CHAPTER FIVE

Empirical Modelling, Object-Orientation and Use Cases

Over the last few years, use cases have become popular as one of the fundamental techniques of object-oriented analysis. This is partly because they capture the system requirements in a simple (informal) and readable format and such a technique is easy to learn. Also use cases describe the requirements from users' perspectives and define who is interacting with the system. There are some similarities between the use case approach and the EM approach, for example, both of them are human-centred and the issue of scenarios is considered within both approaches. We have illustrated the fundamental principles and concepts of EM in chapter 4. In this chapter the details of the use case approach to system development (OOSE) and business process reengineering (Object Advantage)[1] will be discussed and we will show how the EM approach differs from the use case approach.

5.1 Introduction

Object-oriented programming and design have been around since mid-1960s but their realisation in both industry and business only started from the mid-1980s. The notation UML (Unified Modelling Language) – a third-generation object-oriented modelling language – was developed to combine the main object-oriented methodologies and is today accepted as a standard methodology in the OO society[2]. It

1. The concept of use cases is originated from Jacobson's *Objectory*, the process of his use case approach. The use of his approach is detailed in his three books: *Object-Oriented Software Engineering* (Jacobson et al., 1992); *The Object Advantage* (Jacobson et al., 1995); and *Software Reuse* (Jacobson et al., 1997).

combines the efforts from the main OO methodologists (Grady Booch, Jim Rumbaugh, Ivar Jacobson, etc) to construct a common means of using OO concepts for describing and modelling systems. However, UML is the language for software design and is used by developers. Its early version was not well suited for communication between designers and users. For requirements engineering, it is essential that both the users and developers, or the analysts and the domain experts, can communicate with each other and users can be involved throughout the process of system development. This is the reason that the concept of use cases became popular as it addresses such issues and it also bridges the gap between OOA and OOD[3]. Thus most major OO methods added the concept of use cases and recently Jacobson's use case approach has been included in UML to capture the higher level of user functional requirements of the system.

Ivar Jacobson is regarded as the inventor of use cases. In his use case approaches (e.g. Jacobson et al., 1992 and 1995), the Use Case Model created in the analysis process serves as a basis for the models of the system developed subsequently. In this chapter the general concepts of OOSE and Object Advantage are firstly introduced. The potential problems of applying use cases in system development are also explored. Then the comparison between EM and OOSE will be discussed.

5.2 Object-Oriented Software Engineering (OOSE)

The original technique of Jacobson's use case approach is *Objectory*, a process of system development[4]. It was first used in 1987[5] and its fundamental ideas are described in OOSE (Jacobson et al.,

2. The UML was originally developed in response to the Object Management Group's (OMG) call for a proposal for a standardised object modelling language. The OMG web site can be found at http://www.omg.org (20 December 2001).
3. Another reason, according to Dano et al. (1996) and Firesmith (1998), may be that use cases corrected the overemphasis of previous structured methods and early OO methods on the static architecture but ignored the dynamic behaviour issues during the requirements analysis.
4. Objectory was also the name of a company found by Jacobson in Sweden, which was merged with Rational Software Corporation in 1995.
5. At the 1986 Object-Oriented Programming, Systems, Languages and Applications (OOPSLA '86), Jacobson presented his ideas of use cases on the design of large, real-time systems. And in the 1987 OOPSLA conference, Jacobson described his Objectory as a technique and use cases as a tool used within that technique (Firesmith, 1998).

1992). As claimed by Jacobson et al., use cases are an effective way of capturing both system requirements and business processes. OOSE consists of a number of processes which result in different models, each of which captures a specific aspect of the system. We shall summarise these processes and define the models created during different processes.

5.2.1 General Concepts and Modelling Process

The lifecycle of OOSE consists of three main processes: Analysis, Construction and Testing. The aim in the Analysis process is to create a conceptual model of the proposed system in order to understand the system and enable the customer to communicate the essential aspects of the system. The Construction process includes both design and implementation which results in a complete system. The activities in the Testing process include integrating and verifying the system. The activities in each process produce models: Analysis results in the Requirements Model and Analysis Model, Construction in the Design Model and Implementation Model, and Testing in a Testing Model. The processes and models in OOSE are summarised in Figure 5.1.

Requirements Analysis

The aim of the requirements analysis process is to analyse, specify and define the system to be built. As it is essential for the clients to ensure the system to be built is what they want, the models built in this process intended to make it easier for them to understand the system. The first model to be developed is the *Requirements Model*, which consists of a Use Case Model with interface descriptions, and a Domain Object Model. The *Use Case Model* is based on actors and use cases. It specifies the complete functional behaviour of the system by defining what exists outside the system (actors) and what should be performed by the system (use cases). A *use case* consists of structured textual description of a specific way of using the system (a case of usage). Each use case contains a complete sequence of related transactions performed by some actors and the system. The collection of use cases are the complete functional requirements of the proposed system. The *Domain Object Model* – which consists of objects representing entities from the problem domain – is used to communicate with the potential users and to ensure a stable ground for the use case description[6]. It is essential in OOSE that the use cases are the core through all modelling processes, helping in the construction of other models and maintaining the focus on the problem.

Robustness Analysis

The Requirements Model describes the functional requirements specification based on the needs of the users. Once the Requirements Model is developed and has been approved by the users, we then start with the *Analysis Model*. This model defines the 'logical structure' of the system independent from the implementation, i.e. assuming an ideal world for the system. It is developed during the robustness analysis to be oriented to the application and not the implementation technology. Thus the Analysis Model is

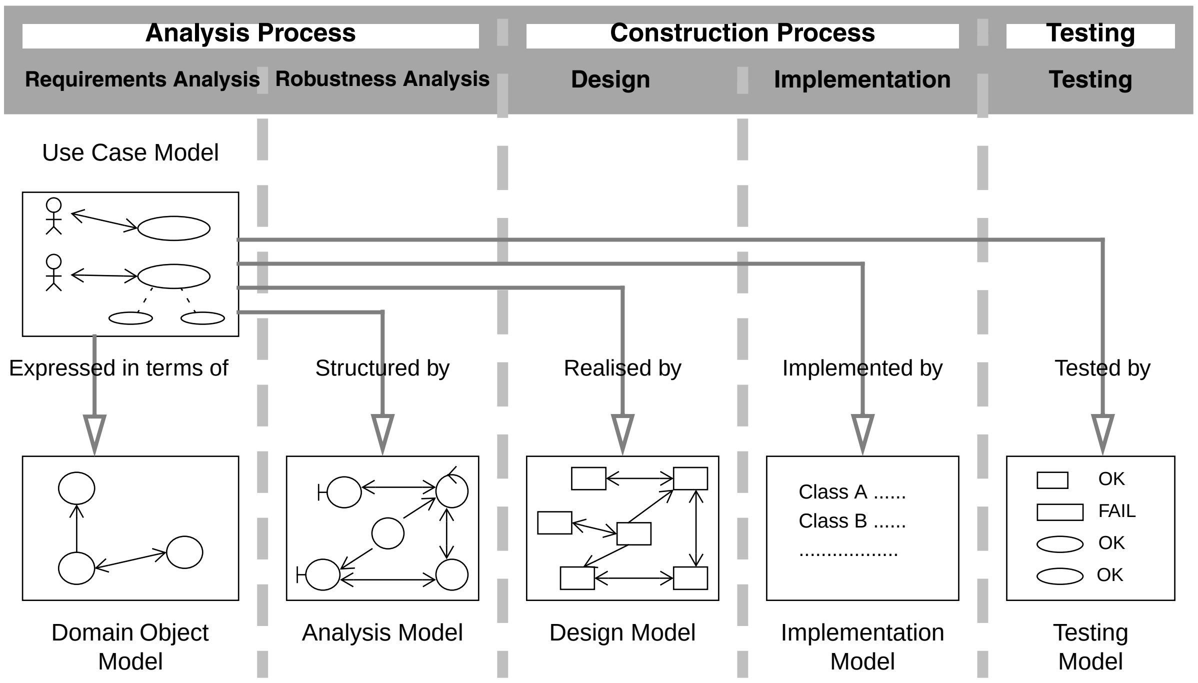


Figure 5.1 The Process and Models in the Use Case Driven Development

6. Jacobson et al. (1992) differentiate between OOSE and other OO methods by observing that many object-oriented methods focus entirely on such problem domain models. In these methods this model forms a base for the actual implementation, i.e. the objects are directly mapped onto classes during implementation. But in OOSE, the Analysis Model is claimed to be more robust and maintainable for the future changes, rather than serving the problem domain model as the base for design and implementation.

the architectural model (a conceptual configuration of the system) used for analysis of robustness[7]. Three kinds of objects are used to separate the control of use cases from their interface behaviour and from entities in the area of the application:

- The *entity objects* are used to model information which the system will handle for a period of time.
- The *interface objects* model the behaviour and information which is directly dependent on the environment of the system. The task of interface objects is to translate the actor's actions with the system into events in the system, and vice versa.
- In some complex cases, there exists behaviour which cannot be placed in either interface objects or entity objects. Such complex behaviour is placed in *control objects*[8].

Design

The construction process is composed of design and implementation. Since the Analysis Model contains a functional specification of the system without considering the implementation environment, the *Design Model* is constructed as a refinement and formalisation of the Analysis Model. The main objective of the Design Model is to adapt to the actual implementation environment. There will be some additions in this model when considering the real implementation, for example, its database system, the distributed environment, a specific programming language or hardware configuration. The Design Model is composed of *packages* (the modules containing the code, sometimes called *subsystems*) and *blocks* (the specifications of the code). Each object in the Analysis Model is initially transformed into a corresponding block, which will be later implemented by classes written in the programming language. These objects are grouped in packages which represent the abstraction of the actual implementation of the system. Both packages and blocks are directly traceable to the modules in the programming lan-

7. The reason for developing the Analysis Model, according to Jacobson et al. (1992), is to ensure that even though many future changes are coming from the changes in the implementation, these changes will not affect this logical structure, thus making this model more robust and maintainable throughout the development lifecycle.
8. Such behaviour is typically transaction-related behaviour or control sequences specific to one or a few use cases, which normally consists of operating on several entity objects, doing some computations, and returning the result to an interface object.

guage, and the Interaction Diagrams – which describe how the use case is realised through the interaction of blocks (through sending/receiving stimuli) – can be traced back to the use cases directly.

Implementation and Testing

Finally, in the implementation process, the code is written from the blocks in the Design Model. The Design Model forms the basis for implementation as it specifies the interface of each package and block and describes their behaviour behind the interface[9]. The Testing Model is developed during the Testing Process. Normally the testing activities include two main works: *verification*: checks whether the results meets with the requirements specification ("are we building the system correctly?"); and *validation*: checks whether the result is what the customers want ("are we building the correct system?"). There are three levels of testing during this process: in the *unit testing* only one unit is tested; the *integration testing* is to verify that these units are working together properly; and finally in the *system testing* the whole system or application is tested.

5.2.2 The Use Case Concepts

The main concepts in Use Case Models are actors and use cases. A use case may have different alternative courses depending on different circumstances of using the system. A single sequence of events which represents the realisation of the use case is called a *scenario*. Hence a use case is a set (or class) of related scenarios. The content of a use case typically can be divided into a basic course and some alternative courses. The basic course, as Jacobson et al. (1992) suggest, is the course which gives the best understanding of the system, but is not necessarily the one which is executed most often. Use cases are related by two associations, *uses* (or *includes* in UML 1.3) and *extends*. The 'extends' association specifies how one use case description inserts (extends) itself into another use case description which is independent and unknowing of the former one. So 'extends' can be viewed as a kind of 'inheritance' between use cases. The 'uses' association can be viewed as a kind of 'aggregation'

9. Normally a block corresponds to one class, which makes it easy to map the block interface to a specific class interface in the code.

because it captures how more use case descriptions incorporate the common description of another use case[10].

Jacobson et al. (1992; 1995) stress that use cases should be used throughout the system development lifecycle and point out that use cases can be an effective tool for business process modelling and BPR. They define each use case as a specific way of using the system and each execution of the use case is viewed as an instance of that use case. In general, the motivation for using the use case technique may include gaining an understanding of the problem and the proposed solution, and identifying the candidate objects for the analysis and design. The use case technique is claimed to help to manage complexity because it decomposes the problem into some major functions (i.e. use cases) and focuses on one specific aspect of usage at one time. It is different to other techniques for capturing requirements as use cases treat the proposed system as a black box and it enables designers and users to see the implementation decision easily during the requirements analysis. McBreen (1998) describes the importance of not considering the internal structure of the system during the requirements analysis because specifying the internals will put extra constraints on the designers. Without these constraints, the designer can have more freedom to develop a system which correctly implements the external behaviour, and some ‘breakthrough’ solutions may arise from this.

5.2.3 The Object Advantage

The Object Advantage is a work by Jacobson et al. (1995) for business modelling which uses the same type of techniques as in OOSE. The *Use Case Model* is used as an external model which describes a company and its environment. It describes the processes in that company which satisfy the customers and also includes other relevant interests outside the company. As an external model, the Use Case Model only shows how the company is perceived by the people who will use it but not the structure of

10.As people are always confused about these two associations (cf. Simons, 1999), Firesmith (1998) compares these with an example: “if A *extends* B, then extended B *contains* A; whereas if A *uses* B, then A *calls* B”.

that company. This is why Jacobson et al. (1995) say the Use Case Model is a ‘what model’ whereas the Object Model[11] is a ‘how model’.

The company is made up of relevant business processes. These processes are modelled as *use cases*. The *actors* in the Use Case Model represent the environment, which includes the customers and other relevant entities such as suppliers who take part in or interact with the processes (the use cases). That is, actors – which can be human or mechanical – are used to represent everything in the environment which interacts with the company. Through the Use Case Model, we can find out how the external environment interacts with the company and how actors communicate with use cases in the company.

The *Object Model* serves as an internal model which describes each business process as defined in each use case. It shows how the processes are built up of different tasks and things, as well as the resources used during the process or the products after the processes. There are also two types of Object Model: Ideal Object Model and Real Object Model. The former is the model of the company which does not consider the implementing factors in practice, for example the human factors or the environment; whereas the latter will take these factors into account. Three types of objects are used in the Object Models: the entity objects (represents products and things handled in the business), the interface objects and the control objects (both represent the tasks in the business). The *interface objects* represent the tasks which are performed by one resource (including the human being) and that involve communicating with the external environment[12]. The *control objects* represent the tasks which are performed without directly contacting with the environment.

Reverse Business Engineering and Forward Business Engineering

The work of reverse engineering involves the design of a model of an existing company. This model aims to serve as a basis for the reengineering work in the forward engineering of the company. Two models are developed during the reverse engineering: the Use Case Model and the Object Model. The

11.The Object Model in the Object Advantage corresponds to the Analysis Model and Design Model in OOSE.
12.Thus the part of the business which has direct contact with the outside world is visible in interface objects; whereas entity and control objects are more independent of the environment.

Use Case Model describes the processes of the existing business in terms of actors and use cases. It is used as the basis for prioritising the processes to be reengineered. The Object Model gives the internal view of how the existing business operates. Most companies are structured in a functional or hierarchical way, which can be modelled by a subsystem for each functional unit or department. The reasons for reverse engineering, as described by Jacobson et al. (1995), may include: (1) to enable the designers to obtain a common understanding of what is not working well in the business and thus identify the areas to be reengineered; (2) to understand how to proceed in order to change the existing business so the objectives and requirements can be satisfied; (3) to describe to the employees why the existing processes are not adequate and why a new way of working is needed; (4) the models can be used later to evaluate the benefits of the proposed changes. The analysis of the models of existing business can help to find the way to achieve a more effective reengineering of the company.

After identifying the existing processes which need to be reengineered during reverse engineering, the next step is to find out how the new redesigned processes will affect the existing business and determine how to carry out the improvement and reengineering. Three models are developed during this forward business engineering: the Use Case Model, the Ideal Object Model and the Real Object Model. The Use Case Model represents the external view of the new company. The Ideal Object Model, based on the use cases, shows the inside view of the new company in terms of objects and the way they interact with each other. This model contains only the objects needed to perform the use cases. The Real Object Model adapts the Ideal Object Model to the real environment with modifications. Some issues or restrictions are considered in the model, for example, the human factors or the structure of the company (distributed or centralised). According to Jacobson et al., the work of developing the supporting information systems for the new business can be done in parallel with the modelling activities and, as they depend on each other, both (the model of the business and the model of the systems) should be completed at the same time.

Object Advantage and OOSE

Both the OOSE and the Object Advantage are introduced by Jacobson et al. (1992 and 1995) for modelling computer systems and business systems. As IT is the main enabler for BPR, the business process models and computer systems models will be highly dependent on each other. It is essential to emphasise the relationship between BPR and system development in order to develop the support system to meet the need of BPR. Jacobson et al. claim that in their methodology for BPR it is easier to express such relationships because they are using the same type of techniques.

In OOSE, the computer system to be built is modelled as a system which contains use cases (its functionalities) and has some actors outside which interact with it. But in business modelling, software development is viewed as a business process in a company. Thus it is represented as a use case in the business model. The actors (of the use case model in OOSE) of such a system are thus modelled as objects (interface object or control object) in the business model which means the users or resources of the system. Each model in OOSE, such as the Use Case Model or Analysis Model, is represented by an object (entity object) in the business model. Each stage in the development lifecycle, such as Requirements Analysis, Design, or Implementation, is modelled as a subsystem. Each of the subsystems represents the sub-flow of the use case Software Development. More details of how to define objects in the business model which correspond to the actors, use cases and objects in OOSE models can be found in chapter 9 in (Jacobson et al., 1995).

5.2.4 Some Potential Problems of Applying Use Case Approach

Recently use cases have become a fundamental part in many OO methods. However like many system development methodologies, there are some problems arising when using use case techniques in developing a system. This subsection provides an overview of these problems.

Functionality Orientation vs Object-Orientation

The Use Case Model in the requirements analysis is developed from a system perspective because it defines and captures the major functionality of the proposed system. Thus use cases are system-oriented (or functionality oriented) rather than object-oriented. Jacobson (1994) also admits that:

> It should be clear that use case modelling is a technique that is quite independent of object modelling. Use case modelling can be applied to any methodology structured or object-oriented. It is a discipline of its own, orthogonal to object modelling.

The functionality orientation of use cases can enable users and designers to define or understand the system (or the business when applied in BPR) easier by using functional descriptions than using data-centred descriptions such as object models. However this can cause some problems when applying two different paradigms in system development and business modelling. For system development, this kind of functional decomposition into use cases may compromise the benefits of object-orientation and cause the problems which OO was intended to avoid. Also each use case represents one functional partition which may involve different features of objects or classes; and individual objects or classes may be involved in multiple use cases. Firesmith (1998) describes how the decomposition based on use cases scatters the features of objects and classes among the use cases. In this situation, the designers may have to check all the partitions to make sure the objects are designed accurately. This can also result in problems in system integration, because different use cases (partitions) may be implemented by different designers or teams. The multiple or redundant objects and classes that will be designed decrease the productivity and reuse of software. Even the same objects in different parts of the system will have different implementations. This will result in significant effort and time in redesign.

Another potential problem is the mapping from the Use Case Model to the Object Model. In Jacobson's OOSE the use cases are directly used to create the Analysis Model which describes the structure of the system in terms of objects. As we can see the Use Case Model and the Object Model belong to different paradigms and thus use different concepts, techniques and notations. This process may be problematic because we present a set of functional requirements but aim to produce an OO solution.

Further the structure of the Use Case Model does not clearly map to the structure of the Object Model and the requirements trace from the use case to the objects or classes is not one-to-one. Such mapping in OOSE is informal and arbitrary, with little guidance as to the identification of objects and their interactions.

No Clear Definition

It is argued that the use cases are poorly defined and the lack of precise definition has led to many researchers and institutes calling their approaches use-case based[13] (cf. Graham, 1996a; Dano et al., 1996; Cockburn and Fowler, 1998; Regnell, 1999). Even the definitions of use cases by Jacobson are a bit vague: a use case is “a behaviourally related sequence of transactions *in a dialogue with the system*” (Jacobson et al., 1992) and “a sequence of transactions *in a system* whose task is to yield a result of measurable value” (Jacobson et al., 1995). Further a use case can be a sentence or an essay or as Jacobson says ‘as long as you like’. It is not clear what kind of events we should include in use cases. For example, should we include only external stimuli-responses or internal system activities as well, because they are all about the functionalities of the proposed system. The translation of use cases into design and implementation is based on the informal understanding of designers on what must be done. As there is no accepted definition of use cases, most companies as well as academic institutes have re-invented their own version of use cases, for example, Regnell (1999), Dano et al. (1996) and Firesmith (1998).

The lack of clear definition of use cases may result in the problem of the explosion of use cases. For example when modelling a business, the use case does not only address a single system but all of the systems used by the business. In this kind of situation there may be hundreds or thousands of use cases because they are many exceptions in the business processes. Graham (1996b) says that these exceptions may not be errors and they may be important and business critical. For system develop-

13.Graham (1996b) criticises that “the ugly phase ‘use case’ itself, possibly being a transliteration from Swedish, can also cause problems with English prose”. Bruce Anderson (in Cockburn and Fowler, 1998) also points out that the name is a hindrance for business people. Use cases have no clear link to a business process model and are offered as such a model in their own right, which they feel does not make good sense.

ment, the use case is restricted to a single system. But the problem can still happen when the use of concurrency and distributed architectures means the order of the interactions between the system and its environment may be infinite (Firesmith, 1998). In some big projects the use cases are described by different designers or teams. There may exist inconsistencies between these use cases. Regnell (1999) also points out that use cases might be contradictory when they express goals of different actors.

Restricted to User Interface

Jacobson et al. (1992) state that Use Case Models are restricted to the user interface. That is, the intention of use cases is to focus on *what* the system does for its users, rather than *how* it does it. But in some domains this is not adequate. For example when applying use case techniques in business process modelling, users often have a mental model of the internal states of the system being described (Graham, 1996b). Further when developing a system which aims to replace or automate the paper-flow processes, the development team consisting of users and developers will have some expectations about *how* the system will operate initially. Graham (1996a) emphasises that such expectations are often the basis of insights into business processes and opportunities for reengineering them. We will illustrate this situation in the case study of the warehouse management system in chapter 7.

For system development, in some applications there may not be a clear actor who will get the benefit from interacting with the system or who directly or actively participates in the use cases. Systems of this kind, such as embedded systems, do not have actors because they can perform functions without user inputs. Thus use case modelling seems inappropriate for such cases. Even for other applications in which actors are clearly defined in use case modelling, there could be many different actors and use cases can only capture the needs of some actors and sometimes ignore others.

5.3 The Comparison between EM and OOSE

The aim of this section is to compare the approaches to software development of EM and of Jacobson's OOSE. The comparison is based on two concerns: the first is on their different development processes, involving the construction of the models; and the second is on the similarities and differences in the structure of their models.

5.3.1 Comparison between the Development Processes

In subsection 2.1.2 we explained that generally there are some essential stages in the software development process: requirements, design, implementation, testing and validation (cf. Figure 2.2). The process of the OOSE approach also consists of these prescribed stages. Figure 5.2 shows the lifecycle of OOSE and its models developed and used during each process. It is obvious that the focus of the requirements process is to define the functionality of the system, i.e. the external perspective of the system as observed by the user. In OOSE the Use Case Model describes the specific ways of using the system and the Domain Object Model represents a logical view of the system in which the objects have a direct counterpart in the application environment. Following the requirements process, the Analysis Model and Design Model define the structure of the system, i.e. the internal view of the system architecture. The former is the ideal model which is independent of the implementation whereas the latter is the

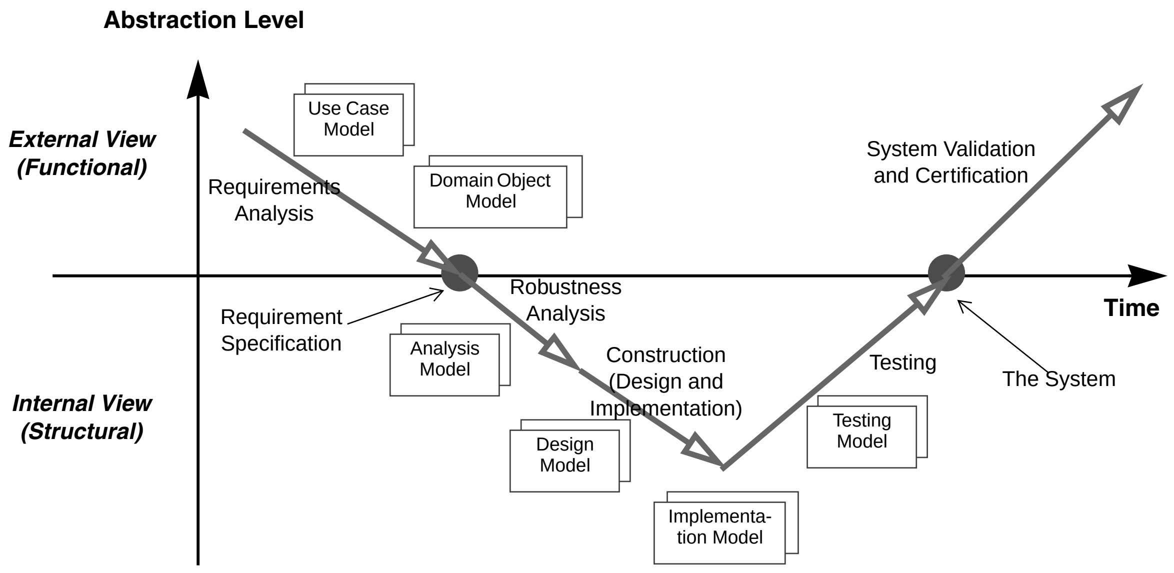


Figure 5.2 The Lifecycle of the Use Case Driven Development

real model which considers the implementation environment. The system is then implemented and tested and will be released after its external functionality is validated.

In comparison, EM has no such distinct sequential stages for development, that is, it is a process of model construction and system identification, but alongside which activities related to requirements analysis, design, implementation and even testing are also done. These activities are to be performed iteratively and do not follow the strict sequence of conventional methods, i.e. analysis then design then implementation. The modellers can perform any activity at any time for the best result of the development. For instance, when a design for the system emerge, the modeller can refine the model to address implementation issues or revisit the analysis activity behind the design. That is to say, the design decisions do not need to be laid down at an early stage and the modeller can change the variables and dependencies at any time to ensure the system meets the requirements of its users. In OOSE or other methods such design decisions have to be made at the early stages. For example, the functionalities of the proposed system should be decided and described in the Use Case Model; or the interfaces of objects or classes have to be defined while developing the Object Model (the Analysis Model or Design Model). The following processes may not be started without such activities having been done. We can also find that to make such decisions, or to describe the requirements of the proposed system, needs a kind of prediction and foresight of the future situation and this is sometimes difficult as we can not have complete knowledge of the system at the early stages of the system development. Furthermore, many decisions may need to be taken along the line as the design progresses, even though these decisions could ideally be taken at a later stage. Thus it is important that the users are continually involved throughout the design process, and this issue will be further detailed in chapter 6.

Figure 5.3 illustrates the procedure of EM modelling for system development. The development procedure may start from the existing or new model which represents the elements of real-world states related to the problems to be addressed or the system to be developed. This starting point is in the form of a *seed*-ISM. The aspects of the real-world states may be represented by different seed-ISMs. Alongside the process of EM modelling, the activities such as requirements analysis, design, implementation and testing are also achieved but in different forms from the conventional methodologies. By having observation and experience with the ISM and its referent, the modeller identifies the relevant agents, observations and protocols which inform the modeller's conceptual model (or construal). After this, the modeller can have the initial idea about the new inputs or the requirements for the new system[14], for example, adding new agents and definitions or modifying the existing definitions. These activities are mainly carried out in relation to the visualisation of the ISM and the modeller's interaction with the artefact by which the external behaviour of the system is observed. The processes and the modeller's activities mentioned above are mainly conducted from an external view of the model, that is, with the reference to the EDEN visualisation. At the same time, the modeller can intervene in the current behaviour of the ISM by modifying the values of variables or the dependencies and immediately experience the result. After this modification to the ISM, the correspondence between the states of the ISM and the

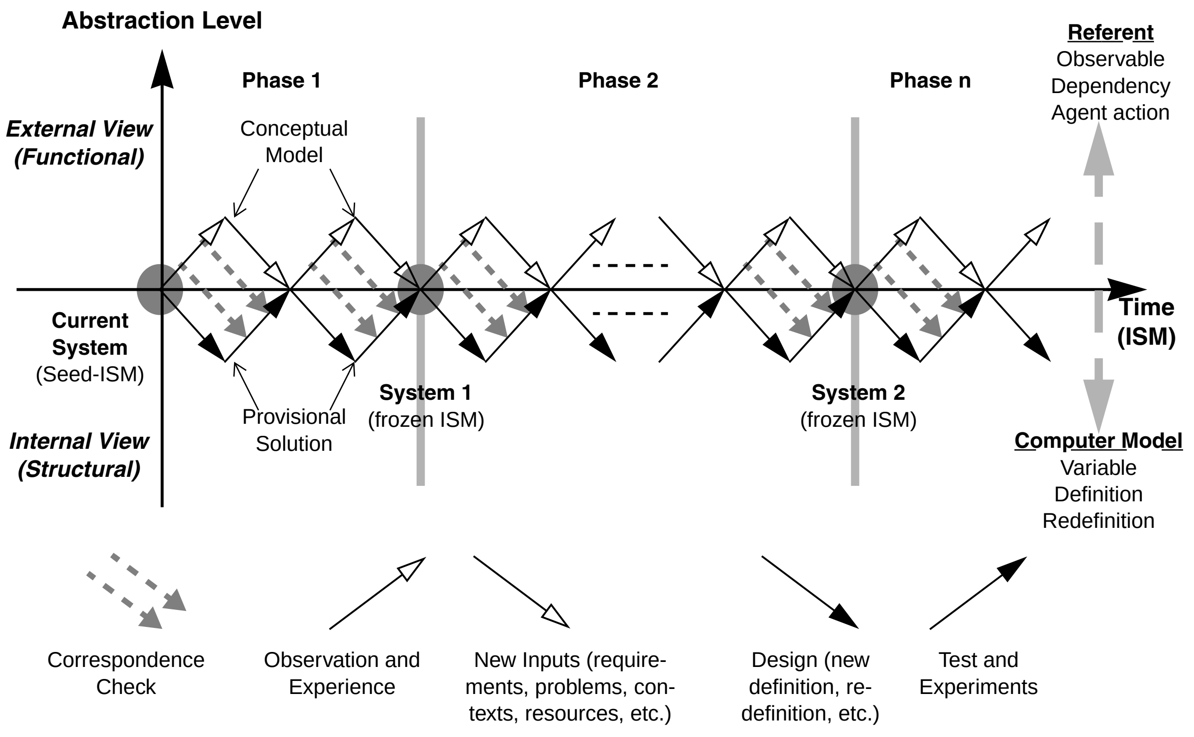


Figure 5.3 The Unified Development Procedure in Empirical Modelling

14.The 'system' in this paragraph refers to the software system, which is regarded in this thesis as a computer model. The details of how ISMs support the system development can be found in Beynon et al. (1998).

states of the referent is checked. This resembles the testing process in the conventional development lifecycle. These processes focus on the internal view of the model (i.e. the structure of the definitive script itself), in which the modeller modifies the state of the ISM through the EDEN input window. Also the commentary window shows information about the current status of the ISM and the outputs of the modeller's interaction.

All processes of EM modelling are iterative and through the continuous and open-ended interactions with the ISM, the modeller can ensure and maintain the correspondence between dependencies in the model and dependencies in the referent. When the result, i.e. the change of states in the ISM, contradicts the modeller's expectations, then the modeller can determine whether the model is constructed in an inappropriate way or any unsuspected behaviour is identified. Conversely, when the result is consistent with the requirements of the users or the modeller's expectations, the ISM can be 'frozen' as the final 'system' after the modelling phase. After the 'system' is released, when the requirements change due to the dissatisfaction of the users or changes in the environment, the 'system' developed during the previous phase will become the seed-ISM of the new development phase and a new modelling activity can be commenced.

Figure 5.4 gives a general concept of the development processes in both OOSE and EM. The aim and the final product of these two processes is a useful system. The lifecycle of OOSE shown in Figure 5.2 is summarised in the left-hand side of Figure 5.4. The arrow in the right-hand side represents the unified development procedure of EM modelling in Figure 5.3. By comparing these three figures (Figures 5.2, 5.3, 5.4), we can conclude that the models in OOSE can be viewed as phased-based models as the development of such models is through a kind of rigid sequence of prescribed phases. Each phase or stage reflects a practice done by prescribed and proven methods, techniques or tools. This enables the designers to develop the systems in a systematic way. But it may only be of limited use in today's rapidly changing domains of application. This is the main issue of circumscription which is emphasised in section 2.3. OOSE can be said to fit the culture of 'closed world paradigm' because it offers a preconceived framework for system development and once the models are created, they are no longer in direct connection with their referent. For EM there are no such prescribed phases and specific methods or techniques during the development process. It fits the culture of ‘open development paradigm’ as the focus of EM is on the open-ended interaction between actors and the models and the referent, not following a fixed pattern of activities. We will furthermore discuss the comparison between EM and OOSE, focusing on the two main activities of requirements analysis: the understanding of the domain and functional requirements description.

Figure 5.5 depicts the Requirements Process of OOSE and the relationships among the models created during this process. This can be compared with Figure 5.6 (reproduced from Figure 4.2 in chapter 4) to show the differences between OOSE and EM in requirements-oriented activity. The main difference between these two approaches is in the correspondences between the real world system and the models. In OOSE, such correspondence is established through the developer’s pre-understanding of the problem domain as well as the negotiations with the customers and the future users. This can be

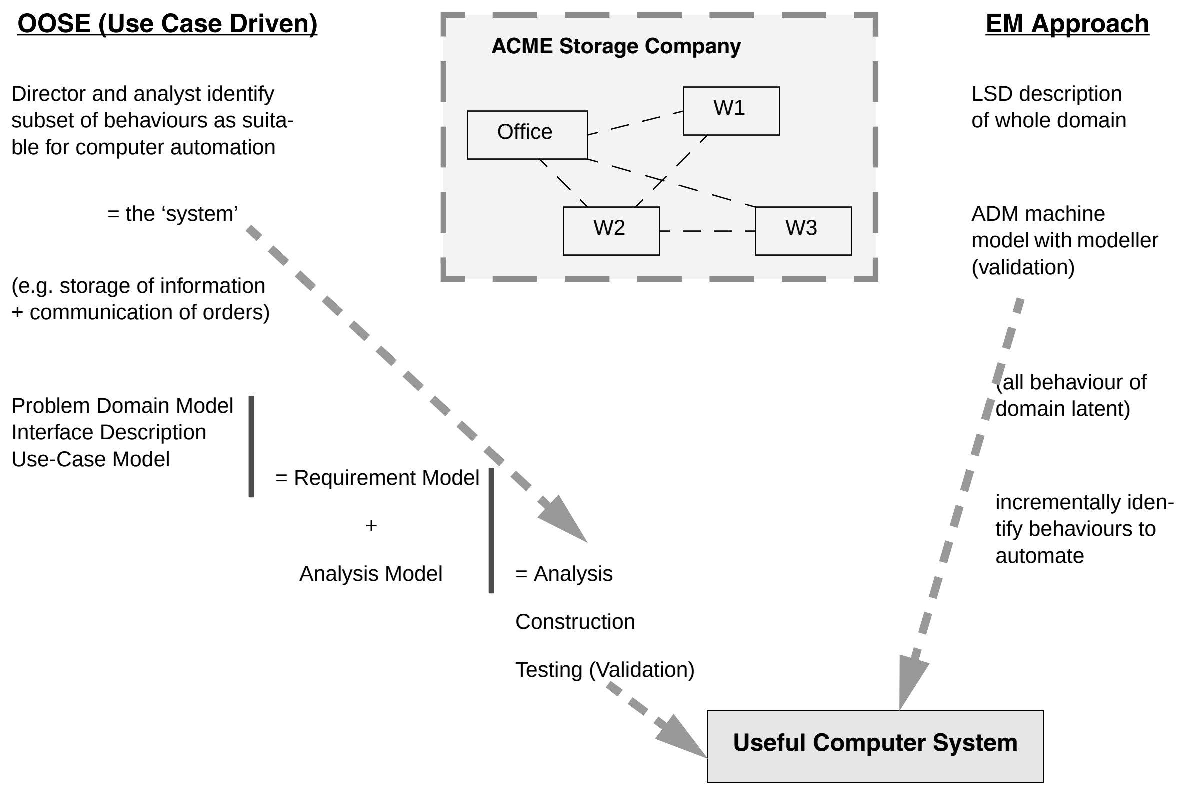

OOSE (Use Case Driven)
Director and analyst identify subset of behaviours as suitable for computer automation
= the ‘system’
(e.g. storage of information + communication of orders)
Problem Domain Model
Interface Description
Use-Case Model
= Requirement Model
+
Analysis Model
= Analysis
Construction
Testing (Validation)
ACME Storage Company
Office
W1
W2
W3
EM Approach
LSD description of whole domain
ADM machine model with modeller (validation)
(all behaviour of domain latent)
incrementally identify behaviours to automate
Useful Computer System

Figure 5.4 Contrast between OOSE and EM Approaches to System Development

viewed as a textual correspondence because it is achieved in the form of text descriptions, i.e. the use cases, to define the desired functionalities of the proposed system. By way of contrast, the correspondence in EM is one which links the states of the model and the states of its referent. This correspondence is established through the modeller's mental model of the current situations with both the ISM and the referent (which in turn arises through his observation and experiment), rather than the prediction of all the possible states and the behaviour of the future system. There is also a difference between the 'actor' in OOSE and the 'modeller' in EM. In OOSE the actor is a generic term which means any external entity, for example the users, developers or other systems. But each of them has a specific role in

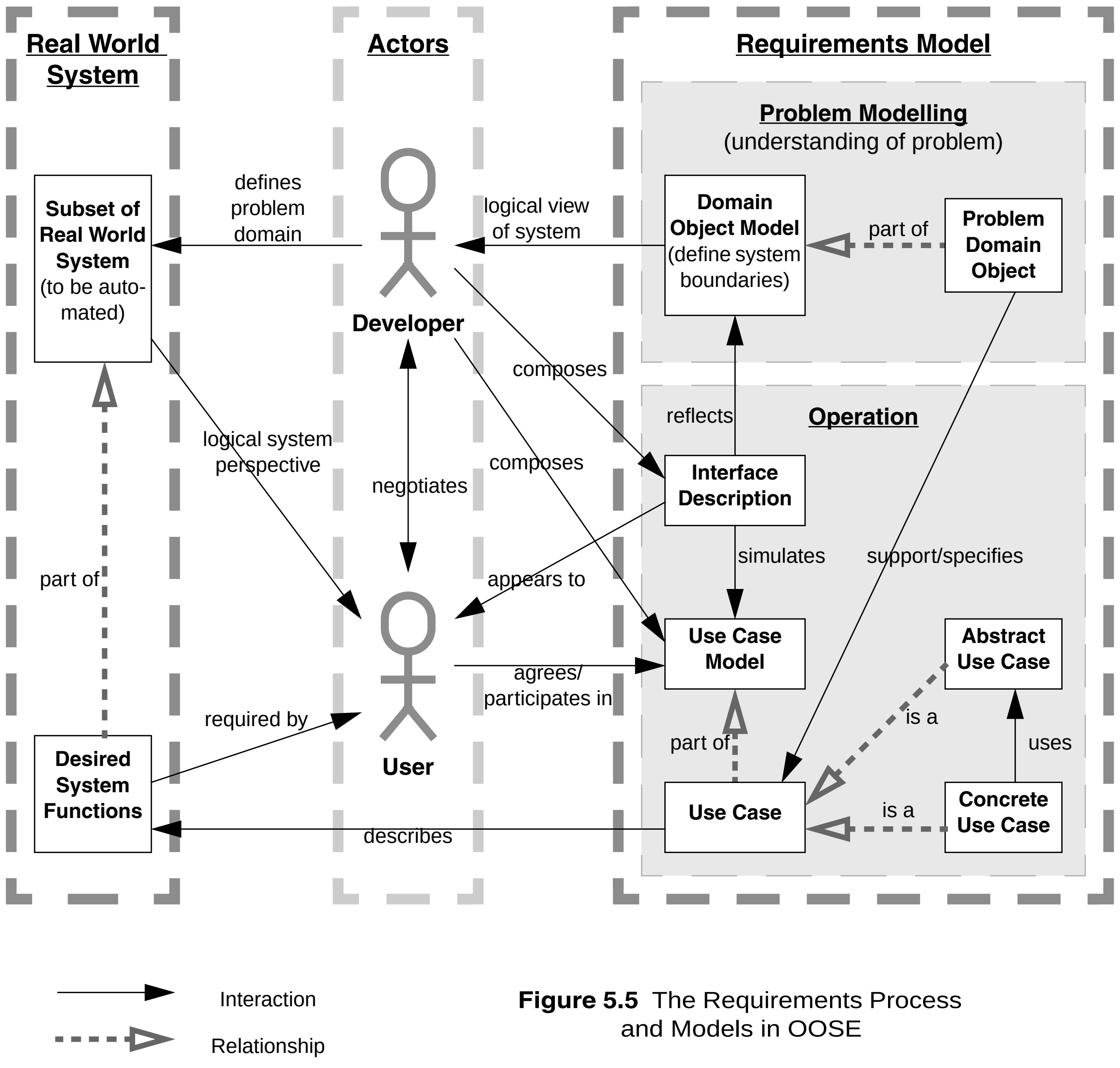
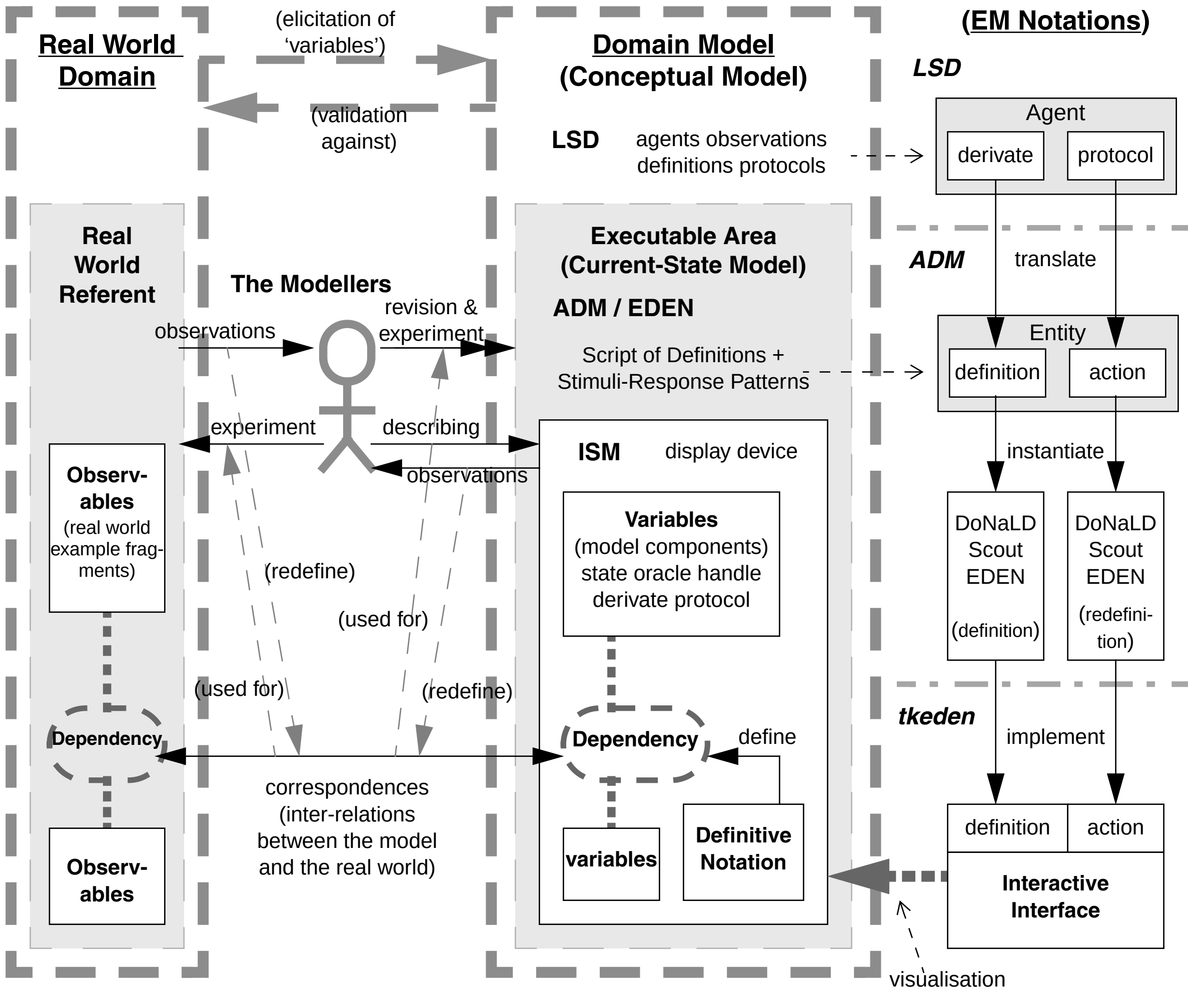


Figure 5.5 The Requirements Process and Models in OOSE

interacting with the system. For EM the modeller can be a designer or user or any other participant. There is no specific role for the modeller as he can interact with the ISM in a flexible and open-ended manner. Through this, different types of interactions with the real world can be simulated by interacting with the ISM. The right-hand block in Figure 5.5 representing the Requirements Model of OOSE can only reflect the inner block of the executable area in Figure 5.6. This means the domain of OOSE is mainly the 'system' itself, whereas the domain of EM involves the real world situation which could be outside our prediction of the system states. It is also interesting to see that in OOSE the activity of understanding of the problem domain (the upper inner block) and the activity of requirements/function-



Real World Domain
(elicitation of 'variables')
(validation against)
Domain Model (Conceptual Model)
(EM Notations)
LSD
LSD
agents observations definitions protocols
Agent
derivate
protocol
Real World Referent
The Modellers
Executable Area (Current-State Model)
ADM
translate
observations
revision & experiment
ADM / EDEN
Entity
Script of Definitions + Stimuli-Response Patterns
definition
action
experiment
describing
ISM
display device
instantiate
observations
Observ-ables (real world example frag-ments)
Variables (model components) state oracle handle derivate protocol
DoNaLD Scout EDEN (definition)
DoNaLD Scout EDEN (redefini-tion)
(redefine)
(used for)
(used for)
(redefine)
tkeden
Dependency
Dependency
define
implement
correspondences (inter-relations between the model and the real world)
variables
Definitive Notation
definition
action
Observ-ables
Interactive Interface
visualisation

Figure 5.6 Empirical Modelling and its Tools and Notations (copy of Figure 4.2)

ality description (the lower inner block) are separate whereas in EM these two activities are 'fused'. (These issues will be further discussed in the next subsection.)

Finally, it remains to discuss the user interface. In OOSE, the user interface description is created before the actual system is developed. It serves as a prototype and many use cases here will often need the description of such an interface. This kind of prototype differs from the 'prototype' of the EM model. In OOSE the interface is static and passive, and the actor's interactions with the interface are represented by single arrows. The interface of the EM model represents a 'virtual prototype' but one which is integrated as part of the whole model and is as open to interactive modification as any other part of the model.

Understanding of the Domain

The activities of understanding of the domain in the requirements analysis are done by the Domain Object Model in OOSE and the LSD account in EM. The Domain Object Model mainly serves as a logical view of the proposed system. It consists of *problem domain objects* which represents the entities from the problem domain which the system must know. Through this model some concepts which the system should work with can be defined. In EM the LSD account records the modeller's conception of the situation. This account captures the observables and dependencies which are significant or relevant, the agents which are present and the classification of observables based on the view of these agents. We can compare the Domain Object Model and LSD in the following ways:

Objective vs Subjective The Domain Object Model, as well as other conventional models, is objective because it is constructed to acquire the objective knowledge about the system behaviour in order to achieve a specified goal. As Jacobson et al. point out, the Domain Object Model is to enable the users to recognise all the concepts needed when defining the functionalities of the system. It is also the tool for users and designers to communicate about the system. This model is developed through discussion among these people and aims to form an objective base for understanding of the domain and the development of the Use Case Model. In contrast, the LSD account is subjective as it represents only the modeller’s perception and experience of a particular subject in a particular situation. It is subjective because in EM, the definitive script or the activity of constructing an ISM is tentative and provisional and is open to change and extension in order to meet changing requirements as well as the changing environment. In this sense, Beynon et al. (2001) characterise the computer as an instrument (or interactive instrument) whereas in conventional approaches the computer is a tool. In other words, the instrument-like use of artefacts is more subjective because the emphasis of using instruments is on exercising personal skills; and the tool-like use of artefacts is more objective because the use of tools is to perform a specific function or goal in a organised and public pattern of interactions. Within the EM context, the LSD account records the modeller’s conception of the referent which may be different to the objective knowledge of the referent or the intended functionality and interaction with that referent. This characteristic differs from those methodologies which seek to form a formal specification. Ness (1997) classifies the conventional (object-oriented) methodologies as being like an agentless or 0-agent system in EM because of their absence of considering the role of the modeller in the process.

Domain The problem domain of OOSE is mainly the ‘system’ itself, i.e. the aim of the OOSE development process is to build a new system to replace the existing one. Thus the domain defined in OOSE is a part of the real world in which the activities or processes can be replaced or automated by the new system. For this situation it is essential to define the boundary of the system at an early stage in order to develop a system which is meaningful and useful for its users. In comparison, the domain of EM involves the real-world situation. That is, the domain of EM involves the situations which reflect to some extent the way in which the modeller perceives, and interacts with, the world. Even the past experience of the modeller or the legacy of other people’s experience can be drawn on here. The states in the EM model are a metaphorical representation of the relevant situations in the real world. The possible transitions between states are recorded within the LSD account in terms of agents, observables and dependencies. This LSD account is consistent with the modeller’s construal of the referent.

System Behaviour The system behaviours in OOSE models are preconceived because these behaviours have to be defined at an early stage in order to construct the subsequent models. In the Use Case Model, each functionality, or usage, of the proposed systems is defined by a use case and its potential users are defined by actors. Normally such functionalities or usages defined in use cases are based on the frameworks which have been identified earlier to be reliable or predictable. This model serves as an agreement between the customers and the designers in which the clear description of the system functionalities is included. Thus we can say the focus of OOSE methods is on the representation of the system behaviour. In contrast, the system modelled by EM exhibits the same behaviours which may be appropriate to the applications but, in the process of development, they are not preconceived. Such behaviour is represented in the EM model as immediately experienced rather than circumscribed. This is because the changes in the states of the EM model are not anticipated and thus cannot be derived in advance. However, it is still possible to circumscribe the system behaviour within the EM model just as in other models, and the modeller can introduce agents or dependencies in the order which is appropriate.

Ontology vs Epistemology An important issue, relevant to the discussion above, is whether the philosophical orientation of a system development approach is towards *ontology* or *epistemology*. The philosophy of object-orientation is generally viewed as concerned with ontology[15] – the common way of thinking of 'object' is as a representation of a real-world entity, i.e. any real-world entity is an object (cf. section 2.2). Thus the OO models are objective in character and their artefact use is tool-like, and their domain is limited to the proposed system itself. In contrast, the philosophy of EM modelling is more related to epistemology because we are emphasising experiment and long-established practice during the process of modelling. This is similar to the outlook of Checkland's SSM and Lehman's E-type program that were described in chapter 2. Lewis (1995) comments that the philosophical orientation may not be significant when OO is applied at the implementation level for a problem domain which is well-defined. But if applied in less well-defined situations, then "the assumption of one-to-one correspondences existing between the objects in the data model and parts of the external [real-world] reality is more dangerous and blinkering"[16]. And McGinnes (1992) has the same view:

15. Lewis (1993 and 1995) has a different viewpoint. He mentions that "the recent interest in object-oriented analysis has led to re-interpretations of the nature of data analysis and at least some recognition that a data model might be an epistemological device, a coherent means of investigating the problem domain rather than being a description of the real world" (Lewis, 1993). We will further continue this discussion later in this paragraph.

> The idea that object-oriented systems are a 'natural' representation of the world is a seductive but dangerous over-simplification. In reality, the fact that the object model seems so close to reality makes it far easier to misuse than other modelling techniques which do not propose to represent the world so directly. (p. 13)

Many researchers (Winograd and Flores, 1987; Stowell, 1995b; Mingers, 1995; Lewis, 1995; Checkland and Scholes, 1990) argue that OO and many traditional methodologies which are based on an objectivist viewpoint are inappropriate for designing information systems as they are a part of the whole process of human communication. Instead they argue that human interaction involves understanding and meaning[17], and thus our actions cannot simply be described objectively by an external observer. Thus Mingers (1995) describes the task of system analysts as not simply the objective description of particular information flows or data structures, but as the interpretation and elicitation of the socially constructed patterns of meaning which generate observed behaviour. For EM we do not aim to model the proposed system directly through one-to-one mapping in a preconceived manner, but rather focus on the process of human agent's perception and experiment with the real-world reality. This is consistent with the view of Lewis (1995), who suggests that OO analysis, as well as other models or database, is not modelling the real-world reality, but modelling the way the reality is understood by people – they are the models of user's models of the world[18]. Thus the analysis leads to models which do not reflect any objective reality but a particular group's knowledge and perceptions of a problem situation. Thus we need ways to investigate and model that knowledge and perception, especially ways "that are sympathetic to the complex manner in which social realities are created". The EM approach can in this sense complement other analysis approaches, because, as Lewis says, with current methods, analysis "con-

16. He gives an example of whether a 'country' is a tangible item (an object) in the real world or a perception shared by many individuals: "Did there exist a real-world thing called Slovenia in December 1991 when some inhabitants of Yugoslavia had declared its independent existence? Did it exist in January 1992 when the European Community (but not the United Nations or the governments of Yugoslavia) recognised its existence? The answers, of course, depend on how we define 'a country', and this is socially and politically decided: it is not an absolute characteristic of something existing in an independent 'real-world' ". (pp. 194-195)
17. This is why Checkland and Scholes (1990) say "information equals data plus meaning", and Galliers (1995) contrasts *information* systems (which inform) from *data-processing* systems (which automate the operational tasks). Goguen (1994 and 1996) comments that information is *situated* – it is highly dependent on its social context for interpretation and we have to consider how it is produced rather than merely how it is represented.
18. Thus the question for evaluating models should not be "Does this design accurately represent the real world?", but should be "Does this design accurately represent the user's model of his environment?".

tains no model of human sense-making that explains it, and none of the techniques of data modelling assists by making the subjectivity explicit and open to debate".

Functional Requirements Description

In OOSE the functionalities of the proposed system are defined in the Requirements Model. The first step in the requirements process is to create a simple prototype of the system which helps to describe the boundary and the actors of the system. Then the functional behaviours of that system are described by the informal text descriptions in use cases. Jacobson et al. (1992) calls the content of the use cases *interface descriptions* (or *use case specifications*) because they define the interface between the users and the system itself. The use case specification consists of both textual and graphic descriptions. It also consists of various phases each representing a particular set of behaviours in that use case.

In EM the ADM or EDEN is used to animate the LSD account. Through the animation the interaction between agents in LSD will be visible and meaningful and the modeller can intervene in the model by adding or redefining definitions. Through this kind of interaction the modeller can ensure whether the system behaviour meets the requirements with reference to the external observation. The following is a comparison of the techniques of functional requirements description between OOSE and EM.

Verbal (Text-Based) vs Machine-Support Use cases are written in natural language to describe the dynamic process of using the system. According to Jacobson et al., use cases are easy to understand and provide a better way for communicating with customers and users. However Dano et al. (1996) point out that although the description of the use cases makes the involvement of domain experts easier, it is still not entirely satisfactory because the designers have to make sure no requirement is misunderstood as well as ensure the completeness and consistency. Further, such a kind of communication is still passive and Sun et al. (1999) argue that the shared understanding of all participants within this kind of text-based model is invisible and incommunicable. Inevitably the visibility and communicability of shared understanding is restricted to the boundaries of language description or comprehension. Also it is hard to keep the requirements specifications synchronous with changing requirements as the people involved gain a better understanding of the problem and may change their points of view or focus. Maintenance may also be a problem because a change in the requirements may affect many places in the text of the specification. In other words, there can be many versions of a use case. This is especially problematic while developing a complex system as too many or too complex scenarios cannot be fully described by text-based models. But if we can animate these versions and then test them, we will get a kind of feedback through the visual artefact during the analysis and design. And once we have the feedback, we will be able to improve the requirements specification and generate a new version of a use case easily. This is what we have been doing in our EM research. In EM the interaction with the ISMs can make the modeller's insights and the shared understanding with other participants visible and communicable. Pictures are more informative than the textual descriptions: "A graphic is worth a thousand words". In EM the computer is used to generate the metaphorical representation of particular states and to animate the modeller's expectations about the results after state-changing actions. Interaction with the computer model will lead to the evolution of the modeller's insights as well as a shared understanding. Conventionally, much knowledge (especially tacit knowledge) is kept in the participants but cannot reach the corporate knowledge. But in the EM modelling process, we are trying to make such tacit knowledge and other trial-and-error knowledge accessible to the decision process. The knowledge through the interaction with ISMs can solve the text-based problem in the use cases and other methodologies. For this reason, EM can be regarded as an alternative approach for creating use case specifications. The difference between the different versions of use cases is mainly from the change of responsibilities of objects or the addition of new objects. EM allows such kinds of change to be made 'on-the-fly' by redefining or adding definitions in the script. Sun et al. describe this synchronisation between the evolution of computer models and modeller's insights allowing the participants to 'see' the viewpoints of others and to 'communicate' with them by interacting with versions of their artefact. Another advantage of the EM models is, it can capture the richer reality of the real-world situation and make the revision of the model easier and more faithful to reality.

Scenarios In OOSE, a use case in its normal course and alternative courses can be regarded as a collection of the possible scenarios between the actors and the system. That is, a use case describes the possible scenarios of user's interaction with the system and represents the steps to accomplish the result.

Figure 5.7 illustrates some different types of scenarios in system development. The first type of scenario is the system internal scenario which consists of the interactions of the internal components within the proposed system. This kind of scenario is described by the use case specifications and is modelled by the following Analysis Model, in which the external context of the system is not considered. The second type of scenario is the interactions between the system and a part of its external environment, which only includes the actors and other systems directly interacting with the proposed system. Such scenarios are defined in the Use Case Model. The third type of scenario includes the wider context of the external environment. In addition to the direct interactions between the system and its context, it also includes the information about the context of that system. We argue that the scenarios in the EM model are categorised into this type because the state of the referent is metaphorically represented in the EM model and the consequent results of the state-changing actions by the modeller may or may not meet his expectation. Obviously the EM technique can be applied to model all these types of scenarios. For example, the perspective of an external observer, as described in 'Scenario 1'[19] in Beynon (1997),

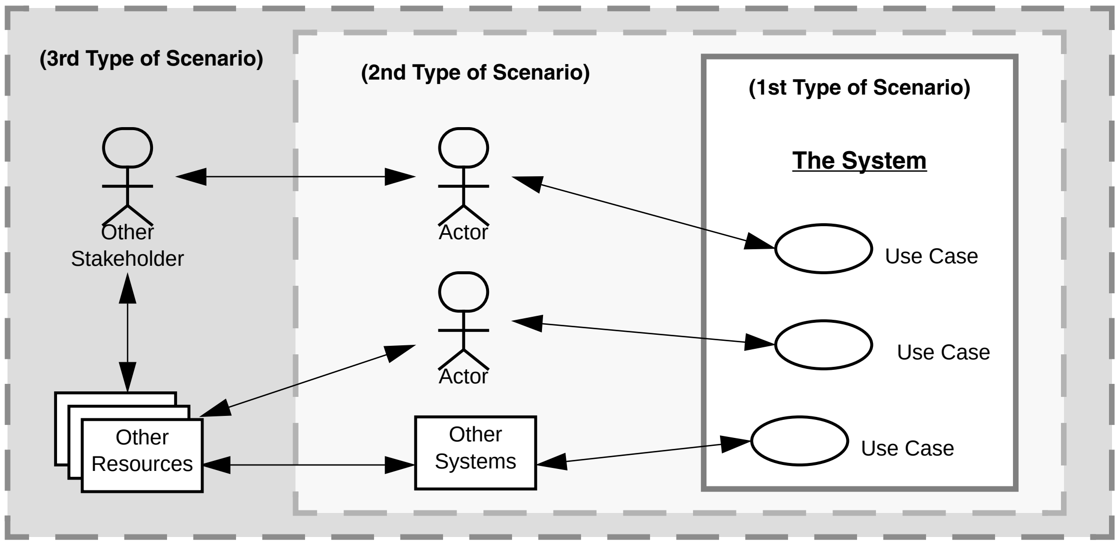


Figure 5.7 The Scenarios in System Development

is similar to – but even broader than – that of the designer in OOSE, as the functionality of the proposed system and possible interaction of users have to be identified in the Use Case Model before the objects and their interactions are modelled. The first type of scenario can be represented through the interaction of internal agents in the EM model. However, according to systems thinking, each agent (or object) can be specified, but the whole system behaviour made up of the cooperation of their interactions may sometimes lead to conflict or incoherence. This explains why sometimes existing methods fail to develop a system to meet the user's actual needs as they did not take the third (or even the second) type of scenario into consideration when developing the system.

Systems-Oriented vs Agent-Oriented The use case is systems-oriented because it defines and captures the major functionality of the proposed system. It is user-centred because the aim of use cases is to ensure the system is developed to meet the requirements from the user's viewpoint. A use case may involve many actors, but only one actor initiates the use case. However the actors are beyond the scope of the system considered, the use case modelling does not consider the interactions between actors. In contrast, EM is agent-oriented because its process involves the identification of agents as well as the observables and dependencies in the subject. However the concept of agent-orientation is different to the one in the AI field. In EM the agents are state-changing agents which refer to entities related to the representation and transformation of the state, for example the individual components of the system or the potential users and designers of the system. The agents in EM can directly change the value of a variable owned by other agents. Changes to the state are caused by agents and constrained by the capabilities (i.e. the privileges for change) of the agents. Thus the agents identified reflect the perspective of the observer. The system behaviour is implicitly defined by the privileges of agents. The introduction of new agents or new privileges of existing agents will affect the system behaviour. This is different to OOSE as the system behaviour comes from the circumscribed way of observation and description, and the objects and their interactions are identified afterwards.

19.Scenario 1: the modelling activity is centred around an external observer who can examine the system behaviour, but has to identify the component agents and infer or construct profiles for their interaction; Scenario 2: the system can be observed from the perspectives of its component agents, but an objective viewpoint or mode of observation to account for the corporate effect in their interaction is to be identified (Beynon, 1997).

Programming through Modelling vs Modelling through Programming

Beynon and Joy (1994) describe the primary motivation of the EM paradigm as a philosophy of *programming as modelling* or perhaps more clearly *programming through modelling*. That is, using modelling as a means to program a computer. This idea differs from the concerns of object-orientation and other modelling methodologies which can be characterised as *modelling through programming* as we program the computer in order to model a system.

By 'programming through modelling', the emphasis of EM is to model what we observe of the whole system and its environment in terms of interacting agents, rather than constructing the models independently of the real world situation. One advantage of the EM approach is that we can specify the synchronised changes which may cut across the object boundaries. Further, according to Beynon and Joy, the development process of the EM models is the process of formulating relationships (i.e. the dependencies) between observables which are provisional. This means that the EM models can be viewed as a specification of a program only *after* the majority of the modelling process has been done, i.e. the reliability of the relevant observations have been validated. By way of contrast, in OO methods the specification of the system is decided *before* the construction of models. For EM, the emphasis is on software construction to establish a *prototype* of the real-world system within the computer; whereas in OO the emphasis is on developing a *finished model* based on the requirements which are in turn based on the assumptions and initial experience of the real-world system (Rawles, 1997).

5.3.2 Comparison between the Models

This subsection will compare the similarities and differences between the EM model and the models of object-orientation (and OOSE). For EM we are concerned with matters of state in ISMs and comparing this with the states of OO models in terms of the different characteristics of agents and objects. We also consider the issues of modularity and reusability, which are fundamental features of OO, to find out the different concept used in the EM model.

The Concept of State

EM differs from conventional programming in that the focus of EM modelling is on *state* rather than the structure of control or the representation of behaviour. The 'state' here broadly includes the state of mind in the subjective experience of the modeller as well as the states of the artefact and its referent. The values of variables in the EM model at a time correspond to a particular state in the real world. The change of state is only achieved through the automatic update of dependencies or the explicit action of agents, that is, through redefinitions or the addition of new definitions. Thus change can be made at any time during the animation. For EM the concept of state, which differs from the public sense, is primarily *state-as-perceived-by-agent* or *state-as-experienced*. That is, the state represents what the person currently perceives/experiences of the environment and is subject to continuous change. In most conventional approaches, such a subjective state is not directly represented. In order to prescribe the process, the inputs and outputs have to be preconceived before the construction of the model. The OOSE method is an example of emphasis on prescribing the system behaviour in use cases before constructing the model. If any new inputs and outputs and additional features of systems need to be added, the revision and redesign of the whole process may cost time and effort. Also the EM model seems to be more robust than the OO model: because EM enables the user to experience an unfamiliar situation, which includes unexpected situations or even abnormal conditions.

Generally in object-oriented programming, the representation of states is through the identification of the state of each object. Thus we can identify the difference between agents of EM and objects in OO in modelling state-transitions. In object-orientation, each object is responsible for changing its state through performing its internal action or method. Other objects can send a message to an object to invoke its method. The message passing is the only way in which these objects interact and thus change their internal variables and states. This is different from the agents of EM in which the actions of one agent can directly affect the changes of state in other agents, and sometimes result in an indivisible propagation of state changes which involve several agents. The agents in EM can be either active or passive. The active agents can perform autonomous actions to change the state of the model; whereas the passive agents serve to record state information but cannot perform actions (Beynon et al., 1990).

The character of passive agents may be close to that of objects in OO. The system state represented in OO models is more tricky than in an EM model, because the designers need additional information about the message sending, receiving and responding for objects in order to understand the system behaviour.

When BPR is concerned, the mathematical models used in conventional methods are not suitable for modelling states in the business environment. It is essential to identify the factors which affect the manager's or user's perception of the state of the business which they are in. Such factors cannot be appropriately represented in the mathematical model. As Beynon et al. (2000a) describe, modelling these factors involves consultation with other related parties, the development of physical artefacts or prototype products, and computational models based around databases and spreadsheets. In the next chapter we will illustrate an ISM which encompasses models of this nature and is well-suited to modelling business processes.

Issues of Modularity and Reusability

Modularity is one of the fundamental properties of the object-oriented methodology which has made OO popular and makes system development more effective. The central theme of object-orientation is to synthesise the software system from modules which can be developed independently. But the decomposition into objects in the OO paradigm means a commitment and knowledge about the problem domain is needed before defining the behaviour and attributes of objects. From the viewpoint of the object-oriented paradigm, it is essential to minimise the dependencies between modules for the reason of maintenance and reusability. In the construction of large systems, the division into modules sometimes can be a difficult task.

In EM the emphasis is on observation rather than the object. That is, our emphasis is on modelling the observation of the whole system with interacting agents but not constructing objects in isolation and then integrating them by means of message passing. The observables and variables in the EM model are global. The indivisible propagation of state changes in the EM model will result in state changes across the object boundaries. This makes EM more suitable than object-orientation in the synchronisation design of system development, due to the synchronised updates of variables through definitions. In OO the protocols between objects are not made explicit and thus the synchronisation of messages cannot be specified.

On the other hand, as there is no kind of modularity in the EM model, the issue of reuse cannot be coped with well within EM. For object-orientation, each object can be easily reused due to the features of encapsulation and information hiding. Some techniques, for example isolating the agents and observables, can make some kind of modularity in the definitive scripts, it is still hard to achieve modularity in the EM model because of the rich dependencies in the definitive scripts. Rawles (1997) suggests two structures for applying the idea of modularity in the EM paradigm. The first is through the construction of scripts, each of which models an individual element of the system. But this does not make it different to normal EM modelling because the system is still developed as a whole. This only makes the modeller construct the scripts more conveniently and easily, i.e. splitting the scripts into some conceptual chunks. In this case the scripts may be reusable. But the modeller will still make more effort to reuse such scripts than to reuse objects in OO in which only the change of class interface is needed. The second is using agents as modular units. However even if we modularise the agents, they are still with global character due to their observables and the dependencies between them. Further work such as localising these dependencies may be needed. This indicates the need for further investigation into the status of modular design within the EM framework.

Even though software reusability has been regarded as a claim for object-orientation, Gammack (1995) points out that such software reusability still has been a massive problem for the industry. Together with other researchers, he concludes that

> hardware reuse benefits from the fact that standard functions are easy to identify owing to their close mapping into the real-world model of hardware systems, and if software reusability is to become a reality languages must support a more direct mapping from the model of the real world functions to the implementation. (p. 165)

This argument is closely related to the discussion of relationships between software (or the software system) and the real world (its business environment) in section 3.3. Such discussion may provide another direction for research into software reusability within the EM framework.

5.4 Concluding Remarks

The concept of use cases has become more and more popular in the object-oriented community and has been established as one of the fundamental techniques of the OO methodology. It provides some advantages in the process of requirements elicitation which the conventional object-oriented methods failed to achieve. But like many other development methods, there are still some problems when applying the use case technique in developing the system. This chapter summarises the general concepts of the use case technique and the processes of applying this technique in both system development (OOSE) and BPR (Object Advantage). We also gave an overview of the drawbacks associated with use cases.

The concepts of the EM approach have been described in chapter 4. Several EM projects have identified issues of common interest in the EM approach and object-oriented approaches (including the use case approach). Related work on this theme can be found in Ness (1997), Rawles (1997), Beynon and Joy (1994) and other research reports of the EM and AMORE projects. In this chapter we have compared these two approaches mainly in regard to software development. The comparison is based on two concerns: first, their processes of system development which involve the construction of the models; and second, the structures and characteristics of their models.

The paradigm of object-orientation has been long established and been widely accepted for software development. But EM is a novel approach to modelling which has been developed for just over 15 years. The research of EM projects shows that EM can bring a new approach to development in some different fields, for example, business modelling. Through this comparison, it is hoped that we gain a better understanding of how the EM approach can relate to existing methodologies of system development as well as an appreciation of how this approach can itself be used in system development.