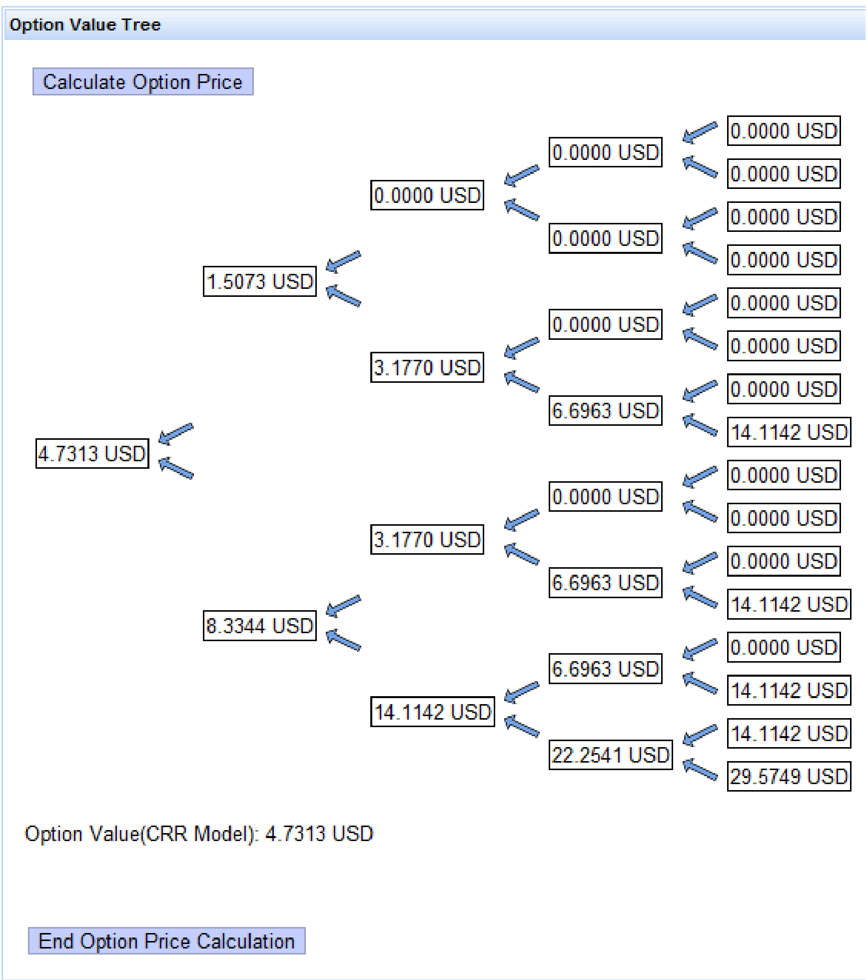


Figure 123: Option value tree for an American Stock Put Option

After the valuation procedure, as shown for a node in (91), for all nodes of the tree the resulting value for the specified American Stock Put Option equals 4.7313 US Dollars.

5.3.2.5 Comparison of the Option Types

The following table contains the values of the various types of options. All options are specified with the following data:

Stock/Forward Price: 100
Strike Price: 95
Option Maturity: 0.5 Years
Forward Maturity: 0.7 Years (only for forward underlying)
Interest Rate: 8 %
Volatility: 30 %
Time Steps (CRR): 4

	European (Euro)				American (US Dollar)			
	Put		Call		Put		Call	
	Stock	Forward	Stock	Forward	Stock	Forward	Stock	Forward
Cox, Ross, Rubinstein	4.6071	5.4356	13.3321	10.2395	4.7313	5.4615	13.3321	10.4097
Black-Scholes	4.4494	-	13.1744	-	-	-	-	-
Black	4.4494	5.7402	13.1744	10.5441	-	-	-	-

Table 16: Value comparison of all financial options

As you can see in table 16, the values of the various option types differ from each other. As mentioned before, for stock options the Black/Black-Scholes Model provides exact solutions and the CRR Model only provides an approximation of the option value. In contrast to that the analytical solution for forward options according to the Black Model is only an approximation of the numerical solution based on the CRR Model.
The values of a European and American Option can also be equal as you can see, for example, on the values of the stock call options in the table above. In this case the American Stock Call Option was not exercised before expiration. As mentioned before, American Options may be exercised at any point of time before the expiration. European Options may only be exercised at the expiration day.

As shown in table 16, the value of a call option is higher than the value of a put option. To clarify this let’s take a closer look at the difference between call and put options.

Figure 124 shows a call option. Here the call buyer acquires the right from the call seller to buy the underlying stock for the strike price. If a cash settlement is supposed, as for a forward, a buckled payment function as in figure 124 is the result for the option buyer.
If the stock price lies above the strike price at the end of the term, the call buyer may exercise the call option and receive the difference between the stock price and the strike price. The area in figure 124 where the stock price is above the strike price is called *“In the Money”*. The value of a

call option is the time value plus the intrinsic value of the underlying stock as you can see in figure 124.

The area below the strike price is called *"Out of the Money"*. If the stock price is below the strike price at the end of the term, the buyer may let the call option expire which results in a zero payment.
So an increasing stock price will result in a profit for the option buyer and a loss for the option seller. For taking the risk of an increasing stock price and so a financial loss, the call seller will demand a premium price for selling the call option.

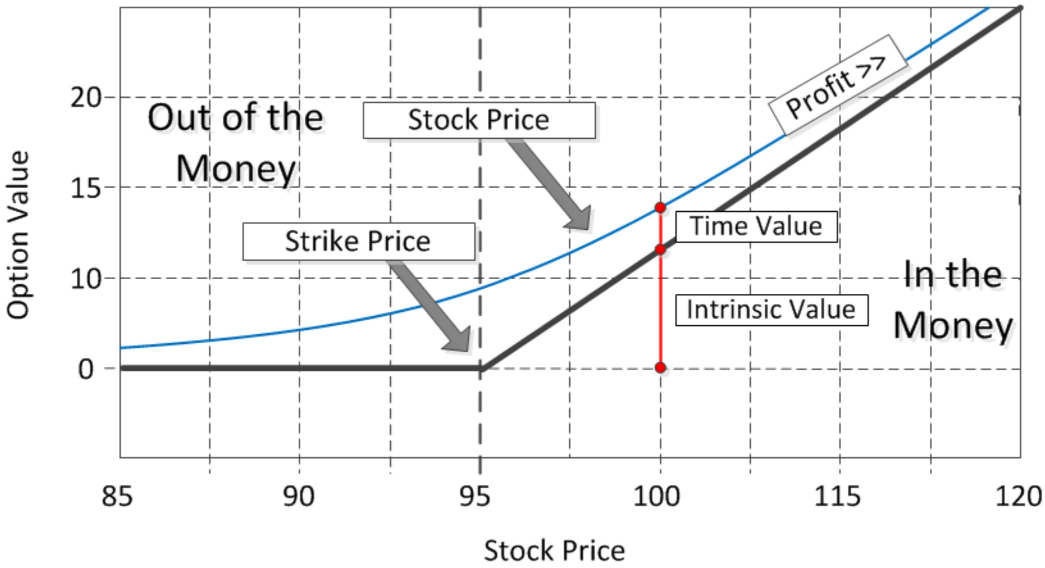


Figure 124: Call option

Figure 125 shows a put option. Here the option seller gives the option buyer the right, but not the obligation, to sell the underlying object for the strike price. So the option buyer receives a right to sell and not a right to buy.

In contrast to a call option, exercising a put option results in a profit for the option buyer if the stock price of the underlying is lower than the strike price. In this case the put buyer receives a higher price from the option writer than selling the underlying at the spot market.

If the price of the underlying is above the strike price, the option buyer may let the option expire because selling the underlying at the spot market gains a higher profit. So here the area "In the Money" marks the region where the spot price is below the strike price and "Out of the Money" marks the region where the spot price is above the strike price. The value of a put option is also the sum of the time value plus the intrinsic value. As you can see in Figure 125 the intrinsic value is 0 because it is "Out of the Money", so the value of a put option is only the time value of the underlying stock. This is because the values of the put options in table 16 are much lower than the values of the call options.

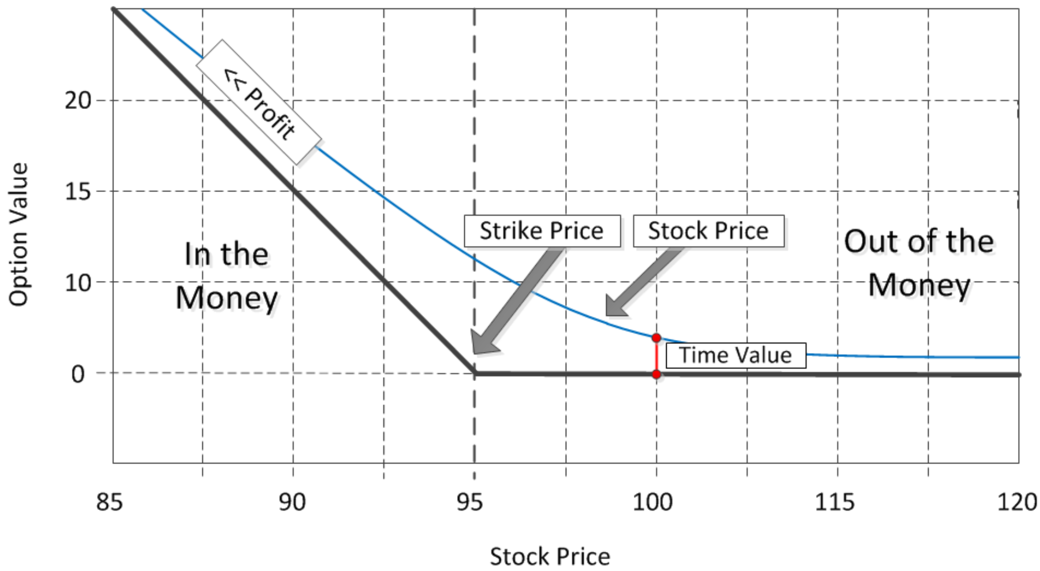


Figure 125: Put option

For the risk of selling the option to a higher price than the spot market price, the option writer will demand a premium price for selling the option to the option buyer.

6. Conclusion

The combination of Economic Science and Computer Science has a very high potential for new and innovative products and approaches in nearly every area of today's organizational structures, not only in the industrial sector but in nearly every part of our daily life.

The ERPControl Software System unifies innovative approaches as well as state of the art planning and controlling procedures in the field of business administration with high end software technologies.

Implementing and developing software modules for the planning and controlling of financial instruments demanded not only the design of new algorithms and appropriate data structures but also a detailed knowledge of distributed enterprise system technologies as well as state of the art software engineering techniques. This helped me gain new findings and insights in the fields of software architecture, distributed and internet system technologies, and database technologies as in the design and implementation of algorithmic data processing techniques.

On the other hand engagement with the Resources, Agents and Events Model, as well as state of the art procedures for valuation and processing of financial instruments, demanded a significant and thorough understanding of various models and techniques in the fields of business administration and process engineering. Dealing with these models and processes helped me acquire a deeper understanding in the area of financial instruments and financial markets, as well as the operational sequences necessary in a company to plan and control various financial instruments.

The work on this project gave me a lot of insights in new scientific fields, it helped me to deepen my existing knowledge in the outlined areas and it also provided personal gain for me.
At this point I also want to say thank you to my Professor Dr. Walter Schwaiger for the support as well as the interesting discussions we had and all the new things I learned while working with him and his team. Thank you to my parents and all the other people in my family who supported me during the time of my studies. They tried as much as possible to eliminate all my worries so that I was able to focus completely on the work that interests me. Special thanks to my dear friend Gerry Schlintz from California for proofreading my thesis.
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