

TOWARDS A BUSINESS PROCESS MODEL WAREHOUSE FRAMEWORK

by

DINA ELIZABETH JACOBS

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SUPERVISOR: PROF P KOTZÉ

JOINT SUPERVISOR: PROF A BARNARD

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- Supply-chain Council, for authorising reference to the Supply-chain Operations Reference-model (SCOR) as part of this dissertation.

ABSTRACT

This dissertation focuses on the re-use of business process reference models, available in a business process model warehouse, to enable the definition of more comprehensive business requirements. It proposes a business process model warehouse framework to promote the re-use of multiple business process reference models and the flexible visualisation of business process models. The critical success factor for such a framework is that it should contribute to minimise to some extent the causes of inadequate business requirements. The proposed framework is based on an analogy with a data warehouse framework, consisting of the following components: usage of multiple business process reference models as source models, the conceptual design of a process to extract, load and transform multiple business process reference models into a repository, a description of repository functionality for managing enterprise architecture artefacts, and motivation of flexible visualisation of business process models to ensure more comprehensive business requirements.

Keywords: business process models, business process reference models, business process model warehouse, data warehouse, repository, enterprise architecture, comprehensive business requirements

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PREFACE

The consistent usage of terminology is a given, it is not negotiable when writing a dissertation. The question is what to do to resolve the challenge of various authors using terminology in an inconsistent manner. The inconsistent usage of terminology can be classified as:

- The same phrase but different meanings.
- Different phrases but the same meaning.
- The level of specification may differ.

An example of the first type can be found when the same phrase is used by various authors but with a different meaning. An example is that of Bobrik, Reichert and Bauer (2005) and Kannan (2005) using the phrase *process warehouse*, but with different meanings.

An example of the second type occurs when different phrases with the same meaning are used but within the context of this dissertation it is not of importance to differentiate these phrases. An example of this type is the names of the architectural domains listed by Pulkkinen (2006) versus the TOGAF (The Open Group, 1999-2006) terminology used for the types of architecture. Pulkkinen (2006) refers in this regard to a *business architecture*, whereas TOGAF refers to a *business process architecture*.

The third example refers to a phrase being used in the broader context, and within the context of this dissertation, it is important to narrow the meaning. A key example is Verner, Overmyer and McCain (1999) using the term *requirements*. Within the context of this dissertation, the focus is however only on a subset of the requirements, namely the *business requirements*.

To overcome this challenge of inconsistent usage of phrases by different authors, the approach is to align key phrases with the definition given as part of this dissertation. The convention is to stay with the key phrase as defined within the context of this dissertation and to align the phrases used by other authors by adding additional components in brackets to the phrase as used by the original author.

An example here can be that *process warehouse* is extended to *(business) process (model) warehouse* if the meaning of *process warehouse* is similar to *business process model warehouse*. *Business process model warehouse* is a key concept defined as part of this dissertation. A second example here can involve not using the phrase *requirements* but to extend the phrase to *(business) requirements*.

It is important for the reader to keep this convention in mind when reading the dissertation. If the reader needs to relate the phrase used by an author with the phrases used in the dissertation, the extended

phrase indicated by the brackets should also be read. If the reader wants to relate to the phrase initially used by the author, the extended phrases in brackets should be skipped.

The convention for the use of capital letters is to use capital letters for products and the names of techniques as it is used in the material referenced. Applying the convention will result in the use of Supply-chain Operations Reference-model versus IndustryPrint reference model and SAP Solution Manager BPR reference model. Direct quote and names of a reference will used as in the original text, resulting in variations such as Supply Chain Operations Reference (SCOR) Model.

CHAPTER 1: RESEARCH OVERVIEW

1.1 Introduction

This dissertation focuses on the re-use of business process reference models, available in a business process model warehouse, to enable the definition of more comprehensive business requirements. The milieu is set within the enterprise architecture domain of the information management discipline, but the data domain also contributes to this dissertation. Before stating the argument (thesis) of this dissertation the key concepts included in the introductory statement, namely *comprehensive business requirements*, *business process reference models* and *business process model warehouse* will be positioned within the context of the enterprise architecture domain. The role of the data warehouse concept is explained within the context of the data domain.

1.1.1 Domain Description

The enterprise architecture domain, part of the information management discipline, is about bridging the gap between business and information management. *Enterprise architecture*, according to Whitman, Ramachandran and Ketkar (2001), provides the mechanism by which the reality of the enterprise and its systems can be aligned with management intentions. The business architecture, one of the enterprise architecture dimensions, includes business process models, reflecting how activities are coordinated in the course of a business process (Pulkkinen, 2006). Business process models are therefore positioned within the enterprise architecture domain. Business process models are an important component of comprehensive business requirements. It is possible to close the gap between the enterprise architecture concept, business process models and comprehensive business requirements by stating that, to some extent, comprehensive business requirements, including business process models, constitute part of bridging the gap between business and information management. With business process models defined as part of the enterprise architecture domain, business process reference models can be defined as artefacts similar to business process models. In this context, business process models that are predefined business process models available for re-use are referred to as business process reference models (Ramesh and Jarke, 2001). To re-use these business process reference models, the concept of a business process model warehouse is introduced. As the concept of a business process model warehouse is not well defined in literature the intent is to define a business process model warehouse framework as part of this dissertation.

The data domain is the second domain of concern in this research. The business process model warehouse framework to be defined as part of the outcome of this dissertation, is the pivot on which this research hinges. In order to derive the business process model warehouse framework the approach is to inherit as much as possible knowledge from the existing data domain. According to Gray and Watson (1998), two key characteristics of a data warehouse are:

- A data warehouse is a database system that draws its data from multiple production systems.
- A data warehouse enables users to “slice and dice” the data in desired ways.

Aspects of these characteristics are also relevant to the business process model warehouse and therefore a data warehouse framework is used as basis to derive a business process model warehouse framework. For illustrative purposes, these characteristics of a data warehouse are applied to the business process model warehouse concept. The characteristics of a business process model warehouse could then be rephrased as follows:

- A business process model warehouse is a repository, which draws its business process models from multiple business process reference models.
- A business process model warehouse enables users to slice and dice the business process models by enabling the flexible visualisation of business process models.

These characteristics of a business process model warehouse refer to a number of key concepts to be discussed in more detail in Chapter 2. To highlight a number of these concepts, let us compare the concepts used to describe the characteristics of a data warehouse with those used to describe the characteristics of a business process model warehouse.

Table 1.1: Data warehouse versus business process model warehouse characteristics

Data Warehouse Characteristics	Business Process Model Warehouse Characteristics
Database system	Repository (a database about engineered artefacts)
Data	Business process models
Multiple production systems	Multiple business process reference models ¹
Data in desired ways	Enabling the flexible visualisation of business process models

1.1.2 Argument (Thesis) Statement

The argument (thesis) is that a framework for a business process model warehouse can be proposed.

The aims of the business process model warehouse framework are:

¹ The scope of this dissertation is limited to the re-use of business process reference models, but future research could be extended to include other sources of business process models.

- to promote the re-use of multiple business process reference models; and
- to enable the flexible visualisation of business process models.

The critical success factor for such a business process model warehouse framework is that it should contribute to minimising to some extent the causes of inadequate business requirements as stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the (business) requirements really mean.

1.1.3 Overview of Layout of Dissertation

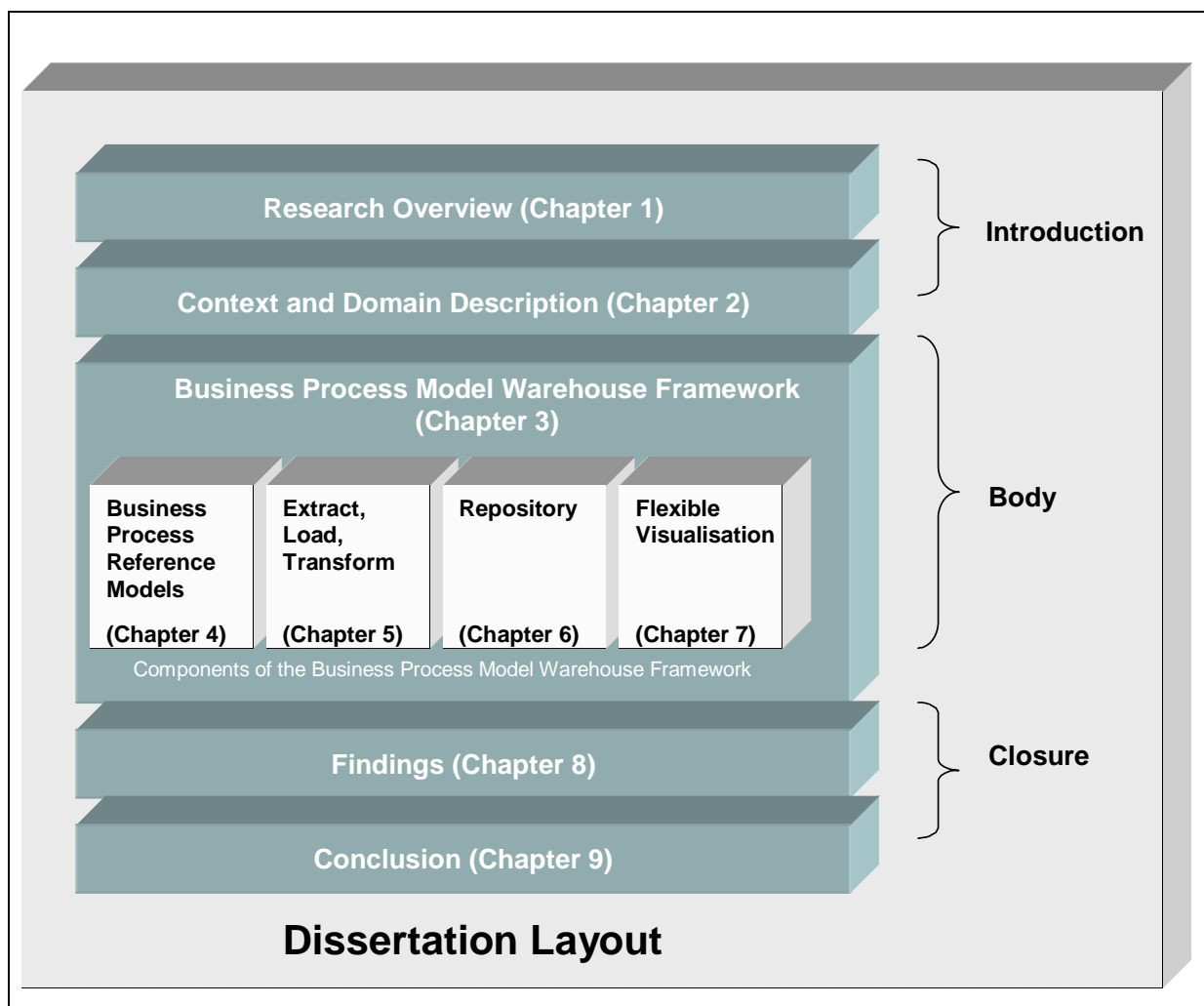


Figure 1.1: Layout of the dissertation

Figure 1.1 gives an overview of the layout of the dissertation. The remainder of Chapter 1 discusses the rationale for the research questions as well as the structure of the dissertation (section 1.6). Chapter 2

provides context and includes the domain descriptions. The key concept of a business process model warehouse framework is proposed in Chapter 3, and the different components of the proposed business process model warehouse framework are discussed in Chapters 4, 5, 6 and 7. The findings regarding the research questions are discussed in Chapter 8. The conclusion, reflections and the value contribution are included in Chapter 9

Before stating the research questions in section 1.4, describing the research method in section 1.5 and reviewing the detail structure of this dissertation in section 1.6, the rationale behind the research topic will be explained. By referring to the problem background (section 1.2) as well as related work (section 1.3), as depicted in Figure 1.2, Figure 1.3 and Figure 1.4, it is possible to confirm that the concept of a business process model warehouse framework addressing the problem of inadequate business requirements is a valid research topic.

The problem background, as described in section 1.2, concerns the negative impact of inadequate business requirements on the success rate of information system projects (Figure 1.2).

- Figure 1.2, note 1: Inadequate business requirements result in information system failure.
- Figure 1.2, note 2: The argument is that a contributing factor for inadequate business requirements is that there is no re-use of business process reference models to derive more comprehensive business requirements.

To confirm that the problem statement is valid, reference will be made to related work stating that comprehensive business requirements contribute to the success of information system projects as depicted in Figure 1.3 and discussed in section 1.3. Two groups of related work are considered from the problem statement perspective:

- Figure 1.3, note 1: Related work stating that comprehensive business requirements are indeed a critical success factor for information system projects (section 1.3.1).
- Figure 1.3, note 2: Work related to improving business requirements further strengthens the viewpoint that business requirement definition is a worthy research topic (section 1.3.2).

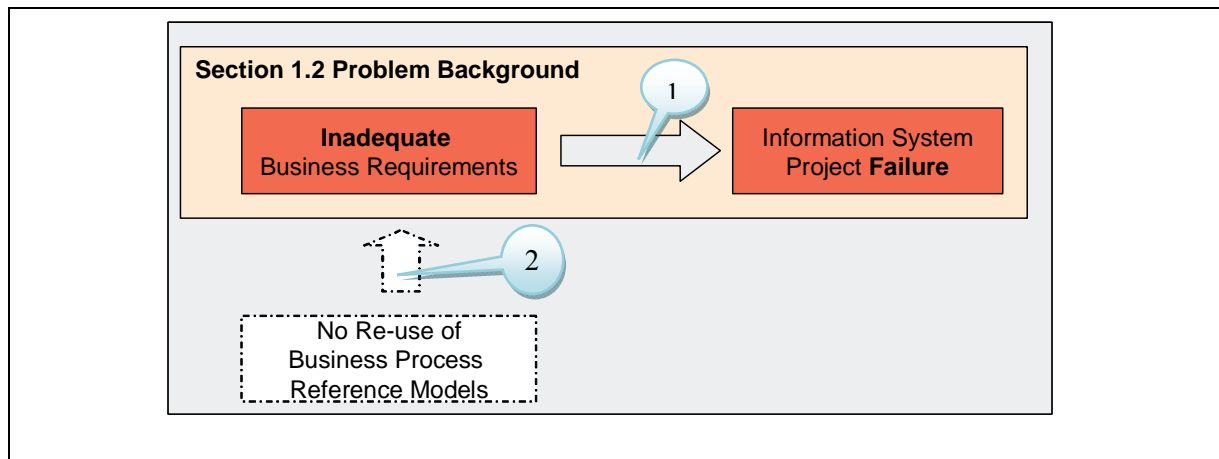


Figure 1.2: Background/Problem statement

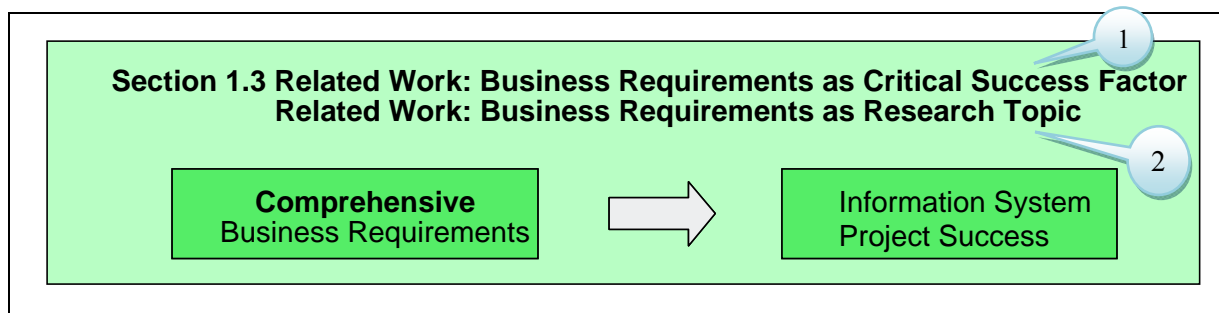


Figure 1.3: Related work to research topic

The rationale of section 1.3.3 (Figure 1.4) is to change the AS IS scenario FROM:

Figure 1.4, note 1	Inadequate business requirements resulting in information system project failure.
Figure 1.4, note 2	Business process reference models not being used as part of the AS IS scenario.

TO a TO BE scenario:

Figure 1.4, note 3	Using business process reference models, available in a business process model warehouse, to derive more comprehensive business process requirements.
Figure 1.4, note 4	More comprehensive business requirements resulting in successful information system projects.

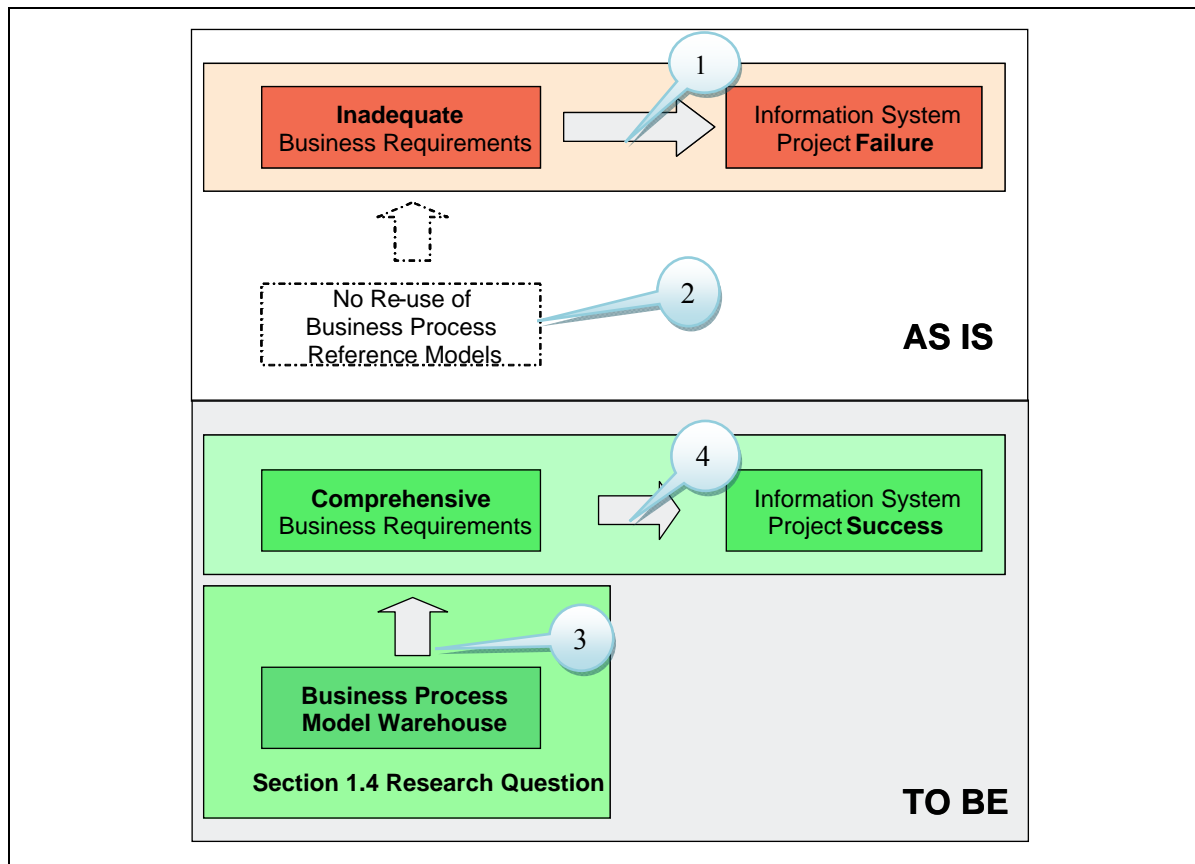


Figure 1.4: Rationale for research questions

1.2 Background and Problem Statement

The question is whether inadequate business requirements are indeed a problem from the perspective of the information management discipline. The seminal paper by Brooks, *The Mythical Man-Month*, which was first published in 1975 (as cited in Verner et al., 1999) was the first major publication to deal with the difficulties of managing large projects of a primarily software nature. Verner et al. (1999) compare the software project management advice given by Brooks in 1975 with practices employed some 25 years later. In 1999, still only about fifty percent of all projects could be viewed as successful. Although there are a number of contributing factors in terms of the lack of success regarding information system projects in general, this dissertation focuses on only one of the problem areas mentioned in the paper by Verner et al. (1999), namely inadequate (business) requirements. Verner et al. (1999) state that in the case of failed projects, inadequate (business) requirements constitute problem areas in about 40% of the projects. They furthermore state that inadequate (business) requirements are mainly due to:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and

- misunderstanding on the part of the customer of what the (business) requirements really mean.

Based on this background information, the first step (section 1.3.1) is to confirm whether comprehensive business requirements are indeed a critical success factor for information system projects. The second step (section 1.3.2) is to determine whether there are other related work focusing on resolving the problem of inadequate business requirements. The third step (section 1.3.3) is to refer to related work that positions the business process model warehouse concept. The final step is to motivate the value of re-using business process reference models.

1.3 Related Work

The intent of section 1.3 is to refer to related work to confirm the rationale behind the argument (thesis) as stated in section 1.1.2.

1.3.1 Related Work: Business Requirements as Critical Success Factor

The question is whether it is possible to find a number of references in literature that confirm the statement by Verner et al. (1999) that the quality of the business requirements is a contributing factor to the successful outcome of an information system project.

As preamble, it is useful to gain a better understanding of what is meant by a failed information system project. It is possible to classify failed information system projects into categories. Lyytinen and Hirschheim (as cited in Dalcher and Drevin, 2003) identified four categories of failed information system projects, namely:

- *Correspondence failure*: when the (business) requirements are not met.
- *Process failure*: when the project runs over time or budget and performance is unsatisfactory.
- *Interaction failure*: if there are problems related to the use of the system or when the system is hardly used.
- *Expectation failure*: a superset of the above three types of failures, when stakeholders' expectations cannot be met.

Although not explicitly stated by Lyytinen and Hirschheim (as cited in Dalcher and Drevin, 2003), it is realistic to assume that if the initial business requirements are inadequate they will contribute to correspondence and expectation failure, but this may even impact process failure as rework may be required. The categories of failed information system projects are not further explored as part of this dissertation, but it is safe to derive that the impact of inadequate business requirements is not limited to a specific category of failed information system projects.

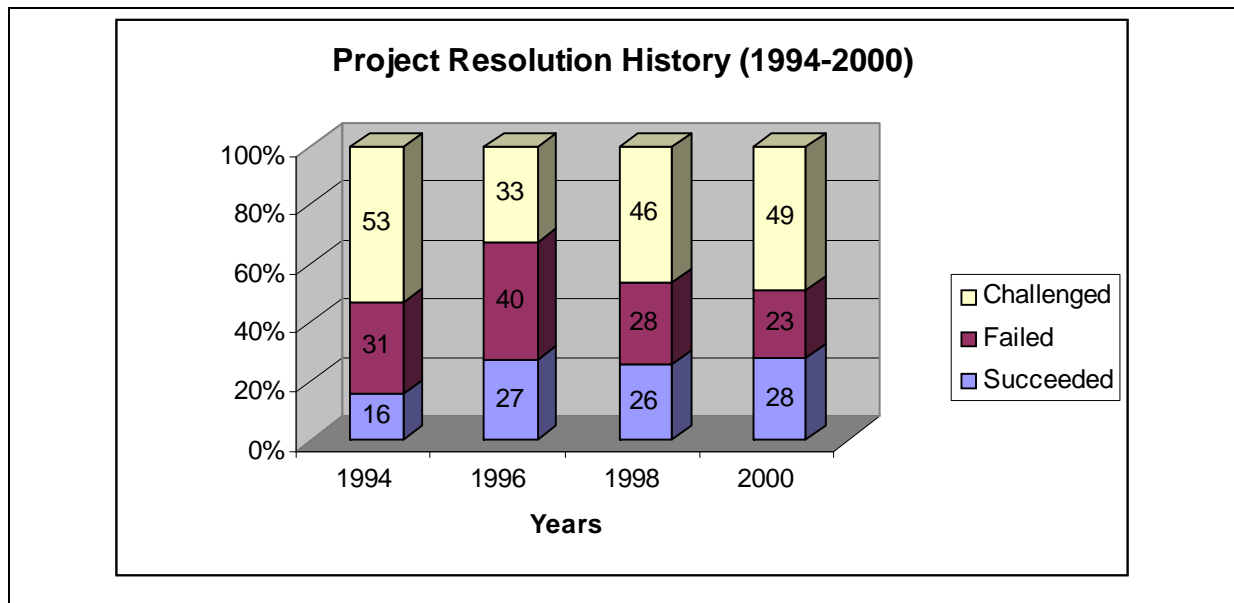


Figure 1.5: Extreme CHAOS report (The Standish Group International, 2001)

The CHAOS study by The Standish Group International (2001) and the work by Kilov (2002) are two sources confirming that comprehensive business requirements are indeed a critical factor for the successful outcome of information system projects. The result of the CHAOS study by The Standish Group International (2001) is published on a regular basis, focusing on the success rate and the contributing factors for success and failure of application projects. As part of the 1994-2000 report, user involvement and firm basic (business) requirements were identified as two of the ten success factors for application projects. The report highlights the role of the user/customer and the impact of the quality of the (business) requirements on the success of the project. In Figure 1.5, representing a summary of the results of the CHAOS report, it is illustrated that the success rate of application projects is improving, however there are still areas for concern. The percentage successful information system projects increased from 16% in 1994 to 28% in 2000. The CHAOS report depicts the resolution of 30 000 application projects in large, medium and small cross-industry US companies tested by the Standish Group since 1994. Two of the success criteria mentioned in the CHAOS report, related to the quality of business requirements, are firm basic (business) requirements and user involvement.

Kilov (2002) more recently confirmed these observations by stating that for information technology systems to be implemented successfully both the business and the information technology requirements need to be understood by all stakeholders. According to Kilov (2002), it is non-negotiable that business people, including decision-makers, should be able to read the business requirements and be convinced that “this is what they do, and this is what they want, no more and no less”.

Various references are also found, stating the importance of well-defined business processes on the successful outcome of information systems. The correlation between a business requirement and a business process will be explored in more detail in Chapter 2, as a business process is part of the business requirement. Both Hammer and Stanton (1999) as well as Paul and Serrano (2003) emphasise the importance of well-defined business processes. Paul and Serrano (2003) noted that the performance of a business process does not depend on the information system behaviour only, but also on accurate changes to the business processes themselves. Hammer and Stanton (1999) even mention that it is impossible to derive the full benefits of an enterprise resource planning system without having integrated business processes.

From the abovementioned discussion, it is not unreasonable to deduce that there is a dependency between the quality of the business requirements, the understanding of the business requirements by the stakeholders and the successful automation of business processes through information technology systems.

The question is whether it is only applicable to specific information technologies and information system projects. Referring to the following related work, the importance of the quality of the business requirements is not limited to a specific information technology, but is relevant to various information technology products:

- Decision support systems in South Africa (Averweg and Erwin, 1999).
- Enterprise resource planning system implementations (Skok and Legge, 2001; Somers and Nelson, 2001; Zhang, Lee, Zhang and Banerjee, 2002).
- Offshore outsourced projects (Balaji and Ahuja, 2005).
- Customer relationship management systems (Kim and Pan, 2006).
- Enterprise portals (Remus, 2006).

A further question to explore is whether there are any specific causes that contribute to the quality of the business requirements. Considering the following references, it is possible to derive a number of causes of success/failure that are related to the quality of the business requirements:

- In the 1990s, the business re-engineering drive information systems were critical to enable new business processes and inadequate business requirements resulted in failure (Caron, Jarvenpaa and Stoddard, 1994).
- The evaluation of an existing application cannot be limited to the system itself but should include its business context and the way an application is used within the organisation, motivating the need for comprehensive business requirements (Mende, Brecht and Osterle, 1994).

- Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters, and these needs should be reflected as part of the business requirements (Larsen, 2001).
- Partial understanding of the information given by the user is one of the pitfalls during the systems analysis and the definition of the (business) requirements stage (Drori, 1997). Lacking domain knowledge is an important cause of failure in systems development (Persson, 2000), and software process improvement success is positively associated with business orientation (Dyba, 2005).
- Modelling of business processes contributes to business process reengineering success (Amoroso, 1998), and it is essential to describe and understand enterprise architecture (Kaisler, Armour and Valivullah, 2005).
- System success or failure is linked to persistent questioning, which demands that the business value of any information system is considered for the entire enterprise whenever new systems proposals are envisioned (Kendall, 1997).

From the above, it is possible to conclude that it is a valid statement that business requirements indeed contribute to the success or failure of an information systems project.² In this section, the statement that comprehensive business requirements comprise a critical success factor for successful information systems project outcome is thus confirmed. The next step is to determine whether *business requirements* as topic in its own right is a valid research topic, and this is discussed in section 1.3.2 below.

1.3.2 Related Work: Business Requirements as Research Topic

The objective of this section is to establish whether the topic *business requirements* is an active research topic. As point of departure we consider general business requirements-related initiatives (section 1.3.2.1). The remainder of the related work is grouped according to factors to be considered to mitigate the causes, according to Verner et al. (1999), for inadequate business requirements, namely:

- *Inadequate (business) requirements gathering.* This should be mitigated by the validation of business requirements (section 1.3.2.2).

² Although excluded from the scope of this dissertation it is important to keep in mind that inadequate business requirements may only be symptoms, and the root cause may be the complexity of reality. Scheer, Abolhassen, Jost and Kirchmer (2002) refer to a model, and thus also a business process model, as a simplified reflection of reality. The question is whether a simplified reflection of reality is possible taking into consideration the following quote from Brooks (1987), if *software* is replaced with *business process*: “*The complexity of software is an essential property, not an accidental one. Hence, the description of a software entity that abstracts away its complexity often abstracts away its essence.*” There is still much to do to improve business requirements, considering the challenge of the complexity of real life.

- *Lack of user input because the customer would not make the time available.* This should be mitigated by requesting less time of the customer by re-using pre-defined business requirements as accelerator (section 1.3.2.3).
- *Misunderstanding by the customer of what the specifications really mean.* This should be mitigated by presenting multiple views for the better understanding of business requirements within a familiar context (section 1.3.2.4)

Sections 1.3.2.1, 1.3.2.2, 1.3.2.3 and 1.3.2.4 refer to related work in a specific area. The argument is that if there is a representative number of related work listed in each sub-section of section 1.3.2, it will be a motivation that *business requirements* is indeed an active research topic.

1.3.2.1 Business Requirements

Work related to business requirements addresses various aspects of requirements in general, and business requirements in particular, and includes but is not limited to the following list:

- Champion and Moores (1996) present a framework for the inclusion of enterprise information in the development of a software requirements specification.
- Francalanci and Fuggetta (1997) discuss new integration needs as a result of the orientation to a (business) process perspective in managing business activities.
- Pohl, Weidenhaupt, Domges, Haumer, Jarke and Klamma (1999) present a framework called PRIME (Process Integrated Modelling Environment), which provides method guidance for the engineers performing the software engineering process.
- Greenspan (2000) lists the challenges when attempting to move from theory to practice regarding (business) requirements engineering.
- Menzies (2000) discusses, from a software engineering perspective, the automatic tools required to reflect business knowledge to identify what is missing or what could be effectively changed throughout the systems development lifecycle.
- Astesiano and Reggio (2002) propose a way of structuring and representing the (business) requirements specification artefacts that is multi-view, uses case-driven and is UML-based.
- McGovern (2002) describes the value of trading traditional subsystem project planning for objective-based (business) requirements-driven project management.
- Tehrani and Ghazarian (2002) propose techniques to provide a mechanism for keeping track of (business) requirements and to help the development team to test the software in a more efficient way.
- Demirors, Gencel and Tarhan (2003) investigate the (business) requirements elicitation approach according to the business objectives and base lining business processes.

- Marschall and Schoenmakers (2003) present an overview of the basic concepts of a model-based (business) requirements engineering approach for web-enabled Business-to-Business (B2B) systems.
- Gan, Wei, Zhang and Varadharajan (2005) introduce a business-process-oriented requirements analysis model and a software requirements automatic generator.
- Kholkar, Krishna, Shrotri and Venkatesh (2005) argue that inadequate analysis of business requirements is a source of many defects in software application development and it is proposed to bridge the gap by extending the UML diagrams.
- Zou and Zhang (2006) present a framework that automatically generates business workplaces using workflow specifications.

There is indeed work, related to business requirements, emphasising that *business requirements* is an acknowledged research topic.

1.3.2.2 Validation of Business Requirements

Work related to the validation of business requirements addresses various aspects of the validation and verification of business requirements to ensure comprehensive business requirements, and includes but is not limited to the following list:

- Cohen, Larson and Ware (2002) designed a toolkit to rectify the most pervasive problem in software development, which according to them is the known fact that (business) requirements specifications are always incomplete, inaccurate and wrong.
- Correa and Werner (2004) propose a scenario-driven approach combined with animation and prototyping techniques in a highly iterative process, which allows the team to reach a precise definition in short and validated steps.
- Kazhamiakin, Pistore and Roveri (2004) propose a framework for representing strategies and goals of an organisation in terms of business requirements and a formal analysis technique to pinpoint problems.
- Lee and Rine (2004) address the problem of missing (business) requirements in software requirements specifications expressed in a natural language.
- Orriens and Yang (2005) explore how compatibility in collaboration designs can be handled in a verifiable manner by establishing a traceability mechanism.
- Melnik, Maurer and Chiasson (2006) state an interest in the capability of executable acceptance tests to communicate and validate functional requirements.

The validation and verification of business requirements are the focus of various related works to ensure more comprehensive business requirements.

1.3.2.3 Re-use of Business Requirements

Related work regarding the re-use of business requirements addresses various aspects to accelerate the business requirements definition process, and includes but is not limited to the following list:

- Daneva (2000) explores SAP (business) requirements re-use measurement. Daneva (2003) also describes lessons learnt from using generic off-the-shelf (business) requirements engineering models. These models apply proven and reusable (business) requirements engineering practices to deliver business requirements for newly implemented Enterprise Resource Planning (ERP) solutions or upgrades. (SAP is the product name for an ERP solution.)
- Ackermann and Turowski (2003) prepared a memorandum with the aim to set a methodical standard for the specification of business components to enable plug-and-play-like re-use.
- Mallya and Singh (2004) propose a business protocol concept enabling the definition of components that could be plugged in and out to readily adjust (business) processes.

Although the number of references are limited it is possible to find related work that focus on the re-use of business requirements to ensure that the precious time of customers is used in an optimal way.

1.3.2.4 Multiple Views for the Better Understanding of Requirements

Further related work on business requirement specification also addresses various aspects to enhance the better understanding of business requirements and includes but is not limited to the following list:

- Harker and Eason (1999) discuss the use of a scenario-based design that arises from a particular concern with the development of (business) requirements for systems.
- Hickey, Dean and Nunamaker (1999) devise a foundation for collaborative scenario elicitation by exploring the first step in that process, namely user definition of scenarios.
- Kaiya and Saeki (2004) propose a method to weave several goal graphs, each of which represents a viewpoint enabling an alternative (business) requirements specification if the initial specification is rejected by stakeholders.
- Arao, Goto and Nagata (2005) define a (business) requirement information model that contains both the business and system viewpoints to realise a technique by which customers (users) can understand the relationship between the business process and system/software functions.

- Bobrik et al. (2005) discuss (business) requirements of flexible (business) process visualisation in distributed environments, including (business) process data integration issues and issues related to adaptable (business) process visualisation.

There is no doubt that business requirements is an active research topic, and all three areas identified by Verner et al. (1999) as contributing causes for inadequate requirements, are addressed considering that there are various references to the validation, re-use and understanding of business requirements.

The reference to related work (sections 1.3.2.1, 1.3.2.2, 1.3.2.3 and 1.3.2.4) to business requirements not only confirms that it is an active research topic, it also positions various concepts and provides context when formulating the research questions for this dissertation in section 1.4.

1.3.3 Business Process Model Warehouse Concept

The primary objective of section 1.3.3 is to position the business process model warehouse concept. The intent is to integrate multiple business process reference models and to enable flexible visualisation of business processes to enhance the validation, re-use and understanding of the business requirements. The concept *business process model warehouse* is introduced to cater for these two specific criteria. The concept originated from the use of business process (model) warehouse, design warehouse and data warehouse in literature. A number of references are included to illustrate some aspects of this concept. The first two references refer to a concept similar to that of a business process model warehouse, as both refer to a repository populated with multiple business process models. The third reference is to a design warehouse, but the approach to compare a design warehouse with a data warehouse is very similar to the approach to compare a business process model warehouse with a data warehouse. The last reference is to a data warehouse, highlighting the similarities and differences between a data warehouse and a business process model warehouse.

- The concept *business process (model) warehouse* is mentioned in the article *Using SCOR and Other Reference Models for E-Business Process Networks* (Kirchmer, Brown and Heinzl, 2002). No specific definition is given for a business process (model) warehouse and it is only mentioned in a single sentence: “A business process (model) warehouse of (business process) reference models has been built, which creates, together with the defined procedures and the enabling ARIS tool a business process factory.”
- The concept *(business) process (model) warehouse* is also mentioned in the article *Requirements for the Visualization of System-Spanning Business Processes* (Bobrik et al., 2005) and, although ARIS

is also mentioned the concept is used in a different context. Bobrik et al. (2005) use *(business) process (model) warehouse* in the following way:

“[the] ARIS Process Performance Manager (PPM) can be considered as a tool for building (business) process (model) warehouses. It allows users to analyse (business) process performance properties. This includes aggregated views on a collection of (business) process instances as well as performance characteristics of single (business) process instances.”

- Laureri and Moke (1997) address the need of manufacturers who want to represent and store their know-how in a system containing all the elements of design and methods of presentation fitting the specificity of these data by referring to a data warehouse. Their definition of the design warehouse is based on the data warehouse concept, namely: “Just as the data warehouse, which it comes from, the design warehouse is an intermediate repository of technical and design data coming from production systems.”
- According to Gray and Watson (1998), two key characteristics of a data warehouse can be identified:
 - A data warehouse is typically a dedicated database system that draws most of its data from production systems.
 - Users *slice and dice* the data in desired ways.

In the article by Bobrik et al. (2005), there are statements that strongly relate to the data warehouse characteristics as described by Gray and Watson (1998), for example:

- “Since we want to integrate (business) process models from different source systems” – similar to the data warehouse sourcing data from various production systems, the business process model warehouse source business process models from different sources. Within the context of this dissertation, the sources for the business process models are specifically defined as business process reference models.
- “One-for-all visualisation will not fulfil expectations and (business) requirements. It should permit us to aggregate or remove parts of a (business) process schema or a (business) process instance, filter the elements according to their types and attributes, or combine several (business) processes in a single representation form” – this is very similar to the *slice-and-dice* concept of a data warehouse as described by Gray and Watson (1998).

At this stage there is no clear definition of a business process model warehouse, but based on the above-mentioned extracts, a business process model warehouse should at least integrate multiple

business process reference models (as source information). A business process model warehouse should also make provision for flexible visualisation of business process models similar to the slice-and-dice concept of a data warehouse. Based on the similarities between a data warehouse and a business process model warehouse, Chapter 3 discusses the business process model warehouse framework as analogy of a data warehouse framework. This is not a totally new approach as a similar approach was followed by Laureri and Moke (1997) to define a design warehouse. The aim of the business process model warehouse framework is to promote the re-use of multiple business process reference models and to enable the flexible visualisation of business process models.

1.3.4 Re-use of Business Process Reference Models

The objective of section 1.3.4 is to motivate the research questions which addresses the contributing factors to inadequate business requirements as listed by Verner et al. (1999). The proposed solution is based on the re-use of business process reference models. A business process reference model is a set of best practice business process models available for re-use and customisation in order to avoid re-inventing the wheel. (The concept of business process reference models is discussed in more detail in Chapter 4 and examples of business process reference models are included as part of Appendix A, B and C.)

The motivation for the re-use of business process reference models or even multiple business process reference models to mitigate the causes of inadequate business requirements, as listed by Verner et al. (1999) is as follows:

One approach to verify the quality of business requirements is to compare such business requirements with a predefined set of business requirements to measure consistency, completeness and integration. Business process reference models are available to use as predefined business requirements to mitigate the risk of inadequate business requirements gathering. Business process reference models can be used as accelerator with the definition of business requirements resulting in more value-adding work sessions and less time required from the customers, mitigating the risk of the customer not making the time available to provide input.

Various sets of business process reference models are available, giving the customer the opportunity to select the most understandable and applicable variant. An additional benefit is that information is available for end-to-end business processes as well as for different levels of granularity, giving definition even to business processes not yet defined as part of a specific project, enhancing the understanding of related business processes.

1.4 From Argument (Thesis) to Research Questions

In sections 1.2 and 1.3, the rationale for the argument (thesis) was discussed and it was concluded that business requirements is indeed an active research topic, paving the way to finalise the research questions. The research questions are stated within the context of the enterprise architecture domain, which is part of the information management discipline, with the enterprise architecture objective to bridge the gap between business and information management. The focus of section 1.4 is to derive the research questions from the stated argument (thesis).

The research questions are driven by the argument (thesis) and are derived from the views as reflected in the previous sections of Chapter 1. The argument (thesis) is stated in section 1.2 as:

The argument (thesis) is that a framework for a business process model warehouse can be proposed. The aims of the business process model warehouse framework are –

- *to promote the re-use of multiple business process reference models; and*
- *to enable the flexible visualisation of business process models.*

The critical success factor for such a business process model warehouse framework is that it should contribute to minimising to some extent the causes of inadequate business requirements as stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the (business) requirements really mean.

In order to report on the findings related to the argument (thesis) it is vital to explore a number of research questions. These research questions are centred around the –

- business process model warehouse framework;
- business process reference models; and
- flexible visualisation of business process models.

Regarding the business process model warehouse framework, there are a number of research questions to address:

- Is there any existing definition of a business process model warehouse framework to be considered when deriving a proposed business process model warehouse framework?
- Is it feasible to use the analogy of a data warehouse framework based on the characteristics of a data warehouse and a business process model warehouse framework?
- Is it possible to select a generic framework for a data warehouse to be used as foundation for the proposed business process model warehouse framework?

- Is there any similar analogy available that could provide valuable input for the analogy between a data warehouse framework and a business process model warehouse framework?
- Is it possible to propose a business process model warehouse framework based on the data warehouse framework?
- If the data warehouse framework is such a good analogy, what is the key differentiator forcing the development of a business process model warehouse framework?

In order to reflect on the promotion of multiple business process reference models there are some additional research questions to consider:

- Is it possible to confirm that the use of multiple business process reference models is an acknowledged concept?
- Which component(s) is(are) lacking in the current references to multiple business process reference models that should be addressed by the business process model warehouse framework?
- Is it possible to motivate the role of multiple business process reference models in minimising to some extent the causes of inadequate business requirements?

The argument (thesis) also refers to flexible visualisation of business process models. Some research questions to include are:

- Is it possible to motivate the value of flexible visualisation to minimise to some extent the causes contributing to inadequate business requirements?
- Is it possible to include examples to explain the concept of flexible visualisation of business process models?

1.5 Research Method

The primary research method is that of analogical reasoning. Straker (2002-2007) states that in analogical reasoning, an analogy for a given thing or situation is found, where the analogy is in some way *like* the given thing. Other attributes of the analogical situation are then taken to represent other attributes of the given thing as well.

To use an analogy:

- Start with a target domain where you want to create new understanding.
- Find a general matching domain where some things are similar to the target domain.
- Find specific items from the matching domain.
- Find related items in the target domain.
- Transfer attributes from the matching domain to the target domain.

The target domain in this dissertation is the business process model warehouse framework and the general matching domain is the data warehouse framework. The intent is to find related items between the data warehouse framework and the business process model warehouse framework.

The secondary research methods are indicated per chapter in section 1.6. These secondary research methods include literature reference, conceptual design and proof of concept.

1.6 Structure of Dissertation

The focus of the research questions are to propose a business process model warehouse framework. The purpose of section 1.6 is to explain the overall structure of the dissertation as well as to provide a more detailed research method per chapter. The theoretical foundation, the context, domains and key concepts are discussed in Chapter 2 to ensure that the scope of the dissertation is clearly defined. Figure 1.6 provides context to the *business process model warehouse framework* (body of the dissertation) and Figure 1.1 reflects the layout of the dissertation.

A data warehouse framework as discussed in Chapter 3 is the foundation for the context diagram represented in Figure 1.6. Chapter 3 gives an overview of the proposed business process model warehouse framework. Chapter 4 focuses on the business process reference models as source for the warehouse whereas the integration of the multiple business process reference models is discussed in Chapter 5. The repository management functionality is described in Chapter 6, and a flexible visualisation of business process models is addressed in Chapter 7. The findings are stated in Chapter 8 and the summary, reflections and value contribution are included in Chapter 9.

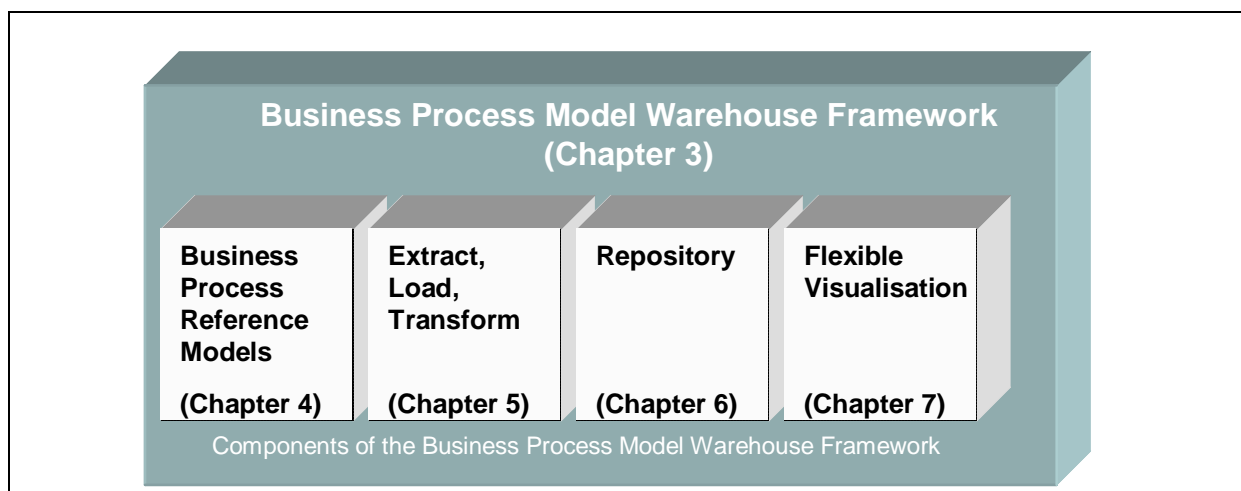


Figure 1.6: Context diagram business process model warehouse framework

1.6.1 Chapter 2 – Context and Domain Description

The key domains that are included in the content of Chapter 2 are the enterprise architecture and the data domains. Key concepts described as part of the enterprise architecture domain are *business architecture*, *business process*, *business process model*, *business process reference model* as well as *flexible visualisation of business process models*. As part of the data domain, the differences and similarities between a *database*, *repository*, *data warehouse*, *process warehouse* and *business process model warehouse* are highlighted.

1.6.2 Chapter 3 – Business Process Model Warehouse Framework

From the perspective of the argument (thesis), Chapter 3 is a key chapter as this is the place where the business process model warehouse framework is proposed. The following research questions are also addressed in Chapter 3:

- Is there any existing definition of a business process model warehouse framework to be considered when deriving a proposed business process model warehouse framework?
- Is it feasible to use the analogy of a data warehouse framework based on the characteristics of a data warehouse and a business process model warehouse framework?
- Is it possible to select a generic framework for a data warehouse to be used as foundation for the proposed business process model warehouse framework?
- Is there any similar analogy done that could provide valuable input for the analogy between a data warehouse framework and a business process model warehouse framework?
- Is it possible to propose a business process model warehouse framework based on the data warehouse framework?

The intent of Chapter 3 is to derive the business process model warehouse framework based on the description of a data warehouse framework, as found in literature, and to extend the definition by an analogy to applicable characteristics of a data warehouse.

The research method used in Chapter 3 is based on analogical reasoning.

1.6.3 Chapter 4 – Business Process Reference Models

From the perspective of the argument (thesis), the promotion of the re-use of multiple business process models is a focal point of Chapter 4. The following questions are addressed in Chapter 4.

The second question is however only briefly introduced in Chapter 4 and then explored in more detail in Chapter 5.

- Is it possible to confirm that the use of multiple business process reference models is an acknowledged concept?
- Which component(s) is(are) lacking in the current references to multiple business process reference models that should be addressed by the business process model warehouse framework?
- Is it possible to motivate the role of multiple business process reference models in minimising to some extent the causes of inadequate business requirements?

From the perspective of the business process model warehouse framework proposed in Chapter 3 the focus of Chapter 4 is the multiple source models for the warehouse, known as business process reference models.

The research method used in Chapter 4 is based on a literature reference with the subject the use of multiple business process reference models.

1.6.4 Chapter 5 – Extract, Load, Transform

From the perspective of the argument (thesis), Chapter 5 is not directly mentioned. However, as part of the research questions related to Chapter 4, the extract, load and transform (ELT) component of the business process model warehouse framework was identified as lacking in current literature references. The following question introduced in Chapter 4 is therefore discussed in more detail in Chapter 5.

- Which component(s) is(are) lacking in the current references to multiple business process reference models that should be addressed by the business process model warehouse framework?

From the perspective of the proposed business process model warehouse framework, the focus is the ELT component. The intent of Chapter 5 is to propose a method to be tested with a proof of concept (to integrate multiple business process reference models into a single repository). The proposed method is based on the following ELT principles:

- A detail understanding of each set of business process reference models to enable the EXTRACT.
- A logical design to accommodate the content of a set of business process reference models in the repository to enable the LOAD.
- A consolidated view of the different logical designs to ensure the integrity of the content of the repository to enable the TRANSFORM.

The criteria for the selection of business process reference models for the proof of concept are included in section 5.3. The background, analysis, abstraction and logical design of the selected business process reference models are described in more detail for the following business process reference models:

- Supply-chain Operations Reference-model (SCOR).
- IndustryPrint 3.0 reference model.
- SAP Solution Manager BPR reference model.

The primary research method used in Chapter 5 is analogical reasoning and the secondary methods are conceptual design and proof of concept.

1.6.5 Chapter 6 – Repository

The content of Chapter 6 is not directly related to the argument (thesis), but it answers the following research question:

- If the data warehouse framework is such a good analogy, what is the key differentiator forcing the development of a business process model warehouse framework?

From the proposed business process model warehouse perspective, Chapter 6 addresses the concept of the repository. The repository is similar to the data warehouse. From a technology enablement perspective, the repository is a critical success factor to integrate and configure multiple business process reference models. The concept of a repository is defined by

- differentiating the content of a repository from the typical content of a database; and
- including a description of the critical repository management functionality required to support the proposed method.

The research method in Chapter 6 is the comparison between a database and repository based on an analogy and the specification of functionality as referenced in literature.

1.6.6 Chapter 7 – Flexible Visualisation

From the perspective of the argument (thesis), the focal point of Chapter 7 is the enablement of flexible visualisation of business process models. The following research questions are specifically addressed:

- Is it possible to motivate the value of flexible visualisation to minimise to some extent the causes contributing to inadequate business requirements?

- Is it possible to include examples of the flexible visualisation of business process models to explain the concept of flexible visualisation of business process models?

From the perspective of the proposed business process model warehouse framework, Chapter 7 focuses on the flexible visualisation component. The concept of flexible visualisation of business process models is motivated and requirements are defined based on the inclusion of various examples.

The research method used in Chapter 7 is the analysis of examples found in literature.

1.6.7 Chapter 8 – Findings

The findings based on the research questions as addressed in the various chapters are included in Chapter 8. The findings related to the argument (thesis) are also stated in Chapter 8.

1.6.8 Chapter 9 – Conclusion

A summary of the dissertation as well as a reflection on the method, the value contribution and future research questions are part of the closure in Chapter 9.

1.7 Conclusion

In Chapter 1, the argument (thesis) is introduced, namely: It is possible to propose a business process model warehouse framework, promoting the re-use of multiple business process reference models and flexible visualisation of business process models, thereby minimising to some extent the causes of inadequate business requirements stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the business requirements really mean.

A positive finding related to the argument (thesis) will not only add value to the enterprise architecture domain but also to the information management discipline in general. From an information management perspective, the quality of the business requirements is important for two reasons, namely firstly improving the quality of the business requirements should reflect an increase in the success rate of information system implementations, and secondly this current research is also particularly concerned with the positive role that a repository (an information system) can play in

enabling the business requirements process. None of the concepts are totally new, but proposing a business process model warehouse framework will contribute to the enterprise architecture domain by giving context to a number of concepts and providing a foundation for further discussion.

The objective of Chapter 2 is to define the scope of the dissertation clearly. The focus is to provide a domain description, to contextualise and relate concepts and to state the inclusions and exclusions for further discussions. The domains to be discussed in Chapter 2 are the enterprise architecture domain and the data domain.

Bridging the gap between business requirements and information system enablement is still a challenge. One of the contributing factors to the failure of an information system project is inadequate business process requirements. Although various disciplines, including project management and software engineering, are involved to ensure delivery of successful information system projects, this dissertation will focus on the role of enterprise architecture in bridging the gap. Business process requirements are part of the business architecture and the business architecture is a key component of the enterprise architecture domain as discussed in Chapter 2.

The re-use of business process reference models, available in a business process model warehouse, to enable the definition of more comprehensive business process requirements is part of the research questions. The challenge is to define a business process model warehouse framework and the research method includes the analogy between a data warehouse framework and a business process model warehouse framework. From the research methodology perspective, the data domain is thus prominent, and is included in the domain discussion in Chapter 2.

CHAPTER 2: CONTEXT AND DOMAIN DESCRIPTION

The objective of Chapter 2 is to position the scope of this dissertation within the context of the enterprise architecture and the data domains, and to ensure a common understanding of the terminology. The relevance of the enterprise architecture and the data domains to this dissertation is motivated in Chapter 1 and can be summarised as:

- The *enterprise architecture* is the domain within information management that addresses the problem known as *bridging the gap between the business requirement and the information system implementation*. The research question includes the objective to minimise the causes of inadequate business requirements, thereby bridging the gap between business requirements and the information system implementation.
- The data domain, including the data *warehouse* domain, is a key source in deriving a business process model *warehouse* framework. Proposing a business process model warehouse framework is the focus of the research questions. As stated in Chapter 1, the research method is to learn from another warehousing domain, the data warehousing domain.

In section 2.1 the enterprise architecture domain will be discussed, while the data domain will be considered in section 2.2. The intent is to provide context, give a definition or description and, if applicable, an example for each concept.

2.1 Enterprise Architecture Domain

Stevenson (1995) relates a quote from Saarinen in Time magazine of 2 July 1956 to enterprise architecture. Saarinen states, “Always design a thing by considering it in its next larger context – a chair in a room, a room in a house, a house in an environment, an environment in a city plan.” Similarly, as depicted in Figure 2.1, a business process is represented by a business process model, a business process model is part of the business architecture, and the business architecture is a domain of the enterprise architecture. Please note that *business architecture* is positioned as part of section 2.1.2 dealing with the enterprise architecture framework. In section 2.1.3, *business process* is defined before addressing the concept of a business process model. The rationale is that a “model” is an abstract representation of reality, therefore a business process model is a representation of a business process and if a business process is undefined, it will be difficult to define a business process model.

There is a parallel between enterprise architecture and other disciplines such as city planning (Stevenson, 1995) and the architect’s deliverables produced in the process of constructing a building

(Zachman, 1987). As an introduction to the discussion of enterprise architecture, business architecture, business processes, business process models, business process reference models and flexible visualisation of business process models, examples from the architectural discipline are included to illustrate the concepts.

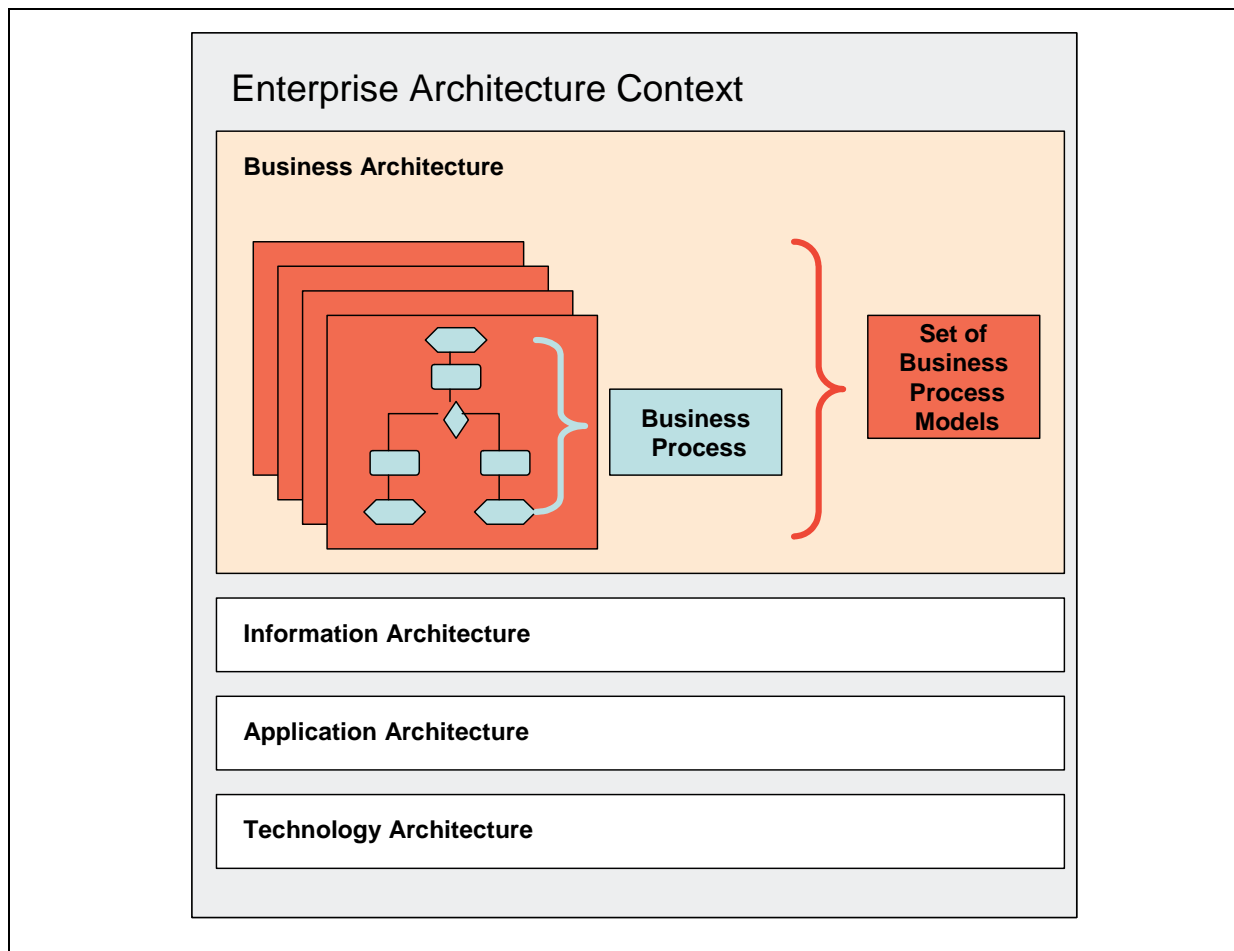


Figure 2.1: Enterprise architecture context

2.1.1 Architect's Deliverables

In 1987, Zachman proposed the analogous information systems architectural representation by first examining the traditional architectural deliverables produced in the process of constructing a building (Zachman, 1987). The Zachman framework will be discussed in more detail in section 2.1.2. The purpose of this section is not to describe the analogy performed by Zachman in detail but to highlight some pertinent principles and to extend it in order to explain, in a similar architectural language, the scope of this dissertation. Please note that the included graphics are for illustrative purposes only and hence the detail and quality of some of the figures may not be ideal. A number of principles related to the architectural and building domains are listed based on Figure 2.2 from Creative Homeowner (2004).

- The first principle is that there is a set of architectural representations produced over the process of building a complex engineering product representing the different perspectives of the different participants. In Figure 2.2, the frontal sheet and the floor plan represent the perspective of the homeowner whereas the foundation plan and the roof plan are of greater importance for the builder.
- The second principle is that the same product can be described in different ways for different purposes, resulting in different types of descriptions. It is important to note that these different perspectives are not necessarily displaying a level of detail greater than the previous one. These perspectives may also differ by nature, in content and in terms of semantics.
- The third principle is that not all information related to building a house is represented as part of the set of architectural representations. As mentioned by Swift, Goodbrand and Szymanowski (2006), more are involved than only the architectural representations. Other information includes, for example, information related to the transfer of land, costing and raising of funds, and the actual building and certification.
- The fourth principle is that predefined home plans are often re-used as basic reference home plans that constitute part of the process for developing the architectural representations. Examples of such home plans (Creative Homeowner, 2004) are included as Figure 2.3.
- The fifth principle is that there are multiple sets of reference material available for different architectural representations. Figure 2.4 includes examples of predefined kitchen lay-outs (Grobbelaar, 2006) and similarly, there could be predefined bathroom layouts or multiple publications of home plans.
- The sixth principle is that there is a difference between predefined kitchen layouts (Grobbelaar, 2006) as depicted in Figure 2.4 and predefined kitchen units (Grobbelaar, 2006) as depicted in Figure 2.5 that may be used to design a kitchen layout from the inception stage.

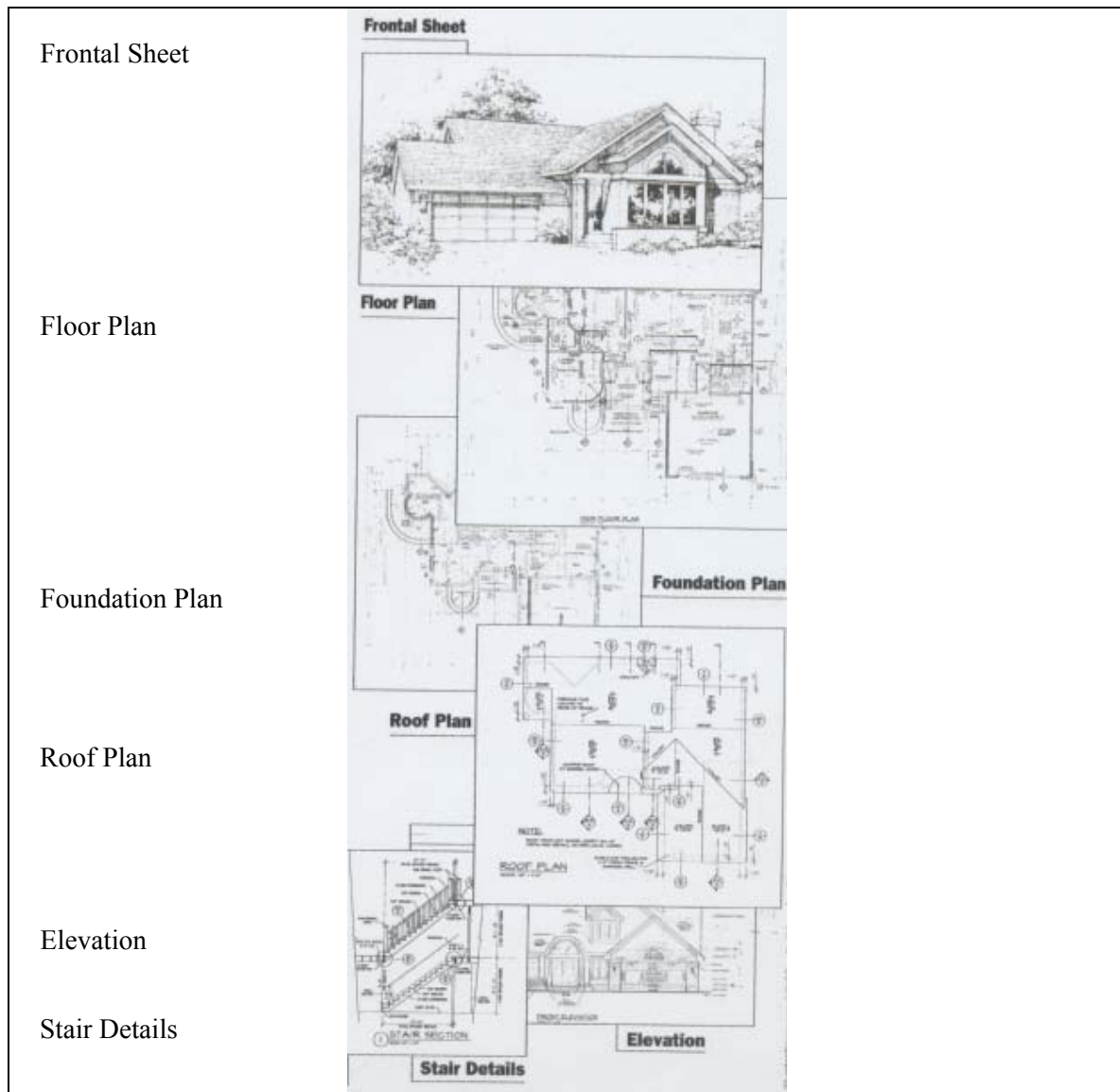


Figure 2.2: Architectural representations (Creative Homeowner, 2004)

- The seventh and last principle is that a cross-section, as included in Figure 2.6, is actually a flexible visualisation of the different representations. The cross-section does not contain any additional information but provides a different angle on the existing representation. It is important to note that there should not be any inconsistencies between the different architectural representations including any cross-section representations.

With the architectural language positioned and a number of principles listed, it is now possible to use this language to present, by analogy, an indication of a number of concepts to provide context to the scope of this dissertation. Not only will this give an indication of the inclusions, but also of some exclusions in order to ensure a better demarcation of the scope of this dissertation.

- The first principle, namely that of a set of architectural representations, is similar to the various representations included as part of the enterprise architecture framework, for example the business process architecture, information architecture and application architecture. Derived from the first principle, there are two important pointers to keep in mind regarding the scope of this dissertation. The first pointer is that in the case of the business process architecture, different perspectives, as defined for the home owner and the builder, are also relevant for the business process model. The second pointer is that only the business process architecture is included and other representations of the enterprise architecture framework are excluded from the scope of this dissertation. (The business process model concept is discussed in more detail in section 2.1.4 and the enterprise architecture framework concept is discussed in section 2.1.2).
- Considering the second principle, namely that the various perspectives are different by nature and do not just include a greater level of detail, is still relevant for the business process model. In the case of a business process model, one person may for example prefer a role-based perspective whereas another role-player may judge a compliance-based perspective to be more informative. Representing the same level of detail may also result in various representations. It is important to keep the various representations in mind to understand the concept of flexible visualisation of business process models discussed as part of this dissertation.
- Based on the third principle, namely that building a house involves more information than just the architectural representations, it should be noted that there are similarities considering business processes. The representation of a business process as a business process model does not include all possible information about a business process. In this dissertation, the focus is on the business process model, and although the importance of all other business process-related information is acknowledged it is excluded from the scope of this dissertation. This is an important pointer to gain a better understanding of the discussion of a process warehouse (excluded from the scope of this dissertation) versus a business process model warehouse (included in the scope of this dissertation) in section 2.2.3.
- The fourth principle concerns the referencing of published home plans and re-using these existing home plans as accelerator for the design of a new home plan. Referencing published business process models is a key concept within this dissertation, and these published business process models are also known as business process reference models. Refer to section 2.1.5 for a more comprehensive introduction to business process reference models.

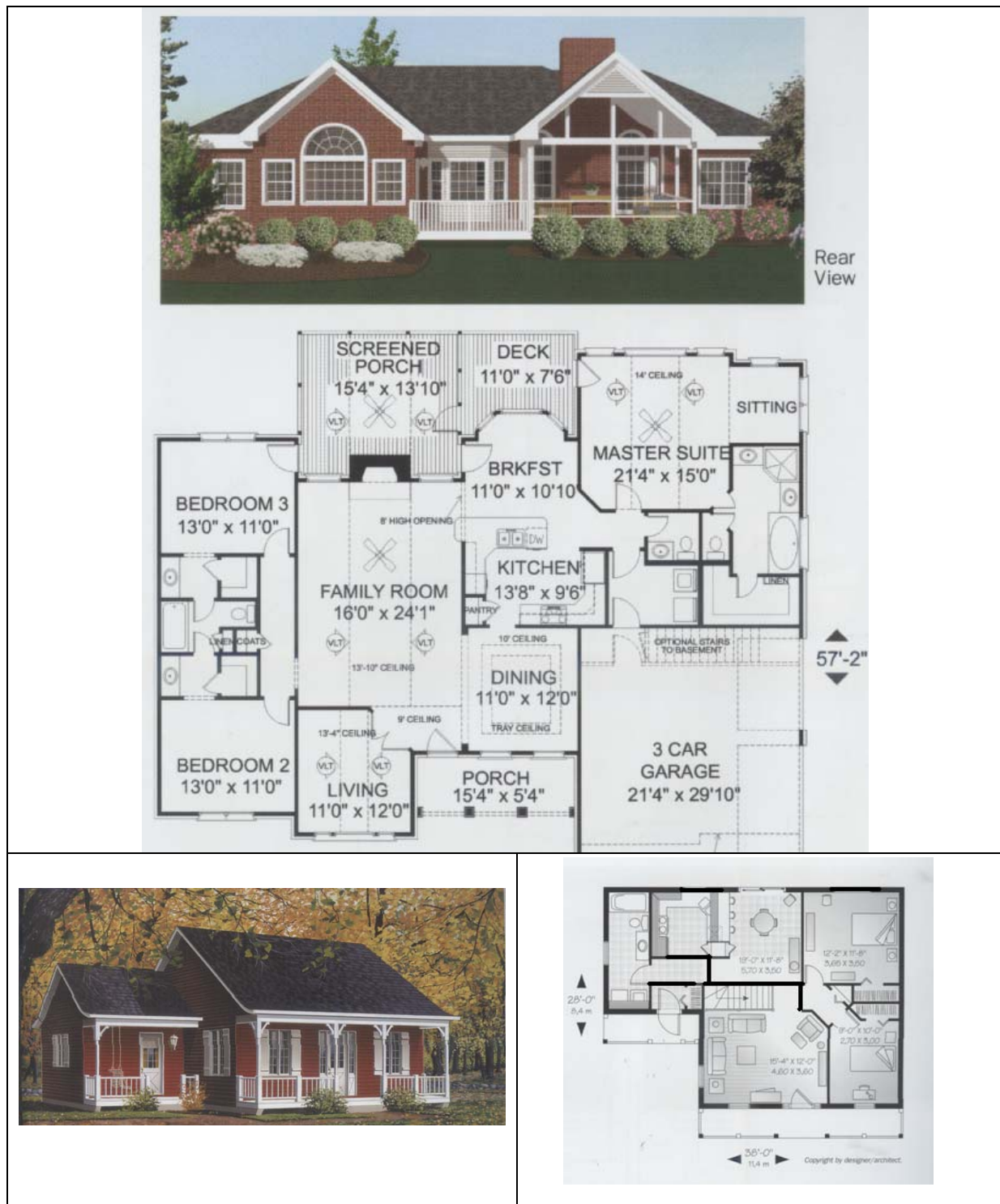


Figure 2.3: Home plans (Creative Homeowner, 2004)

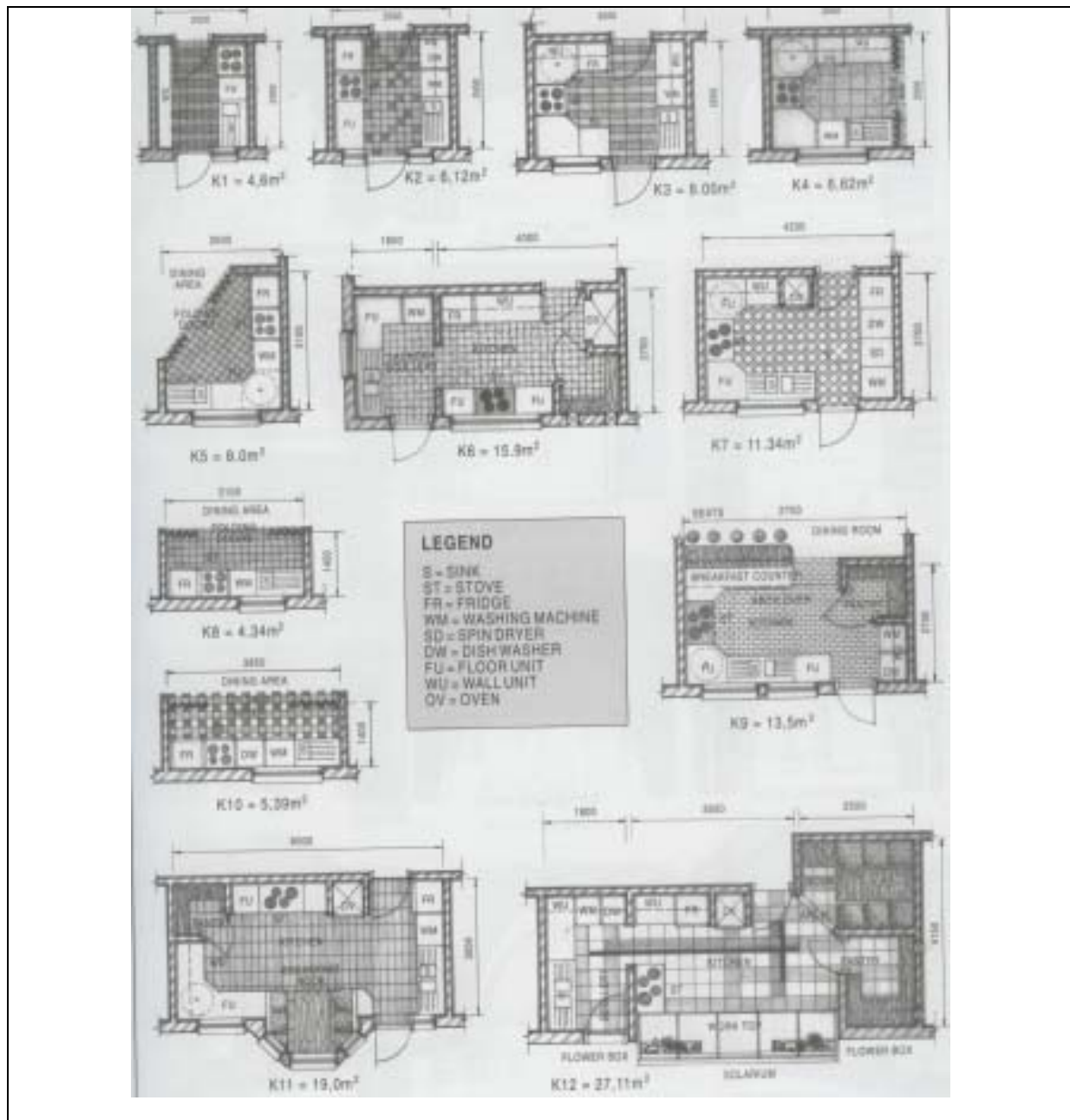


Figure 2.4: Predefined kitchen layouts (Grobbelaar, 2006)

- The fifth principle is an extension of the previous principle as it extends the concept of a single reference model to multiple reference models. Selecting home plans as well as kitchen and bathroom layouts from multiple sources is common practice. Similarly, there is a need to refer to business process models from different perspectives or even different levels of detail, also referred to as part of this dissertation as multiple business process reference models.
- Considering the sixth principle, explaining the difference of referring to predefined kitchen layouts and re-using kitchen units to design a new kitchen, a similar principle is applicable to business process models. It is possible to refer to predefined business process models, but it is also possible to derive a business process by combining predefined components. For the purpose

of this dissertation, the focus is on the re-use of predefined business process reference models and not on the definition of business processes by re-using predefined components.

- Principle seven highlights that there is a need to derive new representations based on the existing information in the different architectural representations, also known as cross-sections (Figure 2.6). From a business process model perspective, there is a similar requirement known as *flexible visualisation of business process models* and these are included as part of the scope of this dissertation. A key concept is that there should be no inconsistencies between these different *cross-sections* of the business process.

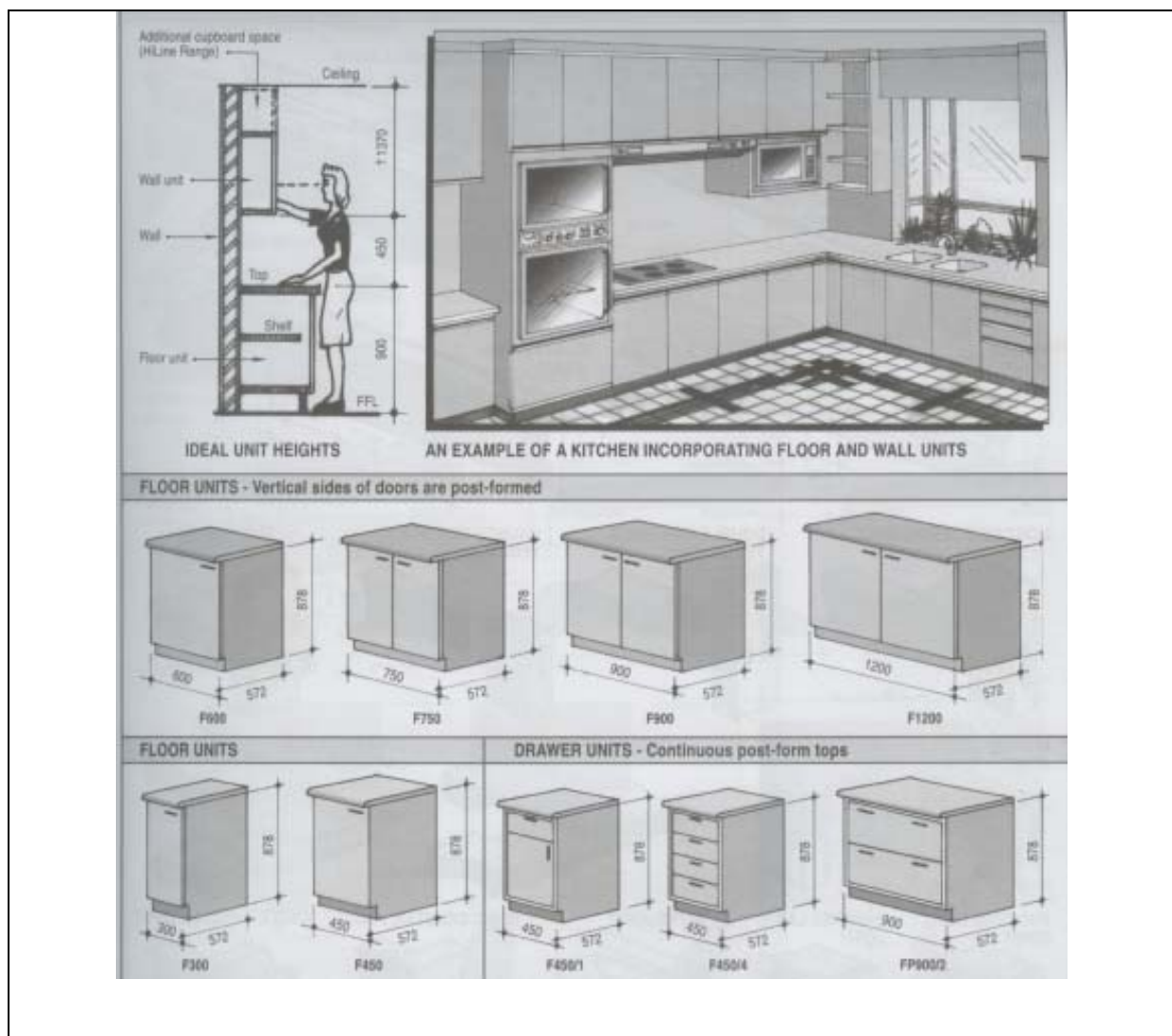


Figure 2.5: Predefined kitchen units (Grobbelaar, 2006)

It is possible to explain to some extent the re-use of business process reference models to address inadequate business requirements, using the language of the architectural discipline. Basically it is similar to the re-use of several of the predefined home plans and various layouts to use as accelerator to design a new home plan and its associated layout. The second challenge is to create the various

cross-sections or even to generate it from the existing plans. Instead of applying this to the home plans and cross-sections, the application as part of this dissertation is to a business process model warehouse. In the remaining sections of Chapter 2, the objective is to give a more formal description of the concepts and principles introduced in section 2.1.1.

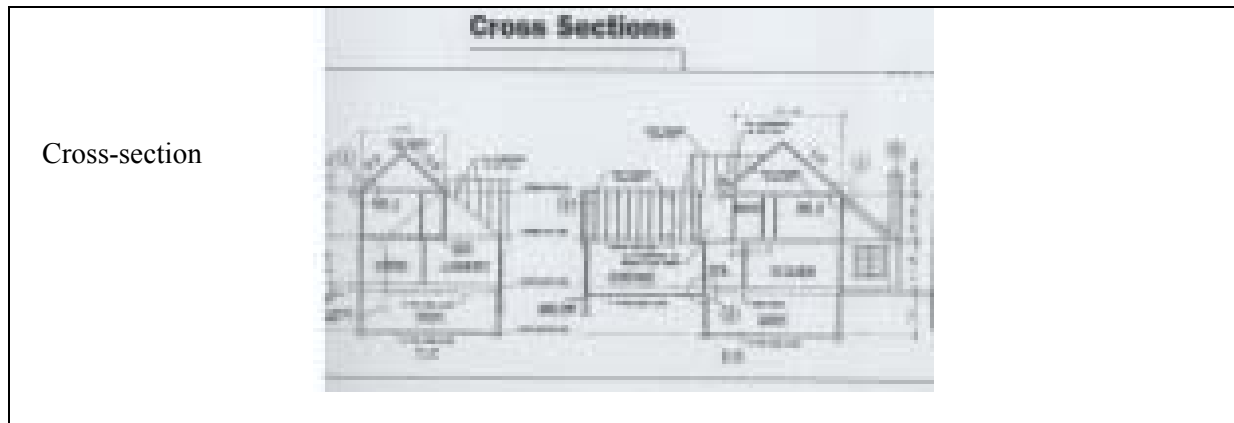


Figure 2.6: Cross-section (Creative Homeowner, 2004)

2.1.2 Enterprise Architecture

2.1.2.1 Theoretical Foundation for the Enterprise Architecture Concept

As mentioned previously, enterprise architecture is about bridging the gap between the business and information management. A number of references to enterprise architecture are found in literature, and among others include:

- Pulkkinen (2006) confirmed that enterprise architecture is a well-suited tool for interconnected planning of business strategies, models and structures, and general information technology architectures.
- Whitman et al. (2001) rephrased *enterprise architecture* as fundamental for enabling the assimilation of internal changes in response to external dynamics and uncertainties of the information age environment. According to Whitman et al. (2001), enterprise architecture not only constitutes a baseline for managing changes, but also provides the mechanism by which the reality of the enterprise and its systems can be aligned with management intentions.
- Stevenson (1995) maintains that it is the master plan, which *acts as integration force* between:
 - Aspects of business planning such as goals, visions, strategies and governance principles.
 - Aspects of business operations such as business terms, organisation structures, business processes and data; aspects of automation such as application systems and databases.

- The enabling technological infrastructure of the business such as computers, operating systems and networks.
- As part of TOGAF³, The Open Group (1999-2006) embraces the ANSI/IEEE standard 1471-2000 regarding an architecture, namely “The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution.”
- In the definition given by Inmon, Zachman and Geiger (as cited by Whitman et al. (2001) is stated as “An architecture is that set of design artefacts, or descriptive representations, that are relevant for describing an object such that it can be produced to requirements as well as maintained to the period of its useful life.”

These various perspectives on enterprise architecture are not contradictory and provide a foundation for further discussions. For the purpose of this dissertation, these references provide context.

2.1.2.2 Enterprise Architecture Framework

However, it is important to differentiate between an enterprise architecture and an enterprise architecture framework. Inmon, Zachman and Geiger (as cited by Whitman et al., 2001) define a framework as –

“The framework as it applies to the enterprise is simply a logical structure for classifying and organizing the descriptive representations of an enterprise that are significant to the management of the enterprise as well as to the development of the enterprise’s systems.”

According to the definition included in TOGAF (The Open Group, 1999-2006), an architecture framework is a tool that can be used for developing a broad range of different architectures.

Typical characteristics of an architecture framework are listed by TOGAF as:

- It should describe a method for designing an information system in terms of a set of building blocks, and for showing how the building blocks fit together.
- It should contain a set of tools and provide a common vocabulary.
- It should also include a list of recommended standards and compliant products that can be used to implement the building blocks.

For the purpose of this dissertation, three such frameworks are briefly reviewed (Figure 2.7):

³ TOGAF refers to The Open Group Architecture Framework

- The Zachman framework, depicted in Figure 2.8 (Zachman, 1987; Hay, 2006), as it is based on the analogy to the architectural discipline.
- An enterprise architecture grid (Pukkinen, 2006), included in Figure 2.9, as it provides context for the business architecture domain as part of the enterprise architecture domains.
- The nine architectural sectors of metadata, included in Figure 2.10 (Blechar, 2003), as the cells are used to explain and motivate the selection of the specific business process reference models for the case study discussed in Chapter 5.

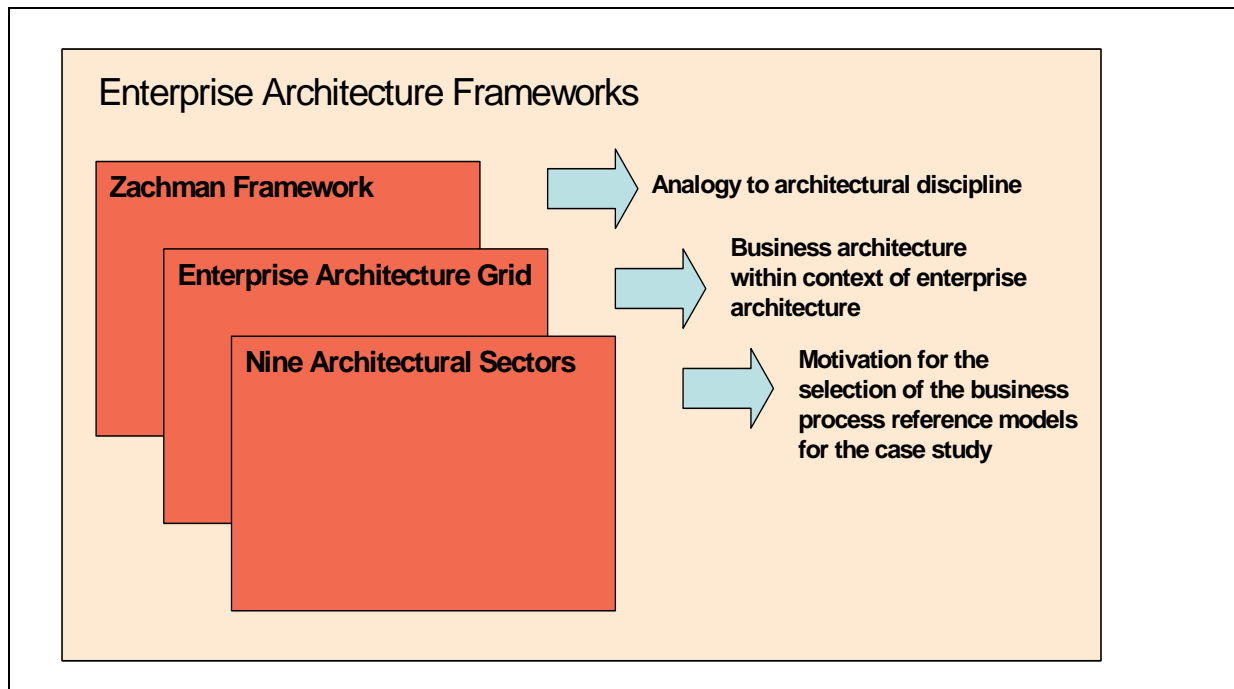


Figure 2.7: Enterprise architecture frameworks

As the Zachman analogy to the architectural representations is the basis for the language definition in section 2.1.1, a subset of the Zachman framework, as defined in 1987, is included. The scope of this dissertation is limited to the PROCESS (HOW) column of Figure 2.8, as the content of the business process reference models is well represented by this PROCESS (HOW) column. The rows and columns concern the grouping or classification of the different perspectives according to a predefined framework.

Pulkkinen (2006) argues that the Zachman framework has been perceived as too analytical and detailed for communication to the business and for high level planning. Another drawback with frameworks like Zachman is that the Zachman framework lacks the technology dimension at the higher abstraction level. The enterprise architecture grid (Figure 2.9) is the result of taking the four main architectural domains and the decision-making levels as three main abstraction levels. The four

architectural domains (Pulkkinen, 2006) have a strong correlation with the TOGAF (The Open Group, 1999-2006) types of architecture, namely:

- Business (or business process) architecture.
- Data (information) architecture.
- Application (system) architecture.
- Technology architecture.

	DATA (WHAT?)	PROCESS (HOW?)	NETWORK (WHERE?)
Scope description (ballpark view)	List of entities important to the business	List of processes the business performs	List of locations in which the business operates
Model of the business (owner's view)	Entity-Relationship Diagram	Functional Flow Diagrams	Logistic Network
Model of the information system (designer's view)	Data Model	Data Flow Diagram	Distributed System Architecture
Technology model (builder's view)	Data Design	Structure Chart	System Architecture
Detailed description (out-of-context-view)	Data Base Description	Programs	Network Architecture
ACTUAL SYSTEM	DATA	FUNCTION	COMMUNI-CATION

Figure 2.8: Zachman framework (Zachman, 1987)

The business process model warehouse framework is strongly related to the business architectural domain with a minor overlap to the application architecture. The cells related to the case study in Chapter 5 are highlighted in Figure 2.10. The other architectural domains are excluded from the scope of this dissertation as the content of the examples from the business process reference models is well positioned within the business and application architecture.

	BUSINESS ARCHITECTURE	INFORMATION (DATA) ARCHITECTURE	SYSTEMS (APPLICATION) ARCHITECTURE	TECHNOLOGY ARCHITECTURE
Enterprise level	Business and management decisions, portfolio of businesses. Mission, business strategies and visions.	Strategic information management considerations; Information Value chain	Strategic systems portfolio (Application portfolio)	Strategic technology portfolio; Vendor relationships; Enterprise technology guidelines and policies
Domain level	Services/products in the domain. Business processes for their production.	Information management of the domain	Domain systems map; Interoperability	Technologies Infrastructure: platforms, networks, data communication
Systems level	Business requirements for systems and data management.	Data architecture; Data harmonization principles; Data storages	Systems architecture; ISA, Application patterns; Developer guidelines	System-level technology architecture; Technical implementation guidelines

Figure 2.9: Enterprise architecture grid (Pulkkinen, 2006)

BUSINESS ARCHITECTURE	APPLICATION ARCHITECTURE	TECHNICAL ARCHITECTURE	
1	2	3	Conceptual level
4	5	6	Logical level
7	8	9	Physical level

Figure 2.10: Nine architectural sectors of metadata (Blechar, 2003)

Following the advice by Saarinen (Stevenson, 1995) in section 2.1.2, the concepts can be related as follows:

- A business process within a business process model.
- A business process model within the business architecture.
- The business architecture within the enterprise architecture. Section 2.1.3 will define a business process in more detail.

2.1.3 Business Process

A number of perspectives from various references are included as theoretical background and as examples of the definition of a business process:

- A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer (Hammer and Champy, as cited in Barothy, Peterhans and Bauknecht, 1995).

- (Business) processes are structured sets of work activity that lead to specified business outcomes for customers (Davenport and Beers, 1995).
- A business process is nothing more than logically related tasks that use the resources of a company to achieve a defined business outcome (Grover, Kettinger and Teng, 2000).
- The term *business process* is intended to embrace not only the control flow, i.e. the chronological sequence of function execution, but also the descriptions of data, organisations and resources that are directly associated with it (Scheer et al., 2002).
- The definition of a business process within the context of the MIT Process Handbook initiative is based on coordination theory, specialisation of (business) processes and inheritance. Business processes are organised in an extensive hierarchical network, somewhat similar to the organising principle used in biological classification (Malone, Crowston and Herman, 2003).

Service-oriented architecture extends the definition of a (business) process. A (business) process can be a simple (business) process, including only a sequence of activities, or a complex (business) process including a controlled composition of services and activities performed under condition, in parallel or encapsulated in sub-processes. According to Aversano and Canfora (2002), in order to define a (business) process, it is necessary to define:

- Activities, the basic elements of a (business) process and the assignment of resources.
- Business services providing a business operation.
- Business logic, including the rules that define the control flow during the (business) process execution.

A detailed consolidation of the various referenced definitions is excluded from the scope of this dissertation. The focus of this dissertation is on a business process model warehouse, and the definitions listed in this paragraph are all acceptable definitions to accomplish the set goal. With the definition of a business process in place it is feasible to explore the business process model concept. In this dissertation, a simplified version of the definition by Aversano and Canfora (2002) is selected, namely, a business process is defined by the activities, the assignment of resources and the rules that define the control flow.

2.1.4 Business Process Model

If the enterprise architecture is represented by the different architectural perspectives in Figure 2.2, then the business process model is represented by one of the specific architectural perspectives, for example the floor plan.

2.1.4.1 Theoretical Foundation for Business Process Model

With a definition for a business process in place the next step is to define a business process model. According to Curtis, Kellner and Over (1992), a model is an abstract representation of reality that excludes much of the world's infinite detail. The purpose of a model is to reduce the complexity of understanding or interacting with a phenomenon by eliminating the detail that does not influence its relevant behaviour. A business process model specifically is an abstract description of an actual or proposed business process that represents selected business process elements that are considered important to the purpose of the model and which can be enacted by a human or machine. Whitman et al. (2001) give a similar definition:

“A model is an abstract representation of reality. Details that are unnecessary are not included as a rule in most modelling efforts. The modeller determined which aspects of the real system are of interest and which system elements are to be modelled.”

The description of a business process model varies significantly in granularity. Often a business process model is considered a product and the relationship between products of the development process at the level of documents. For the purpose of this dissertation, as described in Pohl et al. (1999), a more fine-grained structure is required including the objects, relationships and attributes defining the content of the business process model. Ultimately, business process models must support multiple levels of abstraction to serve various needs (Curtis et al., 1992).

The business process model is typically a graphical representation of the business process. Curtis et al. (1992) list a number of uses and resultant requirements for business process models, namely:

- To facilitate human understanding and communication requires that a group shares a common representational format.
- To support business process improvements requires a basis for defining and analysing business processes.
- To support business process management requires a defined business process against which actual project behaviours can be compared.
- To automate business process guidance requires automated tools for manipulating business process descriptions.

The definition and management of business process models imply the use of a formal language with an underlying operational semantics that ideally enables mechanical interpretation of the business process models (Pohl et al., 1999). If a formal business process modelling approach is used, the

modelling notation can be used to prompt further information gathering, thereby preventing inadequate business requirements as end result (Nuseibeh and Easterbrook, 2000).

2.1.4.2 Business Process Model Notation

Business process modelling is one of the most commonly used techniques in requirements analysis, often taking the form of data-flow diagrams. Many new techniques for business process modelling have been developed. While these techniques differ in important ways, they all have two common structures: a language for specifying the business process model and a process for collecting the model's information (Dennis, Hayes and Daniels, 1999). Most approaches to business process modelling focus on some sort of business process diagram, which shows how activities are coordinated in the course of a business process. There is little disagreement about the key elements of a business process diagram: it should contain activities and activity connectors. In addition, there are usually ways to represent decision points, and ways to express various activity coordination patterns, such as sequential flow, branching and parallel execution. Some techniques introduce swim-lanes to indicate the responsibilities of participants, such as departments or individuals, thus representing the activities these actors perform in the context of the business process. The notation used for these different languages differs and a number of these notations are listed to give an indication of the variety:

- Petri nets: Petri nets gained increase usage and acceptance as method for describing information flow and control (Peterson, 1977). As a modeling language, it graphically depicts the structure of a distributed system as a directed graph with annotations. As such, a Petri net has place nodes, transition nodes, and directed arcs connecting places with transitions.
- State transition diagrams: State transition diagrams are used for various specifications (Chung and Gaiman, 1978).
- IDEF: Historically, IDEF standards are developed in 1981 within an extensive program for automation of the industrial company ICAM (Integrated Computer Aided Manufacturing) and had been offered from the Air-force Department of the USA. IDEF standards had received their name exactly from that program, IDEF=ICAM DEFinition (Mladenova and Zhelyazova,2007).
- On 18 October 1988, Ed Yourdon presented a lecture and the message was clear that one needs multiple modelling tools to document a complex multi-dimensional system. He continued that one needs a combination of data flow diagrams, entity relationship diagrams, state transition diagrams, a data dictionary and (business) process specifications (Yourdon, 1988).
- EPC: Event-driven process chains (EPCs) are being used in the area of business process modelling and reference modelling (Mendling, Recker, Roseman and Van der Aalst, 2006). The Institute for Information Systems at the University of Saarbrücken together with SAP AG

developed the EPC method. The EPC method contains elements of Petri nets and stochastic networks, in particular the graphical evaluation and review technique propounded by Elmaghraby (Scheer et al., 2002; Stefanov, List and Schiefer, 2005).

- Unified Modelling Language (UML): UML is used when modeling business processes using object-oriented analysis tools.. Rumbaugh, Booch and Jacobson developed UML as a universal notation for object-oriented analysis (Mladenova and Zhelyazova,2007).
- Business Process Management Notation (BPMN, 2006): A standard Business Process Modelling Notation (BPMN) provides businesses with the capability of understanding their internal business procedures in a graphical notation and it also provides organisations with the ability to communicate these procedures in a standard manner. Furthermore, the graphical notation facilitates the understanding of the performance collaborations and business transactions between organisations. This ensures that businesses understand themselves and participants in their business and it enables organisations to adjust to new internal and B2B business circumstances quickly (Object Management Group2007,).
- XML and BPEL: eXtensible Markup Language (XML) is becoming rapidly the premier method for exchanging information across the internet (Routledge, Bird and Goodchild, 2002). The Business Process Execution Language for Web Services (BPEL4WS or BPEL in short) is used as interaction language for web services. BPEL is XML-based in a textual format and contains complex constraints.
- MIT Process Compass: The definition of a business within the context of the MIT Process Handbook initiative is based on coordination theory, specialisation of (business) processes, and inheritance. Business processes are organised in an extensive hierarchical network, somewhat similar to the organising principle used in biological classification (Malone et al., 2003). The structure is also known as a process compass. From any activity in the MIT Process Handbook one can go in four different directions as indicated in Figure 2.11:
 - Down to the different parts of the activity (its sub-activities).
 - Up to the larger activities of which the one under consideration is a part of (its uses).
 - Right to the different types of this activity (its specialisations).
 - Left to the different activities of which this one is a type (its generalisation).

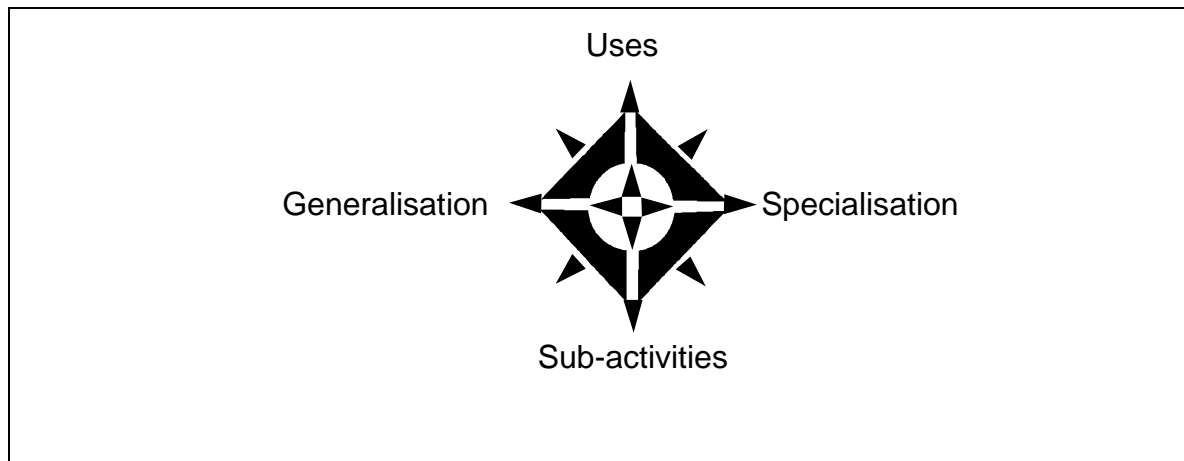


Figure 2.11: MIT Process Handbook process compass
(Malone, Crowston and Herman, 2003)

2.1.4.3 Business Process Model in the Context of this Dissertation

Please note that the bibliographic reference material included may refer to various terms, for example *process model*, *business process model*, *software process model*, *enterprise process model*. It is acknowledged that there are valid reasons to differentiate between these terms. However, within the context of this dissertation, with the objective to propose a business process model warehouse framework, it should not have a major impact using different terms to refer to a (business) process model/diagram/graph. A similar argument is valid for the use of process or business process. Within the context of this dissertation, *business process* and *business process model* will be used if the term is not referring to a specific bibliographic reference in literature.

As the focus is on using various business process models as source information for the business process model warehouse (to be put in context in section 2.2), the proposed approach makes provision for the upload of various business process model notations into the business process model warehouse. The flexible visualisation of the content of the business process model warehouse also includes the presentation of the business processes in various business process model notations. Section 2.1.5 will explore the business process reference model concept, and the business process model notation used per business process reference model is not a constraint. The assumption is however that the business process model notation will not vary within a specific business process reference model.

2.1.5 Business Process Reference Models

Business process models that are available for re-use are referred to as *business process reference models* (Ramesh and Jarke, 2001). In the broader context, a reference model can be defined as a subset of the enterprise architecture artefacts based on best practices pre-populated in a repository. For the scope of this dissertation, the focus is specifically on business process reference models. However, in literature, the terminology is often loosely used and the adjective is sometimes not included and only implied by the context in which the term is used. Within the context of this dissertation, the use of the term *reference model* will imply a reference model in the broader context of focusing on any artefacts. The term *business process reference model* will be used to refer specifically to a reference model containing business process model artefacts. Please note that in the bibliographic reference material included and referred to in this dissertation, the distinction may not be that clear.

2.1.5.1 Theoretical Foundation for Business Process Reference Model

An enterprise wishing to automate its business processes needs to analyse and model such business processes to develop custom solutions. To avoid re-inventing the wheel, the solution proposed by several authors is the sharing of business processes, or fragments of business processes, using standard solutions. The basic idea is very similar to the current generation of ERP (enterprise resource planning) systems, in which the systems are based on industry best practices solutions. These system standard solutions are adopted, but also customised, reconfigured and reprogrammed partly, and adapted to the specific company needs (Aversano and Canfora, 2002). Hammer and Stanton (1999) emphasised that companies should standardise (business) processes as much as possible without interfering with the ability of the company to meet diverse customers' needs. Nuseibeh and Easterbrook (2000) expected that in many domains of application, the development of a reference model will emerge, so that the effort of developing (business process) requirements models from scratch is reduced.

Value is not restricted to cost and therefore the value of (business process) reference models is summarised as savings in time and costs and an increase in the quality of the model (Lang, Glunde and Bodendorf, 1997; Esswein, Zumpe and Sunke, 2004; Thomas, Horiuchi and Tanaka, 2006; Thomas and Scheer, 2006; Winter and Schelp, 2006). Another perspective is that (business) process knowledge gained during process execution is a valuable asset (Becker-Kornstaedt and Reinert, 2002). A (business) process reference model serves as a reference point for transferring lessons learned, and a (business) process reference model establishes a common terminology and (business) process understanding. Kirchmer et al. (2002) state that selecting complete (business process) reference models or just specific parts and elements of those will expedite effort and lead to a much

higher level of standardisation across project teams working off the same (business process) reference database.

2.1.5.2 Business Process Reference Model Classification

Initial best practice (business) processes were documented in (business process) reference books and Scheer published (business process) reference models for industrial enterprises as early as 1989 (Scheer, 1994). (Business process) reference models can be classified according to different criteria and the following represents examples of classifications mentioned in the article by Kirchmer et al. (2002):

- Industry-specific (business process) reference models.
- Software (business process) reference models.
- Consulting (business process) reference models.

The following are examples of business process reference models, the detail of which is described in Chapter 5 and Appendices A, B and C. It is important to note that these business process reference models were not developed with, for example, the business or application architecture set as fixed boundaries. Therefore these reference models may contain artefacts from various enterprise architectural domains as well as different levels of abstraction and granularity. When referring to business process reference models in the context of the dissertation the focus is on the business process model components of these business process reference models.

- *Industry-specific business process reference model*

Industry-specific business process reference models are developed for a specific industry, for example SCOR (Supply-chain Operations Reference-model) for the supply-chain industry. The SCOR model is a business process reference model that provides a language for communicating among supply-chain partners. This specific business process reference model links process elements, metrics and best practices. Business process reengineering, business process management, benchmarking and process measurement concepts are integrated in the SCOR framework (Supply-chain Council, 2003).

- *Consulting business process reference model*

Consulting business process reference models are developed by consulting companies to improve the quality of projects and to reduce the time to complete projects. IndustryPrint (Deloitte Consulting LLP, 2004) consists of enterprise-wide business process models that reflect best practices for key business processes in a given industry segment.

- *Software business process reference model*

Software business process reference models are developed by software development houses but they often include business process models as well as software enablement models. The SAP Solution Manager BPR reference models were developed by SAP AG and IDS Scheer as a joint initiative over the last twelve years (Scholz and Volmering ,2004).

- *Multiple business process reference models*

The MIT⁴ Process Handbook is an extensive, publicly available online knowledge base (<http://process.mit.edu/>), including over 5 000 activities and a set of software tools to maintain and access the knowledge base.

In addition to the MIT Business Activity Models and Business Model Archetypes, the MIT Process Handbook also includes a number of other models of business processes developed by other organisations. These models include but are not limited to the following list:

- International Benchmarking Clearinghouse Process Classification framework.
- Supply-chain Operations Reference (SCOR) models.
- Lean Enterprise Manufacturing model.
- European Foundation for Quality Management (EFQM) model.

The MIT Process Handbook provides an excellent mechanism to organise large amounts of knowledge, but it lacks the business process analysis tool functionality (Blechar and Sinur, 2006) and the ability to accommodate the various business process model techniques and notations. These restrictions are, for example, the lack of ability to synchronise to the application architecture environment or the functionality to configure a specific supply-chain according to the SCOR method.

2.1.6 Flexible Visualisation of Business Processes

The architectural representations in Figure 2.2 provide a good reference to understand the concept of flexible visualisation of business process content as business process models. Various business process model examples are included in Chapter 7, including enterprise architecture views from the different architectural domains, viewpoint-based development views, swim lane-based views, notation-based views, scenarios and aggregated views. The concept is based on the principle of the data warehouse, allowing the slice and dice of content-based on the specific requirement of the end-user.

⁴ MIT = Massachusetts Institute of Technology

2.2 Data Domain

The second domain that is a foundation for this dissertation is the data domain. The inclusion of the data domain is motivated in Chapter 1, as the research method includes the concept of learning from the data warehousing domain, a part of the data domain, to gain a better understanding of the business process model warehouse concept. The definitions of *database*, *repository*, *data warehouse*, *process warehouse* and *Entity Relationship Model* are all considered to be part of the data domain. Within the context of this dissertation, it is important to define the database concept and then to investigate two specific variations of a database, namely a repository and a data warehouse. It is interesting to note that the roles of the repository and data warehouse both form part of the definition of the business process model warehouse framework.

A further inclusion as part of the data domain is the Entity Relationship Model, constituting the notation for data modelling. The Entity Relationship Model is used as modelling technique in Chapter 5 and a basic definition of the technique is included for the benefit of the reader.

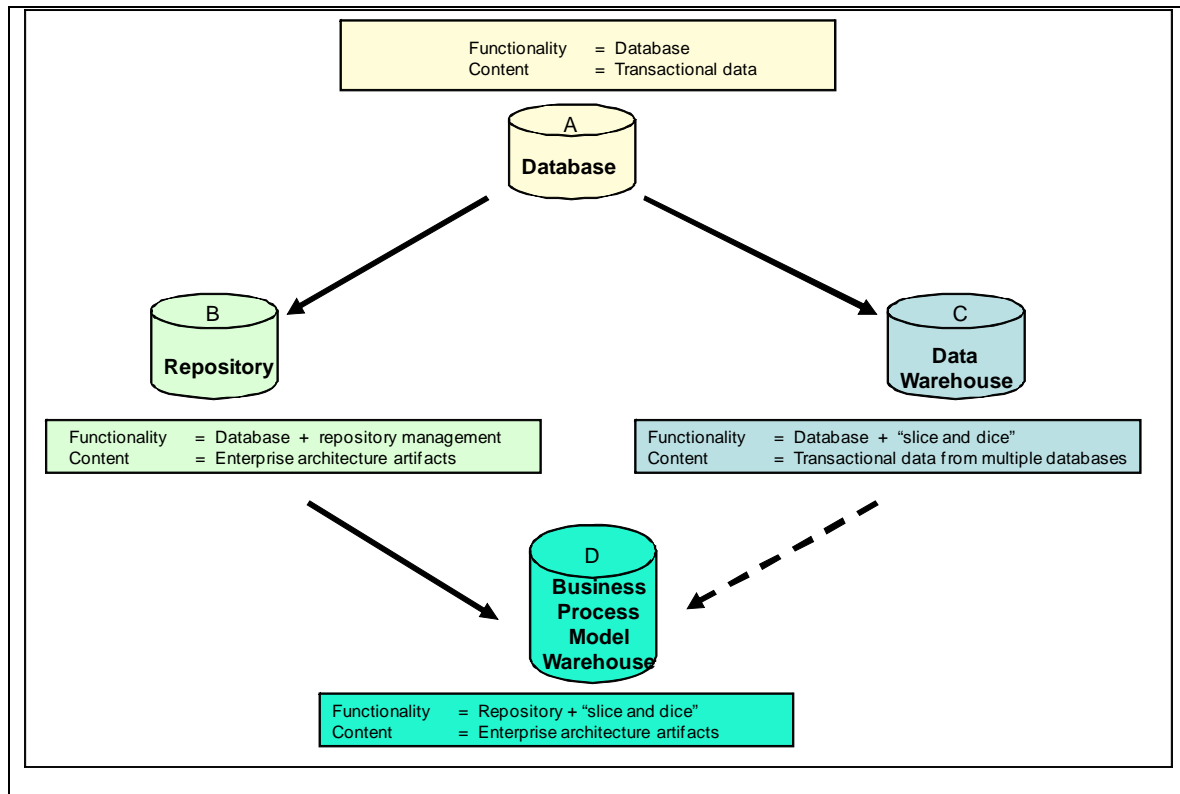
As closure to section 2.2, the concept of a process warehouse as found in literature is briefly discussed. The definition of a process warehouse, as defined by Kannan (2005), is included as part of section 2.2, in order to differentiate between a process warehouse and a business process model warehouse. A detailed discussion of a process warehouse as defined by Kannan (2005) is excluded from the scope of this dissertation as it is considered to be similar to a data warehouse containing information about business processes and not a business process model warehouse.

2.2.1 Theoretical Foundation of Database, Repository and Data Warehouse

The objective of section 2.2.1 is to position the concepts *database* versus *data warehouse* and *business process model warehouse* as depicted in Figure 2.12 (with specific references to components A, B, C and D). The typical functionality and content addressed by each variant of a database is indicated per component.

Component A (Figure 2.12) is the definition of the database concept. According to Date (1981), a database, in general, is both Integrated and shared. *Integrated* means that the database may be thought of as a unification of several otherwise distinct files, with any redundancy among those files partially or wholly eliminated. *Shared* however means that individual pieces of data in the database may be shared among several different users as each of those users may have access to the same piece of data (and may use it for different purposes). Engles (as cited in Date, 1981) defines a database as

“a collection of stored operational data used by the application systems of some particular enterprise”. A database is usually associated with operational or transactional data. The foundation of both data warehouses and repositories is a database.



**Figure 2.12: Database vs. repository vs. data warehouse
vs. business process model warehouse**

Component B (Figure 2.12) focuses on the repository, a variation of a database. Additional functionality is required in order to manage enterprise architecture artefacts that differ from transactional data in a database. Adding this functionality to manage enterprise architecture artefacts in a database, results in a variation of a database also known as a *repository*. A repository is a shared database of information about engineered artefacts (Bernstein, 1998) or enterprise architecture artefacts as discussed in section 2.1 in contrast with the transactional data that is usually stored in a database. A business process and business process model are examples of enterprise architecture artefacts that are stored in a repository. A repository includes specific repository management functionality enabling the definition and management of these enterprise architecture artefacts. Refer to Chapter 6 for a more comprehensive discussion of a repository.

Component C (Figure 2.12) positions the term *data warehouse*. There was also a need to extend the database concept to enable the analysis of data from various databases to create different views of the same data to support decision-making. To address this specific requirement, the concept of a data

warehouse was introduced. A commonly used definition of a data warehouse comes from Inmon (as cited in Gray and Watson, 1998), Srivastava and Chen (1999), Zhou, Zhou, Tao and Hu (2000) and Stefanov et al. (2005): “A data warehouse is a subject-oriented, integrated, time-variant, and non-volatile collection of data to support decision-making.”

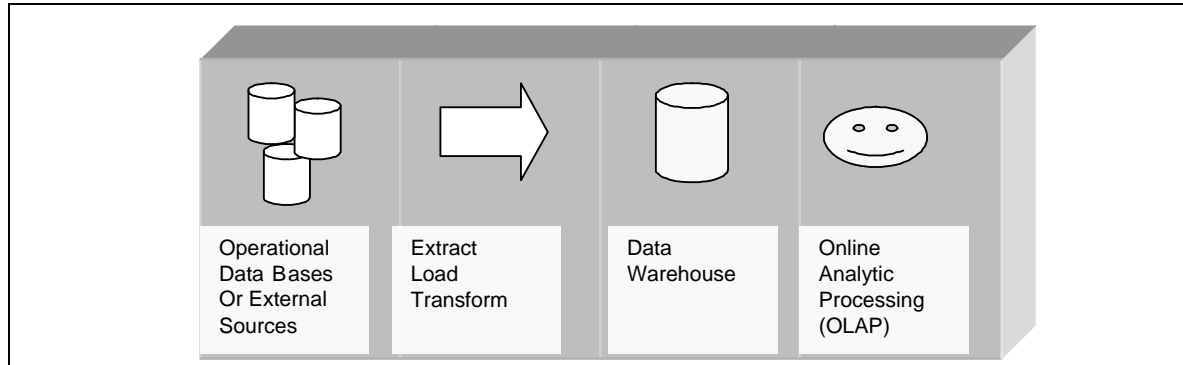


Figure 2.13: Data warehouse framework

Component D (Figure 2.12) introduces the concept of a business process model warehouse. The requirement is to extend the concept of a repository to enable the analysis of business processes (examples of enterprise architecture artefacts) from various repositories to create different views to enable a better understanding and analysis of the business processes. The functionality required is similar to the initial requirement to extend the database concept to the data warehouse concept, namely to create different views from a set of data. The intent is therefore to extend the repository concept to include the data warehouse functionality. The definition of a data warehouse framework is to be used as foundation for the proposed business process model warehouse framework. Various frameworks for data warehouses are found in literature and a number of these are discussed in Chapter 3. The selection of the specific data warehouse framework depicted in Figure 2.13 is motivated in Chapter 3. The basic reasoning is that data from various sources are loaded into a data warehouse and then the user has the ability to analyse and present the information as required.

Within the context of a business process model warehouse, as will be indicated in Chapter 3 and Chapter 6, the data warehouse (Figure 2.13) is actually a repository within the context of a business process model warehouse.

2.2.2 Entity Relationship Model

The Entity Relationship Model is used in Chapter 5 as notation to prepare a data model. The classical requirements definition of data includes a description of the semantic data model. Chen’s entity-relationship model (ERM) is a widely used designing method for semantic data models (Chen, 1976).

A variant of Chen’s ERM, the Information Engineering (IE) data model notation, is used for data modelling as part of this dissertation. The basic definitions as defined by Chen (1976) are:

- An *entity* is a “thing” that can be distinctly identified, for example a specific person, company, or event is an example of an entity.;
- A *relationship* is an association among entities, for instance, “father-son” is a relationship between two “person” entities.
- Information about the number of entities in each entity set that is allowed in a relationship set is indicated by specifying “1”, “m”, or “n”. (Figure 2.14 is an example of the 1:m relationship.)

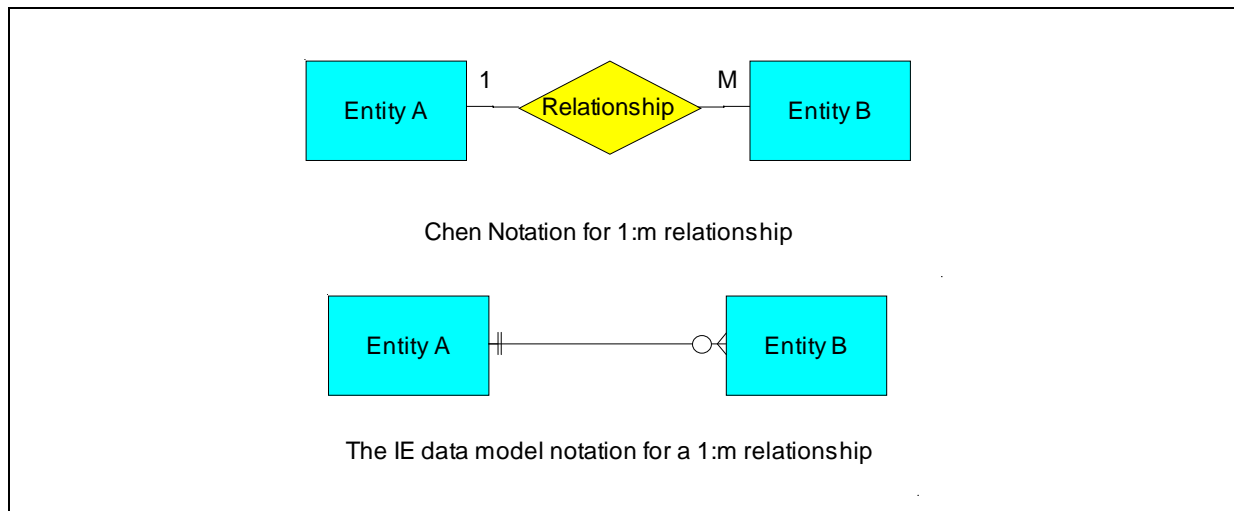


Figure 2.14: Entity Relationship Model notation (IDS Scheer, 2002)

The tool that is used for data modelling in this dissertation is ARIS (Architecture of Integrated Information Systems), a product from IDS Scheer AG. Various data modelling techniques are supported by the ARIS toolset. The selected notation is the IE data model. The IE data model matched the data modelling notation employed by the CASE Tool Information Engineering Facility of Texas Instruments Inc. The IE data model notation does not provide separate object types for relationships between entity types (IDS Scheer AG, 2002).

2.2.3 Process Warehouse

A global search for the term *process warehouse* may result in various hits. However the concepts *process warehouse* and *business process model warehouse* differ. It is important to differentiate these concepts to gain a better understanding of the context of this dissertation. Figure 2.15 illustrates the difference between a process warehouse and a business process model warehouse. The process warehouse is a data warehouse with the content focusing on process-related information.

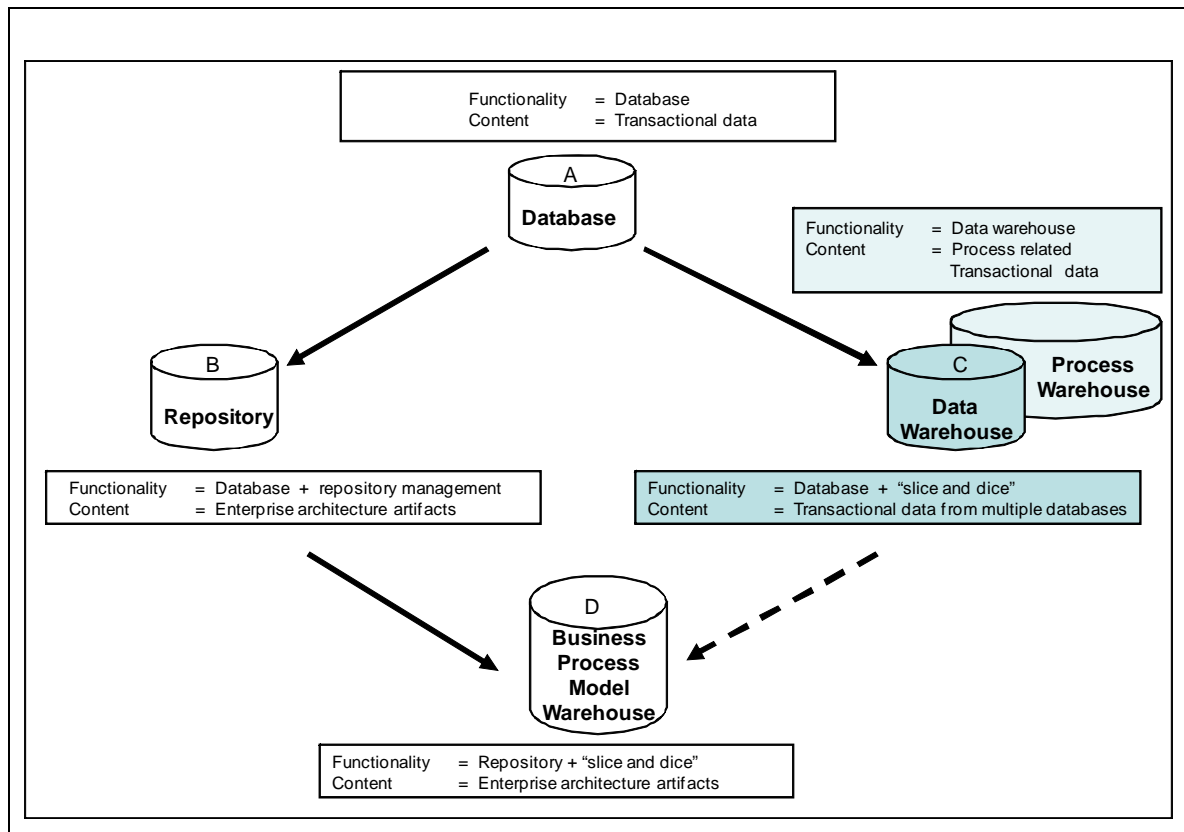


Figure 2.15: Process warehouse vs. business process model warehouse

The first step is to understand the requirements for business process information. Davenport is well-known for his role in positioning the concepts *(business) process redesign*, *innovation* and *reengineering* (Davenport and Stoddard, 1994). Since 1994, the initial focus on (business) process redesign was replaced with the focus on business process management (Hammer and Stanton, 1999). In order to manage business processes, (business) process information is required (Davenport and Beers, 1995) as confirmed by Kannan (2005). Business process information is therefore required to manage business processes.

The second step is to acknowledge the difference between a process warehouse and a business process model warehouse. According to Kannan (2005), the process warehouse provides the internal process key performance indicators from an integrated database and makes available valuable information for decision-making. The process warehouse as defined by Kannan (2005) is very similar to the financial data warehouse and the sales data warehouse. The definition of a data warehouse, as defined by Bill Inmon in 1995, is used by Kannan as basis for the process warehouse, namely "The process warehouse is a (business) process-oriented, integrated, time-variant and non-volatile collection of data that helps management get a handle on its internal (business) processes." Based on this definition, the assumption is made that Kannan is referring to a process warehouse as a data warehouse with the only difference that the content specifically refers to business processes. This definition does not refer to

the definition of a repository and the functionality required to manage business process models in a repository.

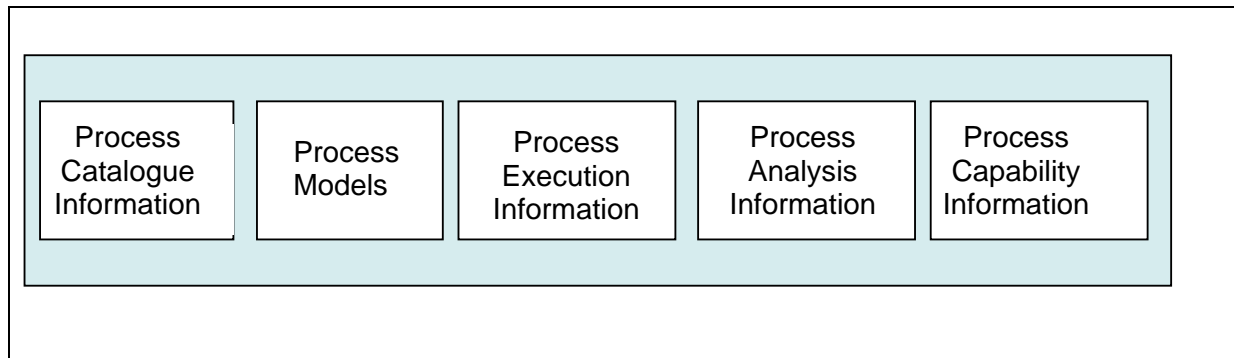


Figure 2.16: Process warehouse (Kannan, 2005)

Figure 2.16 is a representation of the content of a process warehouse as defined by Kannan (2005):

- The (business) process catalogue is an inventory of the (business) processes that an organisation uses in its business. It is a central place where all data about the (business) processes is stored and retrieved as necessary. For each (business) process there may be a few hundred attributes and values to be stored.
- The (business) process model includes the model as well as the different (business) process steps involved. A multi-dimensional cube is to be associated with the (business) process model for fine-grained (business) process analysis. If a (business) process does not meet its target measures a multi-dimensional cube will provide insight into where to concentrate for (business) process improvements. The (business) process models need to capture both quantitative and qualitative information. It is not clear from the definition given by Kannan (2005) whether the (business) process model is a graphical model including objects and relationships or whether it is a text-based sequence of (business) process steps.
- The (business) process execution information is about the collection of execution information to monitor the performance of a (business) process.
- The (business) process analysis information is about the analysis of the execution information to identify opportunities for improvement.
- The (business) process capability information is about monitoring the (business) process improvement efforts.

For the purpose of this dissertation, it is important to differentiate between a process warehouse (Kannan, 2005) and a business process model warehouse, a repository as defined by Bernstein (1998). A major contribution of this dissertation is the way it highlights this difference by proposing a business process model warehouse framework.

Just replacing

- the term *subject-oriented* with *(business) process-oriented*; and
- the term *support decision-making* with *helps management get a handle on its internal (business) processes*,

in the original definition of Inmon, is not going to resolve the challenge to

- accommodate business process models in a data warehouse; and
- provide functionality, similar to Online Analytic Processing (OLAP) functionality, for the flexible visualisation of business process models.

For the scope of this dissertation, a process warehouse as defined by Kannan (2005) is considered to be similar to a data warehouse containing information about business processes. The Kannan definition of a process warehouse (Kannan, 2005) does not make provision for the management of business process models in a repository. A process warehouse in the context of Kannan (2005) is thus excluded from the scope of this dissertation.

The concept *business process model warehouse* is therefore introduced to differentiate between the process warehouse definition of Kannan (2005) and the business process model warehouse concept. However, in literature this difference between a process warehouse and a business process model warehouse may not be that clearly defined. The result is that terminology such as *(business) process warehouse* or *(business) process factory* or *(business) process library* may be used interchangeable for the concept *business process model warehouse* or *process warehouse* as defined by Kannan (2005). Although it may be possible to locate, with search engines, various references to terminology such as *process warehouse* and *process library*, the actual number of articles referring to the concept *business process model warehouse* as defined in this dissertation, is limited.

2.3 Conclusion

The purpose of Chapter 2 is to ensure a common understanding of concepts to follow, the reasoning in the chapters to follow, and to have a better understanding of the concepts that are included as part of this dissertation (and those which are excluded).

- An informal explanation of the concepts is included with reference to architectural representations. Referring back to these concepts to clarify the understanding of a concept is recommended.

- The enterprise architecture framework is used to provide context. The focus of the dissertation (and the preferred terminology) is based on business processes, business process models, business process reference models and a business process model warehouse framework.
- Clearly excluded is the reference to business process information in the broader context, and the focus is definitely on business process models. The term *business process model warehouse* is introduced to differentiate the concept from the *process warehouse* concept as defined by Kannan (2005).
- In order to propose a business process model warehouse framework the existing data warehouse framework is used as comparison.

As the objective of this dissertation is to propose a business process model warehouse framework, (promoting the re-use of multiple business process reference models and a flexible visualisation of business process models), the logical next step is to define the business process model warehouse framework. Chapter 3 will focus on deriving a data warehouse framework and then to use it as foundation to propose a business process model warehouse framework. Chapters 4, 5, 6 and 7 will then explore each of the components included as part of the business process model warehouse framework, namely:

- Business process reference models (similar to the external source of the data warehouse framework).
- Extract, load, transform (the same as within the data warehouse framework).
- Repository (similar to the data warehouse within the data warehouse framework).
- Flexible visualisation (similar to the online analytic processing of the data warehouse framework).

CHAPTER 3: FROM DATA WAREHOUSE TO BUSINESS PROCESS MODEL WAREHOUSE FRAMEWORK

The focus of Chapter 3 is the first part of the argument (see section 1.4), proposing a business process model warehouse framework. The research method is analogical reasoning using a data warehouse framework as the matching domain. From the perspective of the argument (see section 1.4), Chapter 3 is a key chapter as this is the place where the business process model warehouse framework is proposed. The following research questions are specifically addressed in Chapter 3:

- Is there any existing definition of a business process model warehouse framework to be considered when deriving a proposed business process model warehouse framework?
- Is it feasible to use the analogy of a data warehouse framework based on the characteristics of a data warehouse and a business process model warehouse framework?
- Is it possible to select a generic framework for a data warehouse to be used as foundation for the proposed business process model warehouse framework?
- Is there any similar analogy done that could provide valuable input for the analogy between a data warehouse framework and a business process model warehouse framework?
- Is it possible to propose a business process model warehouse framework based on the data warehouse framework?

In order to address all the stated research questions the research method is to:

- Consider references with a strong correlation to the concept *business process model warehouse* with the specific purpose to identify components to be included in a proposed business process model warehouse framework (section 3.1).
- Discuss existing definitions and characteristics of a data warehouse in section 3.2.1 and derive the characteristics for a business process model warehouse.
- Select a generic definition of a data warehouse framework to be used as foundation for the proposed business process model warehouse framework (section 3.2.2).
- Review in section 3.3 a similar analogy between a data warehouse and a design warehouse, highlighting potential differences and similarities to be expected in the comparison of the data warehouse framework and the proposed business process model warehouse framework.
- Propose a business process model warehouse framework based on the data warehouse framework in section 3.4 as first step to address the research questions.

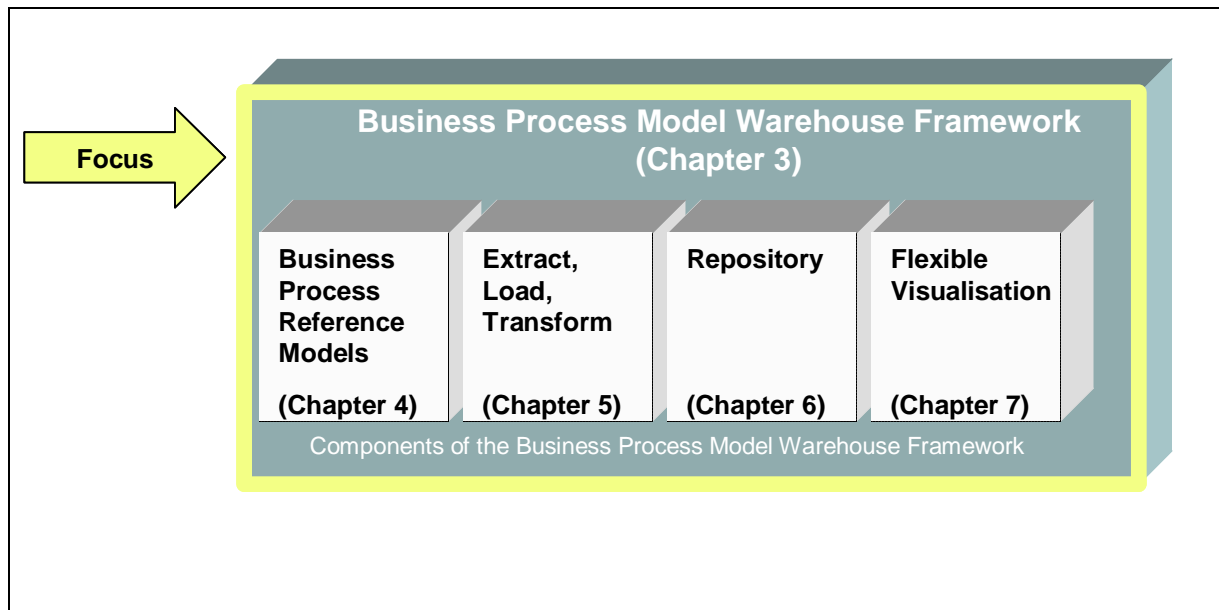


Figure 3.1: Context diagram from data warehouse to business process model warehouse

As the business process model warehouse concept is not yet clearly defined as part of the body of knowledge, a data warehouse framework, as defined or derived from literature, will be used as foundation. Figure 3.1 positions Chapter 3 within the context of the dissertation, indicating that the business process model warehouse framework will determine the content of Chapters 4, 5, 6 and 7.

3.1 References to the Business Process Model Warehouse Concept

Two pertinent research contributions are identified in this section. These will be considered in more detail to derive potential components to be considered for the business process model warehouse framework:

- The business process warehouse as concept is mentioned in the article *Using SCOR and other reference models for e-business process networks* (Kirchmer et al., 2002). No detailed definition is given and the concept is only mentioned in a single sentence: “A business process warehouse of reference models has been built, which creates, together with the defined procedures and the enabling ARIS tool a business process factory”. This article is reviewed in Chapter 4 as part of the review of articles referring to multiple reference models. The concept *business process warehouse* as used by Kirchmer et al. (2002) is related to a repository with pre-populated reference models that can be re-used to configure business processes similar to the assembly line of a factory. Although not clearly defined by Kirchmer et al. (2002), there are at least three aspects to be considered in an attempt to propose a business process model warehouse framework, namely

- Business process reference models, an existing source of business processes models.
- A warehouse or repository where these business processes models are stored.
- The fact that a new product is manufactured/assembled in this factory.

The proposed business process model warehouse framework should at least include a component to use business process reference models as source of business process models, a repository to store business process models and a component to create (assemble) new business processes views from the source business process models.

- The concept *process warehouse* is also referred to in the article *Requirements for the visualisation of system-spanning business processes* (Bobrik et al., 2005) and, although ARIS is also mentioned, the concept is used in the context of business process measurement and not as a business process factory as in the example from Kirchmer et al. (2002). In the following paragraph (quoted from Bobrik et al. 2005), the definition of process warehouse is not clear either:

“ARIS Process Performance Manager (PPM) can be considered as a tool for building (business) process warehouses. It allows users to analyze (business) process performance properties. This includes aggregated views on a collection of (business) process instances as well as performance characteristics of single (business) process instances.”

Refer to Chapter 7 of this dissertation for a more comprehensive discussion of this article.

In contrast with the article by Kirchmer et al. (2002), the article by Bobrik et al. (2005) does not refer to the ARIS repository, but rather to the ARIS PPM (Process Performance Measurement) tool that extracts performance measurement information in real-time from systems to monitor the performance of a business process. With this context in mind, there are a number of concepts to be considered as input for the attempt to propose a business process model warehouse:

- Building a business process warehouse.
- Analyses of the content of the business process warehouse.
- Aggregated views of business process instances.

The components to be included as part of the business process model warehouse framework are a repository populated with business process models (building a business process warehouse) and a component to analyse the business processes in the repository and to generate different views of the business processes.

Based on a review of these references, at least five potential components to be considered for the proposed business process model warehouse framework are identified to be kept as a checklist for use as input in section 3.4 when deriving the proposed business process model warehouse framework:

- Source business process models from business process reference models.
- Build/populate a repository with business process reference models.
- Store business process models in a repository.
- Analyse business processes.
- Create alternative views of the business processes.

As mentioned, the foundation for the proposed business process model warehouse framework is a data warehouse framework, as discussed in section 3.2.2.

3.2 Data Warehouse Definition

The expectation was to find a commonly accepted data warehouse framework in literature, but this was not to be. The only alternative was to derive a representative data warehouse framework from a number of data warehouse frameworks found in literature. The point of departure is to define data warehouse and to identify data warehouse characteristics before looking at the data warehouse framework.

Gray and Watson (1998) state that the most commonly used definition of a data warehouse can be attributed to Inmon and the Inmon definition is referenced by several sources (Srivastava and Chen, 1999; Zhou, Zhou, Tao and Hu, 2000; Stefanov et al., 2005). The Inmon definition of a data warehouse as quoted from Gray and Watson (1998) “A data warehouse is a subject oriented, integrated, time-variant, and non-volatile collection of data to support decision making”. There are two implicit assumptions based on this definition of a data warehouse according to Gray and Watson (1998):

- A data warehouse is physically separate from operational systems.
- A data warehouse contains both aggregated data and transaction (atomic) data, which are separate from the databases used for Online Transaction Processing (OLTP).

The definition of a data warehouse and the assumptions listed by Gray and Watson (1998) will enhance the understanding of the data warehouse frameworks that are considered when deriving a representative data warehouse framework and even when using the representative data warehouse framework as a foundation for the proposed business process model warehouse framework. Similarly, listing the characteristics of a data warehouse as consolidated from the various references

will give a more detailed level of understanding of a data warehouse (Gray and Watson, 1998; Srivastava and Chen, 1999; Zhou et al., 2000; Stefanov et al., 2005).

Table 3.1: Data warehouse characteristics

Data Warehouse Characteristics	Description
Subject-oriented	Data is organised per subject area, across the enterprise, and not by application.
Clean	The same piece of information is referred to in only one manner. The data is stored in a single way, even though the sources may differ.
Correct and complete	Validation of the data is critical to ensure credibility and consistency.
Accurate	The data is up-to-date at some moment of time, but not necessarily momentarily.
Non-volatile	Read-only data and no update of data.
Granularity	Important to determine the amount of detail to include.
Metadata	Metadata is defined as “data about the data”.
Normalisation	Redundancies are allowed and normalisation is not applicable, but the data remains independent of the application- and data-view. (Refer to Lawyer and Chowdhury (2004) for a comprehensive discussion of the difference between the Inmon and Kymball styles).

Based on the data warehouse characteristics, the following business process warehouse characteristics are derived.

Table 3.2 Business process model warehouse characteristics

Business Process Warehouse Characteristic	Description and Comment for Relevance to Business Process Model Warehouse Framework
Business process-oriented	Business processes are cross-functional and not application- or subject area-driven. The business process warehouse should be end-to-end business process-oriented.
Clean	The same piece of information is referred to in only one way. The business process models are stored in a consistent way even though the sources may differ. Refer to Chapter 5 for a method to ensure a common definition of business processes.

Correct and complete	Validation of the business processes is critical to ensure credibility and consistency. The status of the business process should be included as part of the business process attributes.
Accurate	The business processes are up-to-date at some moment in time, but not necessarily right now. The time stamp should be included as part of the business process attributes, but a business process could be classified as for example “as is”, “should be” or “to be”-related. Accuracy will be within the context of the classification of the business process. Compliance criteria may enforce 100% correctness of the business processes at the specific time of enquiry.
Non-volatile	The principle is that the business processes are “read only” and no update of the business processes is allowed. The initial source business processes are considered “read only”, but new business processes views may be added as an additional source for business processes.
Granular	It is important to determine the amount of detail to be included as part of a business process model. Granularity is critical from a flexible visualisation of business process perspective.
Metadata	A definition and management of metadata are prerequisites for the implementation of the business process model warehouse concept. Refer to Chapter 5 for a more detailed discussion.
Normalisation	Normalisation is not applicable, but as will be discussed in Chapter 6, there is specific functionality in a repository to manage object occurrence, variation and definition copies.

Based on this comparison, the definition of a data warehouse, namely “a data warehouse is a subject oriented, integrated, time-variant, and non-volatile collection of data to support decision making”, can be adjusted to describe a business process model warehouse as:

A business process model warehouse is an end-to-end business process-oriented, integrated, time-variant and non-volatile collection of business process models to promote the use of business process reference models and to support the flexible visualisation of business process models to minimise the causes of inadequate business requirements.

3.3 Data Warehouse Framework

The challenge is to derive a data warehouse framework to be used as foundation for the proposed business process model warehouse framework. As no commonly accepted data warehouse framework was found, the approach is to analyse three different data warehouse frameworks and to derive a data warehouse framework to be used within the context of this dissertation. The three data warehouse frameworks are from Gray and Watson (1998), Dehne, Eavis and Rau-Chaplin. (2001) and Chelluri and Kumar (2001).

3.3.1 Data Warehouse Framework as Proposed by Gray and Watson

According to Gray and Watson (1998), the architecture of a data warehouse as depicted in Figure 3.2 includes:

- Backend process: data-acquisition software extracting data from legacy systems and external sources, consolidating and summarising the data and loading it into the data warehouse.
- Warehouse: the data warehouse containing the data and associated database software.
- Front-end use: the client software allowing users and applications to access and analyse data in the warehouse.

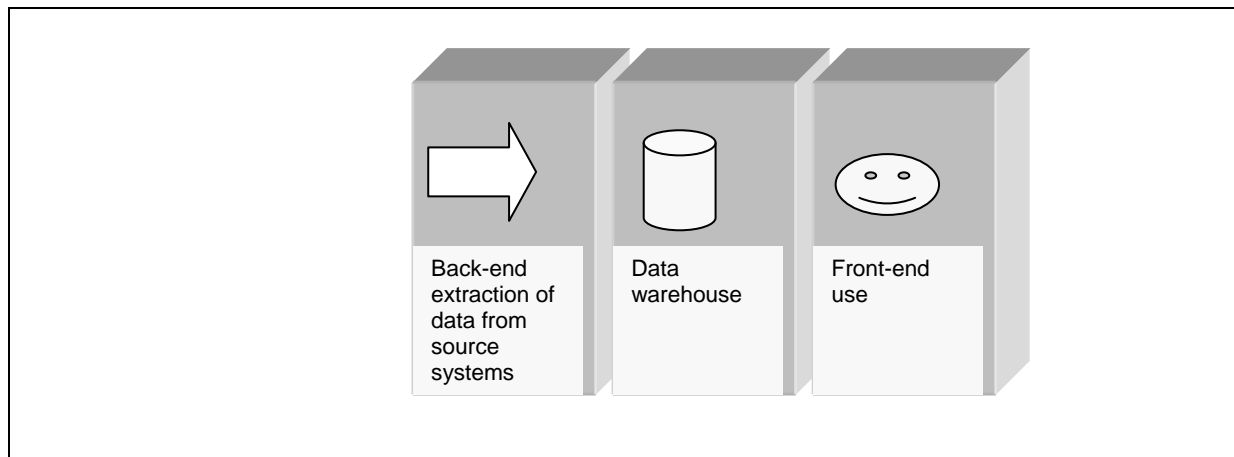


Figure 3.2: Data warehouse framework as proposed by Gray and Watson

3.3.2 Data Warehouse Framework as Used by Dehne, Eavis and Rau-Chaplin

Dehne et al. (2001) focus on the front-end usage and state,

“By exploiting multi-dimensional views of the underlying data warehouse, users can ‘drill down’ or ‘roll up’ on hierarchies, ‘slice and dice’ particular attributes, or perform

various statistical operations such as ranking and forecasting. This approach is referred to as Online Analytical Processing or OLAP.”

The model in Figure 3.3 differs from Gray and Watson (1998) from the front-end use perspective. The back-end extraction for data source systems is similar to data cleaning and integration.

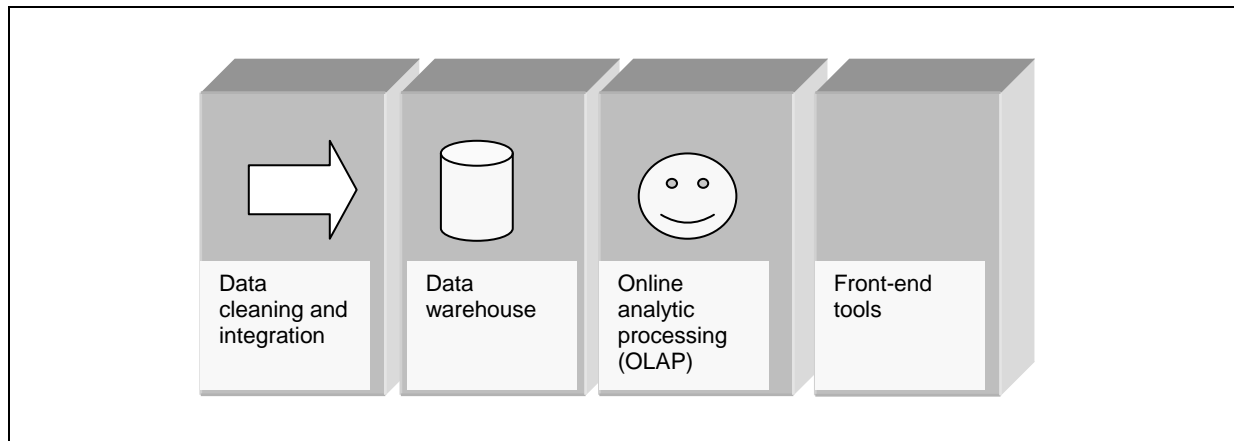


Figure 3.3: Data warehouse framework as used by Dehne, Eavis and Rau-Chaplin

3.3.3 Data Warehouse Framework as proposed by Chelluri and Kumar

The basic architecture of a data warehouse (Figure 3.4) as depicted by Chelluri and Kumar (2001), partly overlaps with Gray and Watson’s framework (1998) and partly with Dehne et al.’s framework (2001). A legacy system contains all the data that is operational. Data from the source systems is transported to the operational data store, which cleans, transforms, combines, archives and prepares source data for use in the data warehouse. The general activity of querying and presenting textual and numerical data from data warehouses, as well as a specifically dimensional style of querying and presenting that is exemplified by a number of online analytical processing tools, are included in the query interface.

3.3.4 Other Data Warehouse Framework Views

Specific framework views for a data warehouse are available in literature to address specific challenges. The following references are an indication of some areas that incorporate specific requirements in the proposed data warehouse framework:

- Customer-centric data warehouse (Kemper and Lee (2002).
- Data warehousing in corporate application architecture (Winter, 2001).
- Business intelligence data warehouse (Stefanov et al., 2005).

- Hierarchically distributed data warehouse (Zhou et al., 2000).

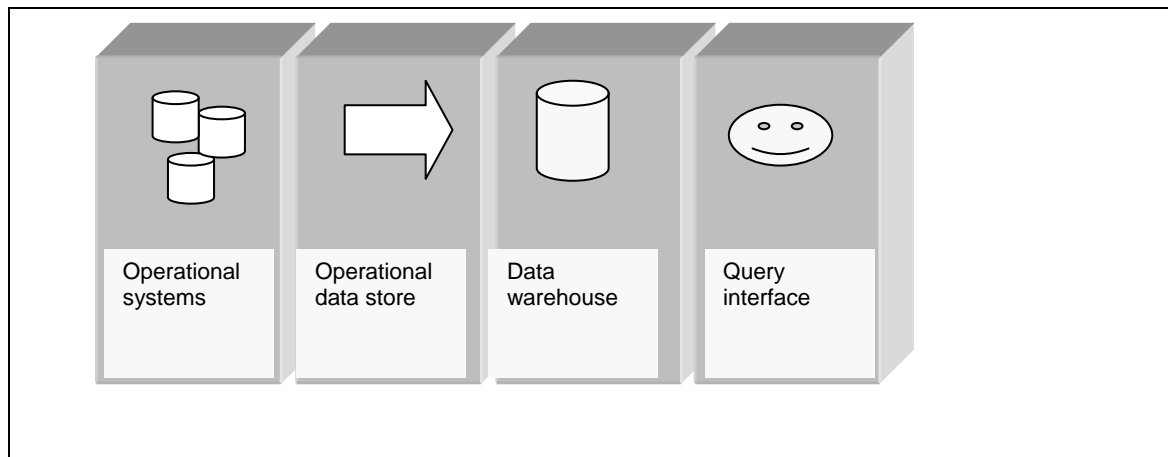


Figure 3.4: Data warehouse framework as proposed by Chelluri and Kumar

3.3.5 Derived Data Warehouse Framework

As mentioned, one of the objectives of Chapter 3 is to derive a data warehouse framework (Figure 3.5) to be used as foundation to propose a business process model warehouse framework. Considering the three views of data warehouse frameworks in Figure 3.2, 3.3 and 3.4, the component that is represented in all three views is the data warehouse component. Although not included in all three views, the operational system as included in the Chelluri and Kumar (2001) is selected as it is a prominent component and part of the envisioned business process model warehouse framework to represent the business process reference models as source for the business processes. The back-end extraction (Gray and Watson, 1998), cleaning and integration (Dehne et al., 2001) or operational data store (Chelluri and Kumar, 2001) are combined and renamed to extract, load and transform. Lastly front-end use (Gray and Watson, 1998), OLAP and front-end tools (Dehne et al., 2001) and query interface (Chelluri and Kumar, 2001) are combined as OLAP in the derived data warehouse framework.

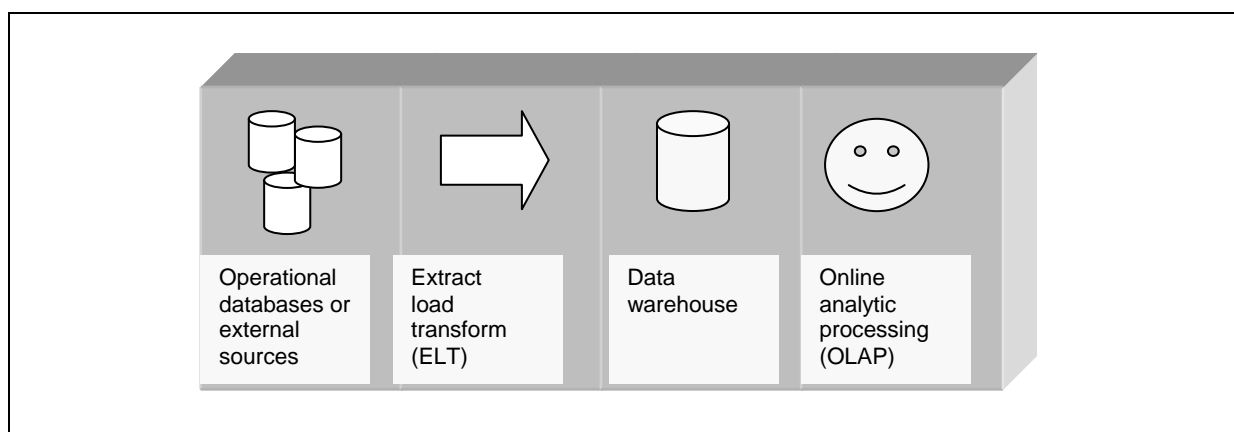


Figure 3.5: Derived data warehouse framework

In section 3.1, a potential component checklist for a business process model warehouse is defined and a derived data warehouse framework is now also in place. The question is whether any further components can be identified from similar analogies with a data warehouse framework. Section 3.3 explores the concept of a design warehouse before the definition of the proposed business process model warehouse framework in section 3.4.

3.4 The Design Warehouse: a Similar Analogy

The paper by Laureri and Moke (1997), *“Design warehouse”: a “data warehouse” for computer aided design*, describes a new concept of information system for Computer-Aided Design (CAD), referred to as a design warehouse, because it is inspired by the model of a data warehouse. Potentially, there are similarities between the requirements of a design warehouse and a business process model warehouse.

The design warehouse concept is described as follows:

- Similar to the data warehouse concepts from which it originated, the design warehouse is an intermediate repository of technical and design data originating from production systems.
- The design warehouse is not devised to provide support for management decision needs, because it is only a warehouse of data representing the engineering know-how.
- Data taken from the production system should be approved before copying it into the design warehouse. This leads to data becoming official and accessible by various users.
- Navigation into the data of a design warehouse is feasible thanks to inter-skill links and consultation tools.
- The data stored in the design warehouse have to remain exploitable beyond its duration of life in the production system.

Laureri and Moke (1997) further describe five rules that characterise a design warehouse, adapting some properties defined by Inmon (Gray and Watson, 1998) for the data warehouse concept:

Rule 1: Engineering memory (independence from production data)

This engineering memory contains know-how by storing and organising elements for the comprehension of design choices, which should hopefully lead to inspiration of future designers. The engineering memory contains only approved and validated technical information. The data is physically disconnected of production systems.

Rule 2: Multi-skill orientation (multi-representation)

The design warehouse offers a structure of data appropriate to each speciality/skill. Contrarily to a data warehouse the design warehouse does not force a global standardisation, as, for example, measurement units may differ per speciality. The creation of links inside the design warehouse is allowed, encompassing a strong semantic meaning between data and different skills/specialities.

Rule 3: Semantic complexity of data (with navigation tools)

Design data used in CAD are naturally complex and have a strong semantic meaning. The user navigates visually inside graphical representations of high level objects. In contrast, the data contained in a data warehouse are often composed of strings and numbers only, which is less semantically complex than design data.

Rule 4: Accessibility (access independence from client workstation)

The system architecture has to be open and modular in order to give access to the design warehouse in different ways.

Rule 5: Durability (independence of data from their process of creation)

This rule originated from a data warehouse where data is extracted from production systems and loaded into the data warehouse. Once this process is completed, data is only accessed and never modified. For the design warehouse, it is important to convert the data to a neutral format before loading it into the design warehouse to ensure that the data remains exploitable beyond its duration of life in the production system.

As mentioned, the objective is to learn from the design warehouse and data warehouse analogy. The rules related to the source data and the flexible visualisation are applicable to the business process model warehouse framework. A key message is certainly not to underestimate the complexity of the warehouse concept. Let us rephrase the applicable rules from the business process model warehouse framework perspective:

Rule 1: Business process model memory

The business process model memory is independent from the source business process model reference models.

Rule 2: Multi-representation orientation

Chapter 7 will elaborate on the importance of flexible visualisation.

Rule 3: Semantic complexity of business process models

The complexity of reality is discussed in Chapter 1 and as business processes it is a reflection of reality and the complexity of the navigation through the business process models is thus implied.

Rule 4: Accessibility (access independence from client workstation)

The importance of accessibility is excluded from the scope of this study.

Rule 5: Durability (independence of data from their process of creation)

As with CAD information, it should be possible to represent the business processes even if the original business process reference models are not available as source.

A number of inputs are now available to contribute to the process to propose a business process model framework in section 3.4. These inputs are the business process model warehouse component checklist, the characteristics of a data warehouse, the data warehouse framework and the design warehouse principles.

3.5 The Business Process Model Warehouse Framework

The approach is to start with the data warehouse framework as derived in section 3.2 and to translate it to a proposed framework for a business process model warehouse. The next step is to ensure that the components as identified in section 3.1 are indeed addressed by the proposed business process model warehouse. The characteristics of a business process model warehouse as derived in section 3.2 will be revisited as well as the five rules based on the design warehouse analogy discussed in section 3.3.

3.5.1 Proposed Business Process Warehouse Framework

Figure 3.6 is the result of the translation of the data warehouse framework components to the business process model warehouse framework components. The various components of the business process model warehouse framework will be discussed in the remaining chapters of this dissertation:

- Chapter 4 will discuss multiple business process reference models as source data.
- Chapter 5 will focus on the Extract, Load and Transform of multiple business process reference models into the repository.
- The repository is similar to the data warehouse but with the additional capability to manage enterprise architecture artefacts. The repository management functionality will be addressed in Chapter 6.

- Instead of a comprehensive OLAP functionality that is text- and number-based, Chapter 7 will focus on the flexible visualisation of business process models, including the additional challenges related to the manipulation of graphics.

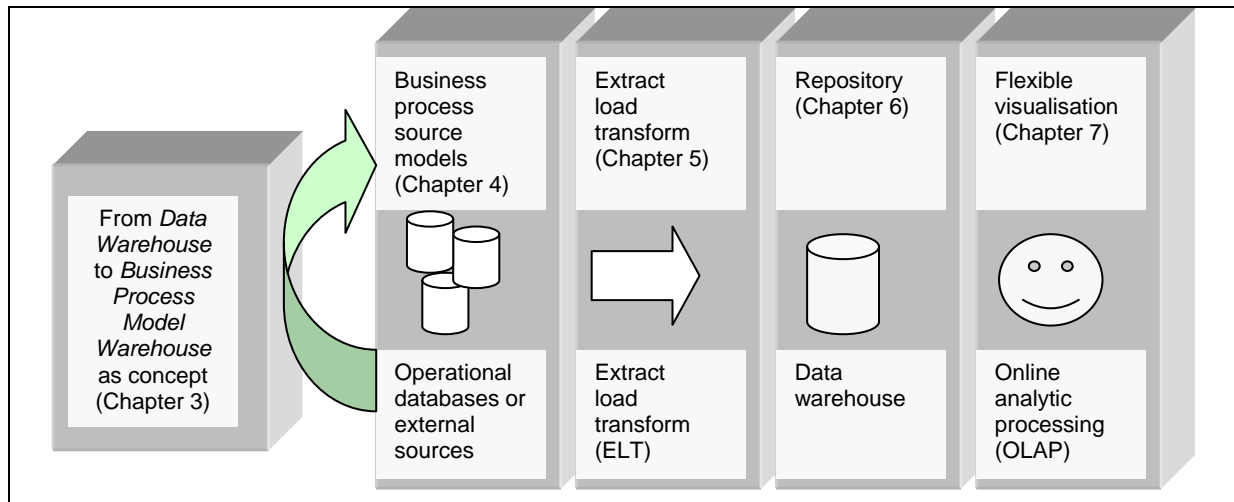


Figure 3.6: Data warehouse framework analogy

3.5.2 Business Process Model Warehouse Reference Check

As part of section 3.1, the following components were associated with the definition of a business process model warehouse. Next to each entry, an indication is given of whether the component is included as part of the recommended framework with a reference to a specific chapter. The conclusion is that all these components are well represented as part of the proposed business process model warehouse framework.

Table 3.3: Business process model warehouse components

Component	Indicator
Source business process models from business process reference models	Chapter 4
Build/populate a repository with business process reference models	Chapter 5
Store business process models in a repository	Chapter 6
Analyse business processes	Chapter 7
Create alternative views of the business processes	Chapter 7

3.5.3 Business Process Model Warehouse Characteristics

The business process model warehouse can be described with referring to the following characteristics:

- End-to-end business process oriented.
- Integrated.
- Time-variant.
- Non-volatile.

3.5.4 Business Process Model Warehouse Rules

The rules applicable to the business process model warehouse can be summarised as:

- Rule 1: The business process model memory is independent from the source business process model reference models.
- Rule 2: Multi-representation orientation is a key factor to successful flexible visualisation of business process models.
- Rule 3: The semantic complexity of business process models should be considered as part of the navigation through the business process models.
- Rule 4: It should be possible to represent the business processes even if the original business process reference models are not available as source.

3.6 Conclusion

The answers to the research questions related to Chapter 3 can be answered as follows:

- *Is there any existing definition of a business process model warehouse framework to be considered when deriving a proposed business process model warehouse framework?*

The derived checklist is reflected in section 3.4.2 and the conclusion is that all these components are well represented as part of the proposed business process model warehouse framework.

- *Is it feasible to use the analogy of a data warehouse framework based on the characteristics of a data warehouse and a business process model warehouse framework?*

The business process model warehouse framework characteristics are derived from the data warehouse characteristics and summarised in section 3.4.3.

- *Is it possible to select a generic framework for a data warehouse to be used as foundation for the proposed business process model warehouse framework?*

A generic data warehouse framework is derived in section 3.3.5 and represented in Figure 3.5.

- *Is there any similar analogy done that could provide valuable input for the analogy between a data warehouse framework and a business process model warehouse framework?*

A similar analogy for the design warehouse is discussed in section 3.3. The rules to be considered as part of a business process model warehouse framework are summarised in section 3.5.4.

- *Is it possible to propose a business process model warehouse framework based on the data warehouse framework?*

The proposed business process model warehouse framework is represented in Figure 3.7.

The proposed business process model warehouse framework (Figure 3.7) reflects the structure of the remainder of the dissertation and is used as context diagram. The reasoning is to follow the logical process of using multiple business process reference models as source data, to extract, load and transform the multiple reference models into the repository, to manage the content of the repository and then to provide flexible visualisation of the business process models available in the repository.

Chapter 4, focusing on multiple business process reference models, will not only explore the business process reference model component of the business process model warehouse framework in more detail; it will also contribute to the part of the argument (see section 1.4) is referring to the promotion of the re-use of multiple business process reference models.

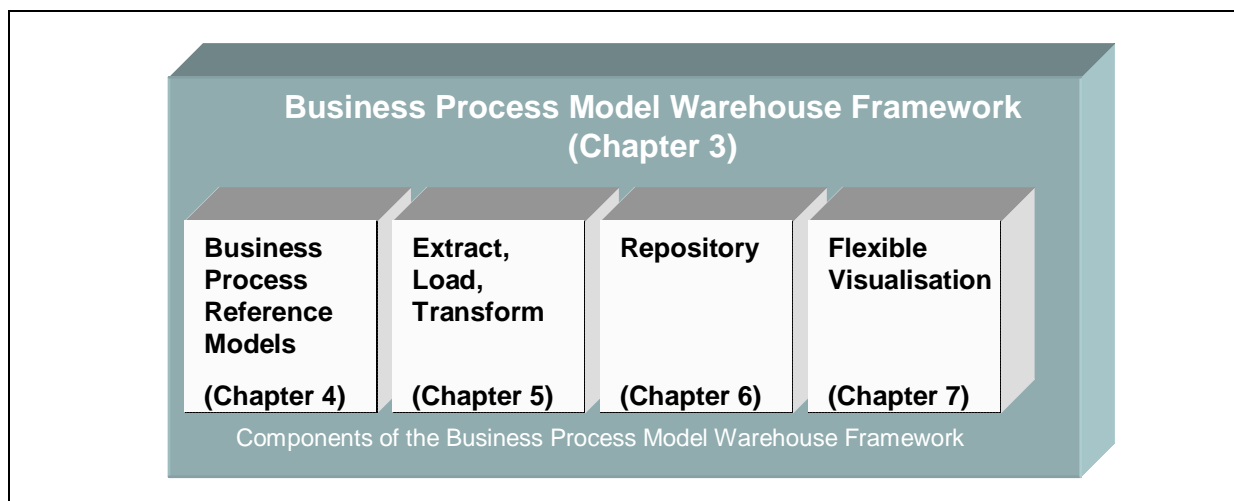


Figure 3.7: Proposed business process model warehouse framework

CHAPTER 4: BUSINESS PROCESS REFERENCE MODELS

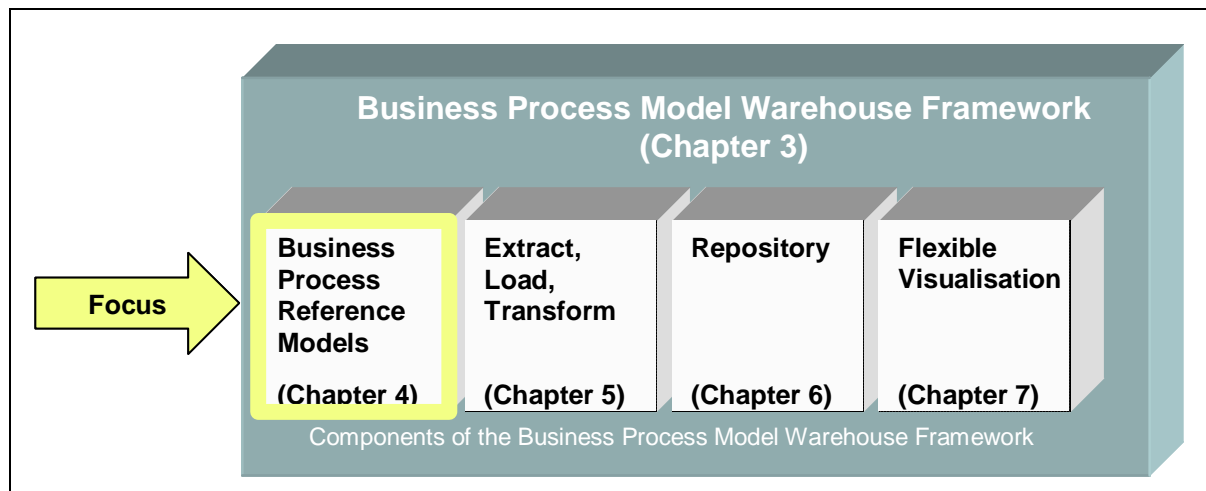


Figure 4.1: Context diagram with focus on business process reference models

From the perspective of the argument (see section 1.4), the promotion of the re-use of multiple business process models is a focal point of Chapter 4. The following research questions are addressed in Chapter 4, although the second question is only introduced in Chapter 4 and explored in more detail in Chapter 5.

- Is it possible to confirm that the use of multiple business process reference models is an acknowledged concept?
- What component(s) lacking in the current references to multiple business process reference models should be addressed by the business process model warehouse framework?
- Is it possible to motivate the role of multiple business process reference models in minimising the causes of inadequate business requirements to some extent?

In Chapter 3, a framework is proposed for a business process model warehouse based on an analogy to a data warehouse. The proposed business process model warehouse framework is depicted as context diagram in Figure 4.1. The first component of the business process model warehouse framework is the business process reference models to be used as source data.

In Chapter 2, the concept *business process reference models* is included as one of the concepts described as part of the enterprise architecture domain. The focus in Chapter 4 is on clarifying the use of reference models versus business process reference models. The SCOR, Industry Print, SAP Solution Manager and MIT Process Handbook are introduced as business process reference models. Examples and more detail of the SCOR, Industry Print and SAP Solution Manager business process

reference models are included as part of the proof of concept in Chapter 5 and in Appendix A, B and C.

The research method of Chapter 4 is based on reference to literature:

- Clarify the diverse use of the term *reference models* in the information management domain in order to position business process reference models in the broader context.
- Give a clear definition of business process reference models, including a description of the features and the potential value of business process reference models.
- Explore the use of multiple business process reference models as source data for the business process model warehouse, as a warehouse implies the extraction, loading and transformation of information from multiple sources.

The structure of Chapter 4 reflects the logical flow of the research method:

- Section 4.1 discusses reference models for enterprise architecture artefacts, for standardisation and for applying methods.
- A more detailed description of business process reference models, a subset of enterprise architecture artefacts, is included in section 4.2. An additional focus is the potential value of business process reference models to ensure more comprehensive business requirements.
- Section 4.3 includes references to literature referring to the use of multiple business process reference models. The references to literature are a confirmation that using multiple business process reference models is an acknowledged practice.

4.1 Reference Model: Various Perspectives

A literature review conducted within the information management domain that refers to reference models, emphasises that the use of reference models is not limited to a single understanding. Although other classifications are valid, it is suggested that for the purpose of this study most of the articles referenced in Chapter 4 be classified as either:

- Reference models for enterprise architecture artefacts.
- Reference models as framework for standardisation.
- Reference models for applying methods.

In order to enhance a common understanding, each of the above-mentioned classifications of reference models are addressed in the subsections below.

4.1.1 Reference Models for Enterprise Architecture Artefacts

In the broadest context, a reference model for enterprise architecture artefacts reflects artefacts and relationships. (Refer to Chapter 2 for a discussion of enterprise architecture.) Business process reference models are also classified as reference models for enterprise architecture artefacts. There are a number of reference models related to enterprise architecture artefacts, and the following list includes some examples from literature:

- The articles by Weske, Goesmann, Holten and Striemer (1999) and Wu, Deng and Li (2004) both focus on a reference model for workflow application development.
- Lynch and Meads (1986) proposes a user interface reference model.
- The article by Tan, Li and Yang (2005) focuses on the extended enterprise model, and although the article includes the business process reference model, it also includes other views for example the information, behaviour, coordination and infrastructure views.

4.1.2 Reference Models as Framework for Standardisation

It is important to specify the context whenever the term *reference model* is used. Although reference models as framework for standardisation is not within the scope of this dissertation, it is important to note that reference models can also be used to refer to a framework for standardisation. Three examples are included below:

- The Database Architecture Framework Task Group of the ANSI/X3/SPARC Database Study Group also known as DAFTG (1986) refers as follows to a reference model as a framework: “A reference model is a conceptual framework whose purpose is to divide standardization work into manageable pieces and to show at a general level how these pieces are related with each other”. The International Organization for Standardization (ISO) reference model of Open Systems Interconnection (OSI) layered architecture is mentioned by DAFTG (1986) as an example of a reference model.
- The definitions given by Averill (1994) provide a second example that is strongly related to a reference model as framework for standardisation, where:
 - A standard is defined as “a criterion by means of consensus as a test of quality”. Every standard has a reference model that provides it with a context.
 - A reference model is a description of the frame of reference for one or more standards. A frame of reference can be thought of as a set of conceptual entities and their relationships, plus a set of rules that govern the interactions of such entities. At the highest level of

abstraction, a reference model is a standard. It prescribes the highest level of architectural structure contained in the model.

- Kim and Fox (2002) presented yet another reference model example, the TOVE ISO 9000 Micro-Theory as a formal reference model of quality best practices. The principle is that a specific organisation's quality management business processes and organisational structures can be represented using a model, and then this model can be compared to a reference model of best practice processes and structures, such as the ISO 9000 standards. The specific organisation models or reference models can be represented using common entities, attributes and relationships.

4.1.3 Reference Models for Applying Methods

Weske et al. (1999) use the term *reference process model*, with a different meaning from that of business process reference models. Reference models for applying methods are excluded from the scope of this dissertation. Examples of reference models for applying methods are:

- The Reference Model of Gunter (Hall and Rapanotti, 2003), defines a reference model for applying formal methods to the development of user requirements and the reduction of such methods to a behavioural specification.
- It is important to differentiate between (business) process reference models as patterns for solutions, and reference process models, for example the waterfall or prototyping model, for software engineering (Weske et al., 1999).

The purpose of section 4.1 is to illustrate that there is no single definition for a reference model and that it is important to confirm the context whenever the term *reference model* is used. For the purpose of this dissertation, business process reference models are referring to reference models for enterprise architecture artefacts and not for standards or applying methods.

4.2 Business Process Reference Models

Section 4.2.1 starts with a discussion of the key features of business process reference models. The second part (section 4.2.2) comments on some examples of business process reference models. Section 4.2.3 concludes with a focus on the value of business process reference models in minimising to some extent the causes of inadequate business requirements as stated by Verner et al. (1999).

4.2.1 Business Process Reference Model Key Features

As discussed in section 2.1.5, business process models that are available for re-use are referred to as *business process reference models* (Ramesh and Jarke, 2001). In the broader context, a reference model can be defined as “a subset of the enterprise architecture artefacts based on best practices pre-populated in a repository”. To ensure a better understanding of business process reference models, key features as identified by Lang et al. (1997) and requirements listed by Esswein et al. (2004) are used as the framework to structure the definition from various bibliographic references:

- Reference to best practices: A key feature of a business process reference model is the representation of best practice solutions as to how a business process can be performed. Business process reference models can also be understood as memories for explicit domain knowledge (Ramesh and Jarke, 2001; Winter and Schelp, 2006; Thomas and Scheer, 2006; Thomas et al., 2006).
- Reusability: The value of a business process reference model is based upon its ability to be re-used in order to generate alternative and innovative business process solutions (Weske, 1999; Ramesh and Jarke, 2001; Winter and Schelp, 2006; Thomas and Scheer 2006; Thomas et al., 2006). Re-usability is related to
 - Adaptability (the possibility to adapt the business process reference model to different situations).
 - Extendibility (the possibility to extend the business process reference model).
- Standardisation: The requirement to build on a standardised structure is fulfilled by defining standards for the layout and properties of the business process reference models. The business process reference models are organised according to an underlying meta model. Completeness checking is possible if based on a methodical frame including integration of all necessary structures, (business) processes and data (Ramesh and Jarke, 2001).
- Hierarchical representation: Decomposition and specialisation (generation of variant business processes) lead to the development of business process reference models on various levels of abstraction. The hierarchical structure and identification codes should guarantee easy search and retrieval.
- Universal validity: Business process reference models are provided for universal use in a wide variety of enterprises, and consequently do not include information related to specific enterprises. Universally valid business process reference models can be arranged and customised in order to generate enterprise-specific business process reference models. Potential usability for derivation of individual models are based upon the completeness, adaptability and usability of the business process reference models.

- Maturation over time: Business process reference models mature over time as the best practices are condensed from numerous case studies and refined and evaluated (Ramesh and Jarke, 2001; Tan et al., 2005). It is important that business process reference models are representative. Just acknowledging the requirements of influential users or customers may result in a low quality of the models that are not used and which will not be accepted by the users. Esswein et al. (2004) discuss the development process of reference models to ensure quality business process reference models. The business process reference models should produce defined results and each model should be regarded as discreet.

It is important to understand the contrast between business process reference models and individualised business process model solutions. A business process reference model is not the solution, but only a pattern or blueprint for the business process model solutions (Weske et al., 1999). Business process models that adhere to these characteristics can be classified as business process reference models.

4.2.2 Examples of Business Process Reference Models

Initially, best practice business processes were documented in reference books, and Scheer (1994) published business process reference models for industrial enterprises as early as 1989. Business process reference models can be classified according to different criteria, and the following represents examples of classifications as mentioned in the article by Kirchmer et al. (2002):

- Industry-specific reference models.
- Software reference models.
- Consulting reference models.

Daneva (1999) gives a more detailed description of a software reference model, the SAP R/3 business process reference model. SAP has developed the SAP R/3 business process reference model, a comprehensive architectural description of the software including four views: business process view, function view, data view and organisational view. Specifically the SAP R/3 business process reference models represent integrated and function-spanning collections of business processes that often occur in practice. Consultants re-use many fragments from the SAP R/3 business process reference model as part of a SAP R/3 implementation project.

An example of a business process reference model that is not limited to a specific industry, specific software or a specific consulting group is the MIT Process Handbook. The MIT Process Handbook is an extensive, publicly available online knowledge base, including over 5 000 activities, and a set of

software tools to maintain and access the knowledge base. One key element of the MIT Process Handbook is that it is a classification system for business activities, similar to the Period Table of Elements or the Human Genome project identifying the approximately 30 000 genes in human DNA. In 2003, the MIT Process Handbook initiative (Malone et al., 2003) was still focusing on the integration with other tools for visualising business processes. The purpose with this initiative is to help people to redesign business processes, invent new business processes and share knowledge on organisational practices. This initiative demonstrates that it is possible to develop a comprehensive framework for organising large amounts of useful knowledge about business. The MIT Process Handbook initiative confirms that it is clear that libraries of business process descriptions, key concepts, and sometimes detailed business process maps have been developed and it is thus possible to have a useful repository of knowledge about business processes.

The Supply-chain Operations Reference-model (SCOR) (industry-specific business process reference model), SAP Solution Manager BPR (software business process reference model) and IndustryPrint (consulting business process reference model) are examples of business process reference models, and the detail is described in Chapter 5 and Appendix A, B and C. It is important to note that these business process reference models were not developed with for example the business or application architecture set as fixed boundaries. Therefore these business process reference models may contain artefacts from various enterprise architectural domains as well as different levels of abstraction and granularity. When referring to business process reference models in the context of this dissertation, the focus is on the business process model components of these business process reference models.

The potential value of reference models are imbedded in the features and requirements, but the value is explicitly stated in section 4.2.3.

4.2.3 Value of Business Process Reference Models

Value is preferably reflected in cost savings and since the analysis of a domain can take an enormous effort when started from scratch, the use of business process reference models has been reported to save up to 80 percent in development costs for systems in standardised domains (Ramesh and Jarke, 2001). Users of business process reference models are interested in the reduction of project cost (Weske et al., 1999). Daneva (1999) states that, as the business process-oriented domain analysis is the most expensive consulting service in a business (re)engineering exercise, the re-use of the SAP R/3 Reference model definitely provides the greatest savings.

However, value is not restricted to cost and therefore the value of business process reference models is summarised as savings in time and costs and an increase in the quality of the model (Lang et al., 1997; Esswein et al., 2004; Thomas et al., 2006; Winter and Schelp, 2006). As an example, Daneva (1999) continues that, more importantly, re-use-driven business requirements modelling ensures that the configured solution can be implemented technically and its future release capability and maintenance are guaranteed. The re-use of business process reference models for the configuration of off-the-shelf software is also addressed by Mendling et al. (2006).

Another perspective is that business process knowledge gained during business process execution is a valuable asset (Becker-Kornstaedt and Reinert, 2002). A business process reference model serves as a reference point for transferring lessons learned, and a business process reference model establishes a common terminology and business process understanding.

Considering the definition and features of a business process reference model as described in section 4.2.1 and the potential value listed in section 4.2.3, it is possible to argue that a business process reference model is indeed a strong candidate to be a business process source model as depicted in Figure 4.1. The question is whether there is reference in literature to the use of multiple business process reference models.

4.3 Multiple Business Process Reference Models

Considering that Chapter 4 is focusing on business process reference models as source business process models as depicted in Figure 4.1, the challenge is to find articles referring to the consolidation of multiple business process reference models into a repository.

Two sources using more than one business process reference model in a repository, were identified. These two sources are:

- *Aligning the Supply Chain Operations Reference (SCOR) model with enterprise application: real-time value chain intelligence* (Gulledge, Cavusoglu and Kessler, 2001a; Gulledge, Cavusoglu and Kessler, 2001b); and
- *Using SCOR and other reference models for e-business process networks* (Kirchmer, Brown and Heinzel, 2001; Kirchmer et al., 2002).

4.3.1 Source 1: Gulledge et al. (2001b)

Gulledge et al. (2001b) refer indirectly to the use of two sets of business process reference models, namely the

- Supply-chain Operations Reference-model (SCOR), as described in Appendix A of this dissertation. The SCOR model is presented as a high-level business process reference model that can be used in designing the supply-chain manager's command centre.
- An application architecture-related set of business process reference models, the Oracle Income Knowledge Base, which is not described in detail as part of this dissertation.

It is possible to generalise the content of Source 1 to some extent. The INCOME Knowledge Bases (KBs) that use best-practice business process reference models for pre-configuring Oracle e-Business Components is according to Gulledge et al. (2001b) a similar approach as the Scheer business process-oriented ARIS approach to SAP R/3 implementation, based on the SAP Solution Manager BPR reference model, discussed in section 4.3.2.

Through the conceptual argument and literature survey by Gulledge et al. (2001b) it is shown that business process reference models can be and are used to improve business process management efficiencies. Although the article by Gulledge et al. (2001b) does not address the extract, load and transform method to incorporate multiple sets of business process reference models into a single repository, it refers at least to the horizontal integration of two sets of business process reference models. The horizontal integration is between the business architecture and the application architecture as reflected in Figure 4.2. The purple line indicates the horizontal integration of the two sets of business process reference models. There is no vertical integration. For an example of vertical integration refer to Figure 5.2 indicating that both SCOR and IndustryPrint are selected within the business architecture sector.

4.3.2 Source 2: Kirchmer et al. (2002)

The second source considered is *Using SCOR and Other Reference Models for E-Business Process Networks* (Kirchmer et al., 2002). Although the method to extract, load and transform multiple business process reference models into a single repository is not the focus of Source 2, at least three sets of business process reference models are mentioned, namely:

- Supply-chain Operations Reference-model (SCOR) – see Appendix A.
- SAP Solution Manager BPR reference model – see Appendix C.
- RosettaNet Standards.

These models are representative of the business architecture, application architecture and technical architecture as defined in Figure 4.2 by the red horizontal line.

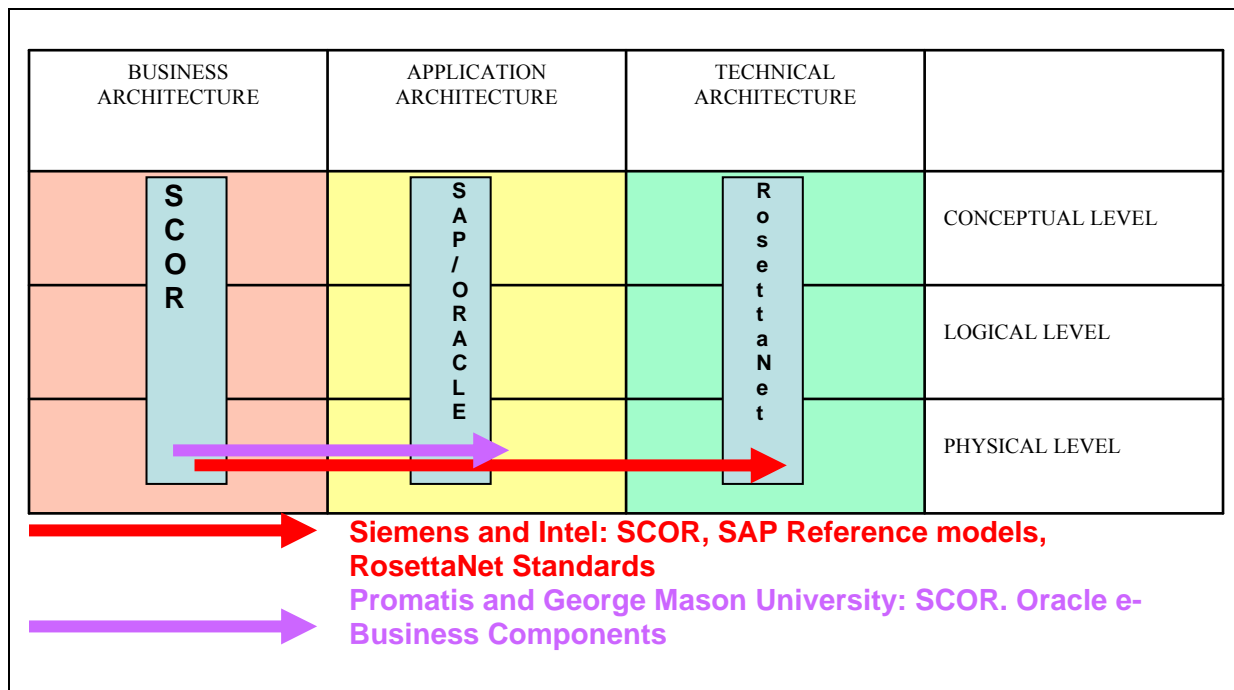


Figure 4.2: References to multiple business process reference models

The major problem or issue being investigated is stated in Source 2 as:

“In order to design and implement inter-enterprise e-business processes efficiently and effectively, more and more organisations use available industry standards in the form of (business process) reference models like the Supply Chain Reference Model (SCOR), developed by the Supply Chain Council, the RosettaNet Standards, or software (business process) reference models. ... What is unclear for many enterprises is how to use those standards” (Kirchmer et al., 2002).

The following major concepts are clearly defined or explained by Kirchmer et al. (2002):

- Definition of SCOR and the use of SCOR as a foundation to ensure focus on inter-enterprise-business-processes in the supply-chain area and the use of a generally available and accepted business process reference model.
- Definition of RosettaNet standards and using RosettaNet standards to specify detailed inter-enterprise interactions, integrated to business processes based on standard application software business process reference models.
- The Architecture of Integrated Information Systems (ARIS) is described as basis for the business process description.

The goal of a joint initiative between Intel, Siemens AG SMS, IDS Scheer and various technology partners has been to develop a comprehensive methodology for the use of business process reference models. Since Intel and Siemens are users of SAP software, the SAP Solution Manager BPR reference models were chosen and included in the development approach. However, business process models based on other software solutions can be used in the same way.

According to Kirchmer et al. (2002), the following benefits have been achieved:

- A single integrated repository of SCOR reference models, standard e-business scenarios and RosettaNet Partner Interface Processes (PIP) information enable the support of future supply-chain projects dealing with inter-enterprise business processes.
- Once a solid meta-architecture is developed for the SCOR to RosettaNet mapping effort, other standards can be incorporated easier.
- Selecting complete business process reference models or just specific parts and elements of these will expedite efforts and lead to much higher standardisation across project teams working off the same business process reference database.
- A business process warehouse of reference models has been built that creates, together with the defined procedures and the enabling ARIS tool, a business process factory. This combined software and tool environment enables an efficient and effective design and implementation of e-business process networks.
- A main contribution is the mentioning of the value of a business process reference model.

The SCOR reference model, RosettaNet Standards and SAP R/3 Reference models were used as multiple business process reference models in a single repository. The importance of a procedural model (method) is critical. The method as described in Source 2 assists in describing how to use the business process reference models only if the models are already available in a repository. One of the criteria for the final selection of the tool was the availability of all required business process reference models in the tool. In contrast, this dissertation focuses specifically on adding or replacing business process reference models not yet available in the repository as source to the business process model warehouse.

As in the article by Gullledge et al. (2001b), Kirchmer et al. (2002) do not address the method to extract, load and transform multiple sets of business process reference models into a single repository. Another concern is that the selected business process reference models do not include the vertical integration between two sets of business process reference models in the same sector as defined in Figure 4.2.

4.4 Conclusion

Let us review the research questions stated as part of Chapter 4:

- *Is it possible to confirm that the use of multiple business process reference models is an acknowledged concept?*

The relevance of the two sources, referenced in section 4.3.1 and section 4.3.2, to this dissertation can be stated as follows:

- It is a confirmation that there is reference in the body of knowledge to the use of multiple business process reference models.
 - It is possible to compare and align concepts, definitions and approaches.
- *Which components lacking in the current references to multiple business process reference models should be addressed by the business process model warehouse framework?*

From the perspective of this dissertation, the areas that are not addressed by either of these sources are:

- A description of the method to extract, load and transform (ELT) (refer to Chapter 5) more than one business process reference model into a repository. A conceptual method for the ELT of multiple business process reference models is proposed in Chapter 5 of this dissertation.
- The integration of models from both the horizontal and vertical sectors as defined by the Gartner nine architectural sectors of metadata (refer to Figure 4.2) is lacking. The sources (Gulledge et al., 2001b and Kirchmer et al., 2002) are both limited to integration across horizontal sectors of business process reference models. As proof of the concept, the proposed method and a case study including vertical and horizontal integration of three sets of business process reference models are discussed in Chapter 5.

The concepts of integration of business process reference models across horizontal sectors or within a vertical sector are important for the reasoning within this dissertation. As indicated in Figure 4.2, Gulledge et al. (2001b) and Kirchmer et al. (2002) do not address the challenge of more than one business process reference model for the business architecture, the application architecture or the technical architecture sectors. If both the SAP and Oracle business process reference models were discussed in both of these two sources as software business process reference models as part of the application architecture sector, the articles would have addressed both horizontal and vertical integration of business process reference models.

- *Is it possible to motivate the role of multiple business process reference models in minimising to some extent the causes of inadequate business requirements?*

According to the information provided in section 4.2.3, there is a definitive cost saving. The cost saving is the result of less time required to define the business requirements and more comprehensive requirements eliminating unnecessary rework. The re-use of business process reference models could indeed minimise to some extent two causes of inadequate business requirements, namely:

- Inadequate business requirements gathering as the business process reference model provides comprehensive predefined business process only to be verified.
- Less time required from the customer as the business processes only needs verification and no redevelopment from scratch.

Chapter 5 will address in more detail the research question about the business process model warehouse framework component that is lacking in the current references to multiple business process reference models. Firstly, neither Source 1 or Source 2 focused on nor discussed the method of extracting, transforming and loading (ELT) multiple business process reference models into a single repository in detail. Secondly, the examples described as part of the sources are limited to horizontal integration and do not address the vertical integration of business process reference models in a single sector as defined in Figure 4.2. The proposed solution and case study as documented in Chapter 5 therefore focus on the method behind the integration of multiple business process reference models in a single repository. An additional challenge of the proof of concept is to verify that the ELT method is suitable for both horizontal and vertical integration as defined in Figure 4.2.

CHAPTER 5: EXTRACT, LOAD, TRANSFORM

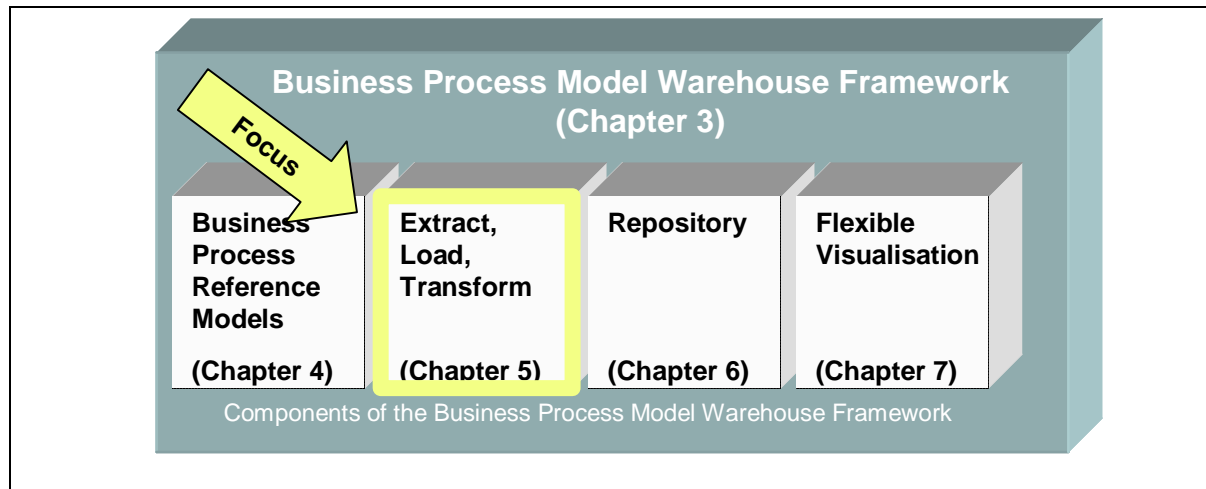


Figure 5.1: Context diagram with focus on extract, load, transform

The intent of this dissertation is to focus on the problem of inadequate business requirements from a business process model warehouse perspective. As the concept of business process model warehouse is not well defined, the overall approach of the dissertation is to understand the data warehouse concept and then to apply the understanding of the data warehouse concept to the business process model warehouse concept. Chapter 5 will contribute to the research question introduced in Chapter 4, namely: *What component(s) lacking in the current references to multiple business process reference models should be addressed by the business process model warehouse framework?*

Two areas of concern were identified in Chapter 4, namely:

- A description of the method to extract, load and transform (ELT) more than one business process reference model into a repository is not defined in the sources referenced in Chapter 2.
- The integration of models from both the horizontal and vertical sectors as defined by Gartner's nine architectural sectors of metadata (refer to Figure 4.2) are lacking.

In Chapter 4 it is argued that business process reference models have the potential to address the problem statement of inadequate business requirements. The challenge however remains that if the multiple business process reference models are not consolidated into a single repository it will not be possible to realise this value. Chapter 5 will focus on the extract, load and transform component as depicted in Figure 5.1 to include a component making it possible to load multiple business process reference models into a single repository. The question is whether it is possible to learn from the similarities and differences of the extract, load and transform process of a data warehouse environment.

As the business process model warehouse framework (Figure 5.1) is derived from the data warehouse framework, the first section of Chapter 5, gives an overview of the extract, load and transform component from a data warehouse perspective. The second section of Chapter 5, proposes a process to extract, load and transform multiple business process reference models (a subset of potential business process source models) into a single repository based on the data warehouse ELT component. The proposed approach is verified as part of an example that is included in section 5.3.

5.1 The Data Warehouse Perspective on ELT

ELT can be defined as a set of tools, which is responsible for the preparation of the data constituting the data warehouse (Rifaieh and Benharkat, 2002, Simitsis, 2005). Traditionally, ETL (extract, transform and load) comprises the set of processes by which data is extracted from numerous databases, applications and systems, transformed as appropriate, and loaded into target systems – including, but not limited to, data warehouses, data marts and analytical applications. The latest third-generation ETL changed the ETL process from transforming before loading to loading and then transforming, and this is currently known as ELT.

According to Rifaieh and Benharkat (2002), ELT includes a transformation process where the correspondence between the sources data and the target data warehouse data is defined. These mapping expressions should be defined in the metadata of the system. There are five components to consider (Srivastava and Chen, 1999, Rifaieh and Benharkat, 2002), namely:

- Metadata model creation.
- Metadata mapping model.
- Extraction process.
- Loading process.
- Transformation process.

Each of these components is discussed in more detail in section 5.1.1 to section 5.1.5.

5.1.1 Data Warehouse ELT: Metadata Model Creation

The first step of the data warehouse ELT method is to create a metadata model, also known as a *schema* (Rizzi, Abello, Lectenborger and Trujillo, 2006). The metadata model is the output of data modelling. Data modelling captures the entities and the relationships between the entities. It is important to create the metadata model for each of the source databases. The next step is to create the metadata model of the target data warehouse. Srivastava and Chen (1999) stated that in an ideal situation such modelling would begin by analysing the various processes in the organisation and by extracting the relevant entities and relationships from these. However, Srivastava and Chen (1999) continue by stating that in most situations it is much more realistic to use the existing entities and relationships modelled by the schemas of existing data sources as a starting point. The result of the meta-model creation is a meta-model for each source and target database.

5.1.2 Data Warehouse ELT: Metadata Mapping Model

The second step of the data warehouse ELT method is to align the different meta-models of the source and target databases with the intent of creating a meta-model mapping model. The metadata mapping model, also known as *schema integration*, describes how a target field could be mapped from a set of source fields. This description of the mapping of source to target data is also known as the *mapping expression*. The metadata mapping is not a trivial activity. See Vassiliadis, Simitsis and Skiadopoulou (2002) for a proposed conceptual model to define ELT activities including formal foundations for the conceptual representation. The challenge is to integrate multiple overlapping models of a set of real-world entities. As the models have been developed independently the entities may not match well. Examples of discrepancies are structural heterogeneity, semantic heterogeneity and constraint incompatibilities:

- Different field sizes, units or scales are examples of *structural heterogeneity*.
- *Semantic heterogeneity* includes the synonym and homonym problems, for example EMP and EMPLOYEE being used to refer to the same class of real-world employees in two different databases. However, EMP could also be used to refer to real-world employees in one database and to real-world employers in another.
- An example of a *constraint mismatch* is two databases with the age of the employee being constrained to less than 60 in the one and less than 65 in the other. As the constraints often influence the quality of the data selection, the lowest common denominator may not always be the recommended approach.

Meta-model integration remains a complex and human intensive task (Srivastava and Chen, 1999). The mapping of the metadata from the source databases to the target database is a prerequisite for the extraction, loading and transformation of the source data to the target database.

5.1.3 Data Warehouse ELT: Extraction Process

The extraction process is concerned with the collection of the needed data, and only the needed data, from different sources. The metadata mapping provides the rules or the parameters for the extraction process. Depending on the type of source it may be necessary to develop programs to extract the data, or the extraction process could be much simpler if it is possible to run queries (Rifaieh and Benharkat, 2002).

5.1.4 Data Warehouse ELT: Loading Process

The loading process is responsible for loading the extracted data into a temporary database. The temporary database has the same structure as the source data, and a temporary database is created for each source database. The loading process comprises a two-step approach:

- The first step is to create the temporary database with a similar structure to that of the source database.
- The second step is to populate the temporary database with the extracted data. It is important not to populate the temporary database with unneeded data (Rifaieh and Benharkat, 2002).

5.1.5 Data Warehouse ELT: Transformation Process

The transformation process here consists of the generation of transformation queries based on the mapping rules as defined in the metadata mapping model. During the transformation process controls and checks are applied to the data to ensure that the content, structure and values are valid. As part of the transformation process it is important to define the rules for the integration of specific data instances and mapping expressions.

Srivastava and Chen (1999) mentioned that integration of specific data instances has its own challenges, including entity identification, attribute value conflict resolution and incremental updates.

- *Entity identification* is concerned with the identification of pairs of records, from different databases, representing the same real-world entity. The challenge is to do the mapping if there is no common key that can be used as identifier for the union of the two sets of records.

- *Attribute value conflict resolution* is required when records from different databases have been matched but it is found that values of the same attribute for an entity instance, coming from different data sources, are different.
- *Incremental updates* are about adding data to an existing warehouse and the integration of the data with the pre-existing data.

The mapping expressions are essential in order to apply the mapping to transfer the data. Rifaieh and Benharkat (2002) included some examples of mapping expressions within the data warehouse context:

- *Break-down/concatenation* refers to establishing the value of a field by breaking down the value of a source and by concatenating it with another value.
- *Arithmetic operation* refers to the calculation of a function to determine the result value of the target attribute.
- *Conditional mapping* occurs when the value of a target attribute depends on the value of another attribute (if $X=1$ then $Y=A$ else $Y = B$).

Section 5.1 gave a summary of the components and some challenges related to the data warehouse extract, load and transform (ELT) method. This summary of the ELT method will be used as starting point to propose an ELT method for a business process model warehouse in section 5.2.

5.2 Business Process Model Warehouse Perspective on ELT

The objective of this section is to document a structured ELT method to incorporate multiple business process reference models into a single repository based on the data warehouse framework. For comparison purposes, the same terminology will be used as in the data warehouse domain, namely extract, load and transform (ELT).

In order to determine whether it is valid to compare the data warehouse ELT method and a business process model warehouse ELT method, it is a prerequisite to have a description of both ELT methods. The data warehouse ELT method was summarised in section 5.1. The challenge is to get a basic description of a business process model warehouse ELT method. As described in Chapter 3, business process reference models will be used as business process source models for the purpose of this dissertation. Although Gullledge et al. (2001b) and Kirchmer et al. (2002) refer to the integration and use of multiple business process reference models, the method to incorporate multiple business process reference models is not addressed. Earlier work on a proposed description of the ELT method of the business process model warehouse is described in Jacobs (2005) and this is summarised in

section 5.2.1. The summary is followed by a comparison between the data warehouse ELT and a business process model warehouse ELT.

5.2.1 Multiple Reference Models Challenging a Single Repository

The basic description of the ELT process by Jacobs (2005) is based a number of prerequisites, namely

- A detailed understanding of each set of business process reference models.
- A logical design (metadata model) to represent the content of the set of business process reference models in the repository.
- A consolidated view (integrated metadata model) of the different logical designs to ensure the integrity of the content of the repository.

Jacobs (2005) summarised the integration of the multiple business process reference models into a single repository in three steps:

- *Step 1: Analysis and understanding of each set of business process reference models*

There is no standard for the development of business process reference models. Understanding a set of business process reference models requires at least consideration of the following areas:

- Background.
- Objective.
- Content.
- Structure.
- Documentation format.

- *Step 2: Abstraction and logical design of the set of business process reference models*

The objective is to populate the repository with the specific set of business process reference models. A repository is a database and, in order to populate it, it is necessary to design the data structure in such a way as to allow the data to be captured. One of the well-known methods to define the data structure design for the database is the Entity Relationship Diagram. One can either re-use an existing data model of the set of business process reference models, if available, or develop a logical design based on the step 1 analysis, enabling the population of the repository with the set of business process reference models.

- *Step 3: Consolidation*

In order to accommodate multiple sets of business process reference models in a single repository, it is important to consolidate the different logical data structure designs to ensure the integrity of the database. This is also known as the *meta-model of the repository*. It is important to consider

both common and unique definitions. Understanding the structure and definition of each object and attribute of a set of business process reference models is critical to ensure the integrity of the content of the repository.

The three steps summarised in the technical report (Jacobs, 2005) is compared with the following five components of the data warehouse ELT method and extended as required:

- Metadata model creation.
- Metadata mapping model.
- Extraction process.
- Loading process.
- Transformation process.

5.2.2 Comparison: Metadata Model Creation

The first step of the data warehouse ELT method is to create a metadata model. In comparison, step 2 of the technical report (Jacobs, 2005) – abstraction and logical design of the set of business process reference models – is similar to the creation of a metadata model. It is important to create the metadata model for each of the source databases and therefore it is also important to define the metadata model for each of the business process reference models.

A difference between the data warehouse ELT method and the technical report (Jacobs, 2005) for the integration of multiple business process reference models is the starting point. Using the existing entities and relationships, modelled by the schemas of existing data sources, is not feasible for the business process model warehouse as for most of the business process reference models it is not available. The starting point is rather the analysis and understanding of each set of business process reference models (step 1 of the technical report) (Jacobs, 2005).

Both step 1 and step 2 of the technical report (Jacobs, 2005) are therefore combined to reflect the metadata model creation component of the data warehouse ELT method. The metadata model creation processes are so similar that it is valid to compare the metadata model creation component of the data warehouse ELT method with the business process model warehouse concept. In order to apply the ELT method to the business process model warehouse, the ELT method (the meta-model creation component) is extended to include a detailed understanding and analysis of the business process reference model.

5.2.3 Comparison: Metadata Mapping Model

The consolidated metadata model of the business process repository can be compared with the metadata mapping model of the data warehouse ELT method. The metadata mapping model describes how a target field could be mapped from a set of source fields. The challenges and discrepancies, as described for the data warehouse ELT method, are also valid for the consolidation of multiple business process reference models. As the models of the business process reference models have been developed independently, the metadata of the multiple business process reference models may not match well.

In order to resolve the discrepancies, including structural heterogeneity, semantic heterogeneity and constraint incompatibilities, an option is to keep each set of business process reference models rather as a separate component of the business process model warehouse and to create relationships between entities from different business process reference models in the business process model warehouse. (Refer to section 5.3 for a specific example of the mapping between different business process reference models in the business process model warehouse.)

Step 3 of the technical report (Jacobs, 2005) is mapped to the metadata mapping component of the data warehouse ELT method. The metadata mapping model component of the data warehouse ELT method is valid for the business process model warehouse ELT. A major difference is that each specific business process reference model is included in the business process model warehouse. The metadata mapping model within the business process model warehouse context is more focused on mapping the relationships between the entities of the different business process reference models.

5.2.4 Comparison: Extraction Process

The extraction, loading and transformation processes were not included as part of the technical report (Jacobs, 2005). Based on the metadata mapping model, it is possible to identify the required entities and relationships from the business process reference source models. The extraction process is concerned with the collection of the required data from different sources. The extraction component of the data warehouse ELT method is therefore applicable to the business process model warehouse ELT method. However, the nature of the extraction may differ. Within the context of a data warehouse, the source data is already available in a well-structured database and the extraction is based on a query from a database. In contrast, business process reference models may not be available in a database and the extraction may involve the extraction of the content from a text document.

An example of the proposed extraction component for a business process model warehouse is included in section 5.3.

5.2.5 Comparison: Loading Process

As with the other components of the data warehouse ELT method, the loading component is also applicable to the business process model warehouse ELT method. The recommended loading process for both the data warehouse and business process model warehouse is a two-step approach, but with a slight difference. Within the data warehouse ELT method the first step of the loading process is to create the temporary database with a similar structure as that of the source database. The difference is that a database for the business process reference model might not exist, implying that the first step is to create a database based on the structure of the metadata model of the business process reference model. The second step of populating the temporary database with the extracted data from the source data, whether a database or a text-based document, is similar to the data warehouse loading process. In the case of business process models, the temporary database will most likely be a repository. (Refer to Chapter 6 for a description of the difference between a repository and a database.)

The importance of the loading process in the business process model warehouse framework should not be underestimated. Ensuring that there is no unneeded data in the temporary database eliminates the filtering and integration of irrelevant information as part of the transformation process.

5.2.6 Comparison: Transformation Process

As with the other components of the ELT method, the transformation process is relevant both to the data warehouse and the business process model warehouse perspectives. Although the transformation process is applicable, the transformation within the business process model warehouse context is not focused on the generation of transformation queries based on the mapping rules, but rather on merging rules. The characteristics and functionality, including merge functionality, of a repository is to be discussed as part of Chapter 6. It is however important to mention at this stage that the transformation to the business process model warehouse is to a large extent based on merge functionality. The merge functionality does not change the purpose of the transformation process, namely to apply controls and checks to the data to ensure that the content, structure and values are valid.

Entity identification, attribute value conflict resolution and incremental updates are still valid challenges with the transformation of the business process reference source information to the target business process model warehouse:

- The reality, as will be demonstrated as part of the example in section 5.3, is that it is rare to find a common key between business process reference models, which can be used as identifier for the union of the two sets of records. Entity identification between multiple sets of business process reference models is initially an intensive and manual task.
- Attribute value conflict resolution may occur with the transformation of business process reference models, but the approach to build relationships between business process reference models rather than to transform records makes it less of an issue. When records from different business process reference models have been matched and it is found that values of the same attribute for an entity instance, coming from different data sources, are different, it is possible to set rules as part of the merge functionality regarding the value to be maintained, for example the source or the target value.
- Incremental updates of business process reference models are published periodically. If the structure of the business process reference model remains the same, the update can be automated. A restructured business process reference model and the impact of changes on other relationships may imply a higher level of manual intervention.

The mapping expressions are certainly playing a role in the transformation of business process reference models, but the type of mapping expressions will differ. Break-down/concatenation and arithmetic operation may not be relevant, but conditional mapping will play a role. The mapping expressions for the business process model warehouse will be more focused on maintaining, deleting or creating relationships.

5.2.7 Proposed Business Process Model Warehouse (BPMW) ELT Method

Based on the similarities and difference between the data warehouse ELT method and the initial proposed method for the integration of multiple business process reference models, the following table reflects a proposed ELT method for a business process model warehouse.

Table 5.1 Business process model warehouse ELT method

Technical report (Jacobs, 2005) method	Data warehouse ELT method	Proposed business process model warehouse ELT method
Step 1: Analysis and understanding of each set of business process reference models.	Metadata model creation	Metadata model creation: <ul style="list-style-type: none"> Analyse each business process reference model. Create metadata model for each business process reference model.
Step 2: Abstraction and logical design of the set of business process reference models.		
Step 3: Consolidation.	Metadata mapping model	Mapping of meta-model: Create a consolidated meta-model.
	Extraction process	Extraction process: Identify the needed entities and relationships from the source business process reference models whether from text or database format.
	Loading process	Loading process: <ul style="list-style-type: none"> Create temporary repository. Merge the selected entities and relationships to the temporary repository.
	Transformation process	Transformation process: <ul style="list-style-type: none"> Merge the content of the temporary database into the business process model warehouse repository. Create relationships between the entities of the different business process reference models.

An example is included in section 5.3 to verify the feasibility of the proposed ELT method for a business process model warehouse. As with the data warehouse ELT method, the business process model warehouse ELT process remains a complex and human-intensive task.

5.3 Example to illustrate BPMW ELT

Section 5.3 describes an example to illustrate the extract, load and transform components of the business process model warehouse. The objectives of the example to illustrate the business process model warehouse ELT method are:

- To verify that the proposed business process model warehouse ELT method to integrate multiple business process reference models into a single repository is feasible.
- To illustrate the potential value of multiple business process reference models available within a business process model warehouse to address the issue of inadequate business process requirements.

The criteria for the selection of the business process reference models are described in section 5.3.1:

- For this specific example, the criterion is to ensure that the example will relate to the research problem of inadequate business requirements as discussed in Chapter 1.
- A second criterion to consider is the concept of vertical and horizontal integration, as mentioned in Chapter 2. Existing sources (Chapter 4) do not address the integration of business process reference models vertically and horizontally as defined in Figure 2.10, Nine architectural sectors of metadata. The proposed solution should specifically include an example that addresses the integration of business process reference models horizontally as well as vertically.

The proposed business process model warehouse ELT method as introduced in section 5.2.7 is verified as part of the illustrative example in section 5.3.2. The proposed ELT method consists of the following process steps:

- Metadata model creation as discussed in section 5.3.2.1.
- Mapping of meta-model as included in section 5.3.2.2.
- The extraction process as addressed in section 5.3.2.3.
- The loading process discussed in section 5.3.2.4.
- The transformation process concluding the example in section 5.3.2.5.

5.3.1 The Selected Set of Business Process Reference Models

The objective of this dissertation is to propose a business process model warehouse framework, promoting the re-use of multiple business process reference models and flexible visualisation of business process models, thereby minimising to some extent the causes of inadequate business requirements stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the specifications really mean.

Multiple business process reference models play a prominent role as part of the argument (see section 1.4). To illustrate the value of the use of multiple business process reference models to address the issue of inadequate business requirements, the following three business process reference models have been selected, namely:

- Supply-chain Operations Reference-model (SCOR) version 6.0.
- IndustryPrint 3.0 reference model.
- SAP Solution Manager BPR reference model.

These selected sets of business process reference models are briefly discussed in the sub-sections of section 5.3.1. A more comprehensive description is available in Appendices A, B and C to this dissertation. In order to motivate the selection of these specific business process reference models, a brief background as well as the objectives for each of the business process reference models is included.

5.3.1.1 Supply-chain Operations Reference-model Version 6.0 (SCOR)

The Supply-chain Operations Reference-model (SCOR) has been developed and endorsed by the Supply-chain Council (2003). The Supply-chain Council (SCC) is an independent not-for-profit corporation. Pittiglio Rabin Todd and McGrath (PRTM) and AMR Research organised the SCC in 1996. The SCC had close to 1 000 corporate members in 2004, a noticeable growth from the initial 69 voluntary member companies. The objective of the SCC is to improve the supply-chain efficiency of its practitioner members and the focus is on the development and application of the SCOR reference model.

The SCOR reference model is a business process reference model that provides a language for communicating among supply-chain partners. This specific business process reference model links process elements, metrics and best practices. Business process reengineering, business process

management, benchmarking and process measurement concepts are integrated in the SCOR framework.

The SCOR reference model contains:

- Standard descriptions of supply-chain management business processes.
- S framework of relationships among the standard supply-chain business processes.
- Standard metrics to measure supply-chain business process performance.
- Management practices that produce best-in-class supply-chain performance.

The value of the SCOR reference model is to be found in its application. Applying the SCOR reference model enables a company to:

- Describe and communicate the supply-chain unambiguously.
- Describe and communicate inter-company supply-chains.
- Configure a supply-chain based on standard SCOR business process definitions.
- Measure and benchmark a supply-chain performance against the standard SCOR metrics.
- Maintain customer-supplier relationships.
- Use software systems supporting common measurements and terms.
- Rapidly recognise and adopt best practices no matter where these originate.

5.3.1.2 IndustryPrint 3.0 Reference Model

IndustryPrint is a proprietary tool created and maintained by Deloitte and initially introduced in 1996 (Deloitte Consulting LLP, 2004). IndustryPrint consists of enterprise-wide business process models that reflect best practices for key business processes in a given industry segment.

IndustryPrint adds value to a project in various ways, including:

- Assisting in developing a proposal.
- Depicting the scope of a project.
- Describing the business context in visual terms for better understanding by the project teams.
- Providing a structure that can be used to organise the project team and/or deliverables around business processes.
- Performing a high-level fit/gap analysis between business processes and the enabling technology.
- Accelerating the modelling of the current and/or future state of a business process.
- Assisting with the design of test scenarios.
- Contributing to the transfer of knowledge related to business processes.
- Allowing practitioners to re-use best practices derived from industry experience.

5.3.1.3 SAP Solution Manager BPR Reference Model

The SAP reference models were developed as a joint initiative over twelve years by SAP AG and IDS Scheer (Scholz and Volmering, 2004):

- 1992 Adopt the Event-driven Process Chain as method.
- 1994 Publish the SAP R/3 reference model.
- 1998 Integrate the organisation structure from the SAP system.
- 2002 Provide redocumentation services for the implemented SAP system.
- 2004 Integrate the business view and static implementation view.

The vision is to combine the strength of a world leading tool for business process management, ARIS from IDS Scheer (IDS Scheer, 2004) with the SAP NetWeaver (SAP AG, 2004) technology to support the total business process management lifecycle. The lifecycle includes the following phases:

- The design and modelling of business processes.
- A business process-driven configuration of different applications.
- The execution of the business processes.
- The monitoring and analysis of business processes.

The ultimate goal is to close the gap between business and information technology (IT) and for IT to act as enabler of change, including business process management. A common repository is necessary to manage business processes across applications and across enterprise boundaries. The SAP Solution Manager BPR reference model plays a role in addressing the following problematic points (Scholz and Volmering, 2004):

- Business owners and IT experts do not speak the same language, do not share the same concepts of business processes and do not use the same tools.
- There is a plethora of tools without integration of views and objects.
- Projects run out of budgets as a result of time lost to ensure alignment of internal needs.
- There is no formal methodology to ensure alignment between business logic and technical implementation.
- There is no traceability and transparency between the business model and the business process configuration.
- For application-to-application and business-to-business specific business processes the solutions are based on a patchwork of hard-coded cross-component integration.
- There is no common repository to manage the metadata.

- There is limited business process management and control across applications and enterprise boundaries.

5.3.1.4 Motivation for Selection of Sets of Business Process Reference Models

The question is whether the combination of the SCOR reference models (Supply-chain Council, 2003), the IndustryPrint reference models (Deloitte Consulting LLP, 2004) and the SAP Solution Manager BPR reference models (SAP AG, 2004) illustrate how the business process model warehouse contributes in minimising the causes of inadequate business requirements stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the specifications really mean.

To motivate the specific selection of these sets of business process reference models the potential value of these specific business process reference models to minimise the causes of inadequate business requirements are discussed:

- From the inadequate business requirements gathering perspective it is at least possible to query content that is represented in the sets of business process reference models and that is not included in the business process requirement. Comparison with business process reference models enables completeness checking as well as integration checking. It is possible to clearly define the business processes that are in scope as well as the business processes that are out of scope as part of the business requirement specification. These statements are applicable to all three selected business process reference models.
- The sets of business process reference models include predefined business processes and it is possible to:
 - Prepare examples of business requirements before the work sessions.
 - Distribute concept business requirements to the customer.
 - Prepare to provide input during the work session.
 - Verify the content before and during the work sessions.

Although not scientifically proven from practical experience, using predefined business processes as accelerator could reduce the effort during work sessions by between 40% and 60%. The result is that less time is required from the customer in work sessions. The objectives listed for the IndustryPrint reference models are also mentioned as objectives accelerating the modelling of the current and/or future state of a business process.

- Enhancing the understanding of the customer of the real meaning of business requirements is a specific objective of the SCOR and IndustryPrint reference models. As mentioned in the previous paragraphs, one of the main objectives of SCOR reference model is to provide a language for communicating among supply-chain partners. As part of the IndustryPrint, objectives describing the business context in visual terms for better understanding by the project teams are listed. Even the listed objectives of the SAP Solution Manager BPR reference model include the issue of business owners and IT experts not speaking the same language.

The second question to motivate the selection of the selected business process reference models is whether the specific sets of business process reference models complement one another. The specific example discussed is related to the supply-chain domain. The SCOR reference model addresses the (business) process element level, but the implementation level (the decomposition of the (business) process element level) is not within the scope of the SCOR reference models. The IndustryPrint reference models close this gap between the higher level business processes and the detailed business process level. Both the implementation level and the technology enabling level is referenced as part of the IndustryPrint reference models. The detailed technology enabling models are found in the SAP Solution Manager BPR reference models. In order to prepare a comprehensive business process model for a work session, addressing both the business process requirements as well as the technology enablement, components of the SCOR reference models, the IndustryPrint reference models and the Solution Manager BPR reference models are required. As the SCOR reference model is not including business processes not related to the supply-chain, such as the financial and human resource management business processes, a more comprehensive set of business process reference models, for example IndustryPrint, is required for the non-supply-chain business processes. The following is a summary of the complementary nature of these three sets of reference models:

- | | |
|----------------------------|--------------------------------------|
| • SCOR | Supply-chain business processes |
| • IndustryPrint | Management business processes |
| • IndustryPrint | Support business processes |
| • IndustryPrint | Reference to technology enabling |
| • SAP Solution Manager BPR | Detailed technology enabling models. |

5.3.1.5 Representative Selection Based on Architectural Sectors

Both the business architecture and application architecture as described by Scholz and Volmering (2004) are considered in the selection of the business process reference models for the BPMW ELT example:

- The (business) process architectural model defines the business processes from a real business perspective without having a proper idea of the technology required to support this business process in the future.
- The (business) process configuration model defines the enablement of the business process with specific application system functionality. The SAP Solution Manager BPR reference model consists of preconfigured content and preconfigured reference models. By mapping the SAP Solution Manager BPR reference model to the business processes it is possible to visualise integration across applications.

Using a single set of software business process reference models on a single project may not be a major challenge. Using both a single set of software business process reference models together with a set of consulting business process reference models may still be manageable. The challenge is to incorporate a set of software business process reference models, together with a set of consulting business process reference models as well as a set of industry-specific business process reference models. The intent of the example is to select a combination of consulting, industry and software business process reference models.

The second objective is to ensure both vertical and horizontal integration referring to Figure 5.2 Reference model sectors. It is recommended that Figure 5.2 is studied together with Figure 2.10 in section 2.1.2.2 and Figure 4.2 in section 4.3. The Nine architectural sectors of metadata (Blechar, 2003) is described in section 2.1.2.2. The intent is to select two sets of business process reference models to illustrate vertical integration, as well as another set of business process reference models to illustrate horizontal integration. There should at least be two lines in the same column (vertical integration) and a line crossing from one column to the next (horizontal integration). Vertical integration is an indication that the business process reference model content may overlap and the mapping is more challenging. Horizontal integration is an indication of complementary fit of business process reference models. By creating a relationship, navigation to another set of models is possible. As proof of concept, the following business process reference models were selected to ensure vertical and horizontal integration as depicted in Figure 5.2 Reference model sectors:

- As business architecture, the Supply-chain Operations Reference-model (SCOR) and IndustryPrint 3.0 reference model were selected as enabling vertical integration. The SCOR reference model is an industry-specific reference model and IndustryPrint is a consulting reference model.
- As application architecture, the SAP Solution Manager BPR reference model was selected as enabling horizontal integration. The SAP Solution Manager BPR reference model is a software reference model.

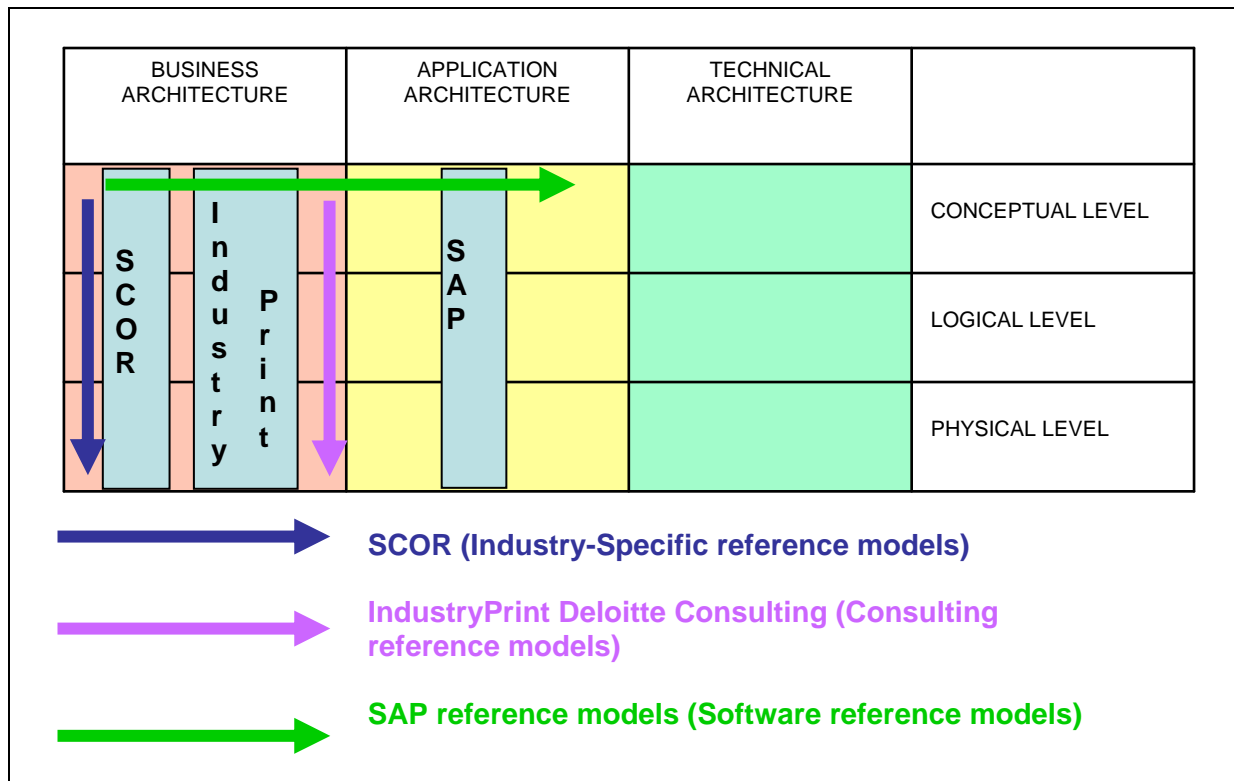


Figure 5.2: Reference model sectors

5.3.2 Applying the Proposed BPMW ELT

5.3.2.1 Meta-model Creation

The detailed analysis of the selected business process reference models to ensure a better understanding of these business process reference models is discussed in Appendices A, B and C:

- Appendix A: Supply-chain Operations Reference-model version 6.0 (SCOR).
- Appendix B: IndustryPrint 3.0 reference model.
- Appendix C: SAP Solution Manager BPR reference model.

The analysis of the business process reference models is the input for the creation of a meta-model per business process reference model. For a description of the entity relationship diagram notation, refer to section 2.2.2.

Figure 5.3 is a simplified and denormalised meta-model of the SCOR reference model.

- Process_Level_1 defines the scope and content of the SCOR reference model (Plan, Source, Make, Deliver, Return).

- Process_Level_2 consists of Process Categories that can be configured to represent a company's competitive environment (Deliver to Stock, Deliver to Order, Deliver to Engineering).
- Process_Level_3 is used in different configurations to define the operational aspect of a supply-chain.
- Metrics is a business process measurement represented in a unit of time, money, quantity or as ratios thereof.
- Best Practices define successful standard operating procedures for a given business type.
- Best Practice Feature is defined as the technology elements that are associated with best practices.
- Performance Attributes define the characteristics of the supply-chain that permit it to be analysed and evaluated against other supply-chains with competing strategies.

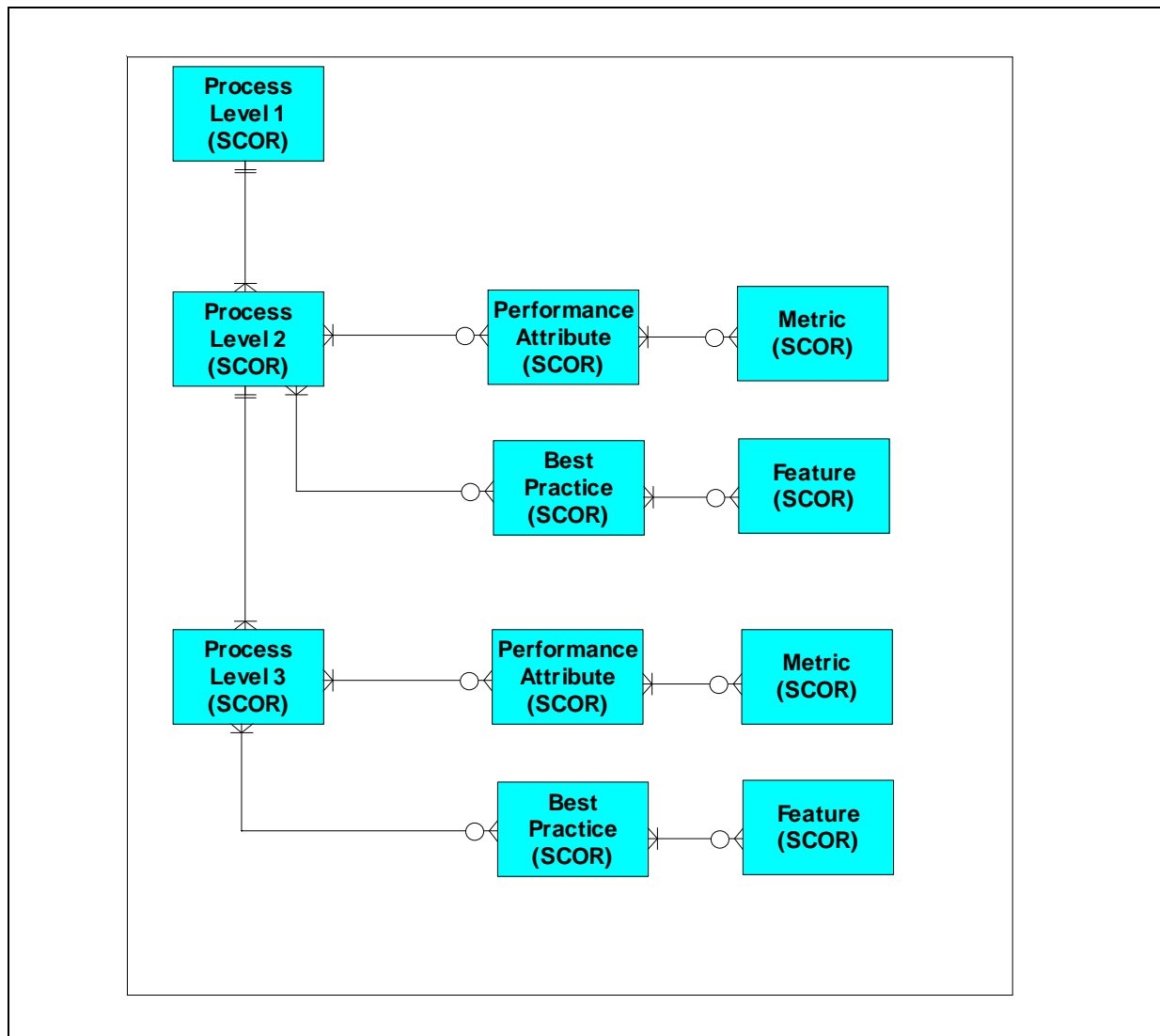


Figure 5.3: SCOR meta-model

Figure 5.4 is a proposed simplified and denormalised meta-model of the IndustryPrint reference models. The decomposition hierarchy of the IndustryPrint reference models is:

- A *Process* is decomposed into one or more *Sub-processes*.
- A *Sub-process* is decomposed into one or more *Business Activities*.
- A *Business Activity* is decomposed (optional) into one or more *Workstep(s)*.

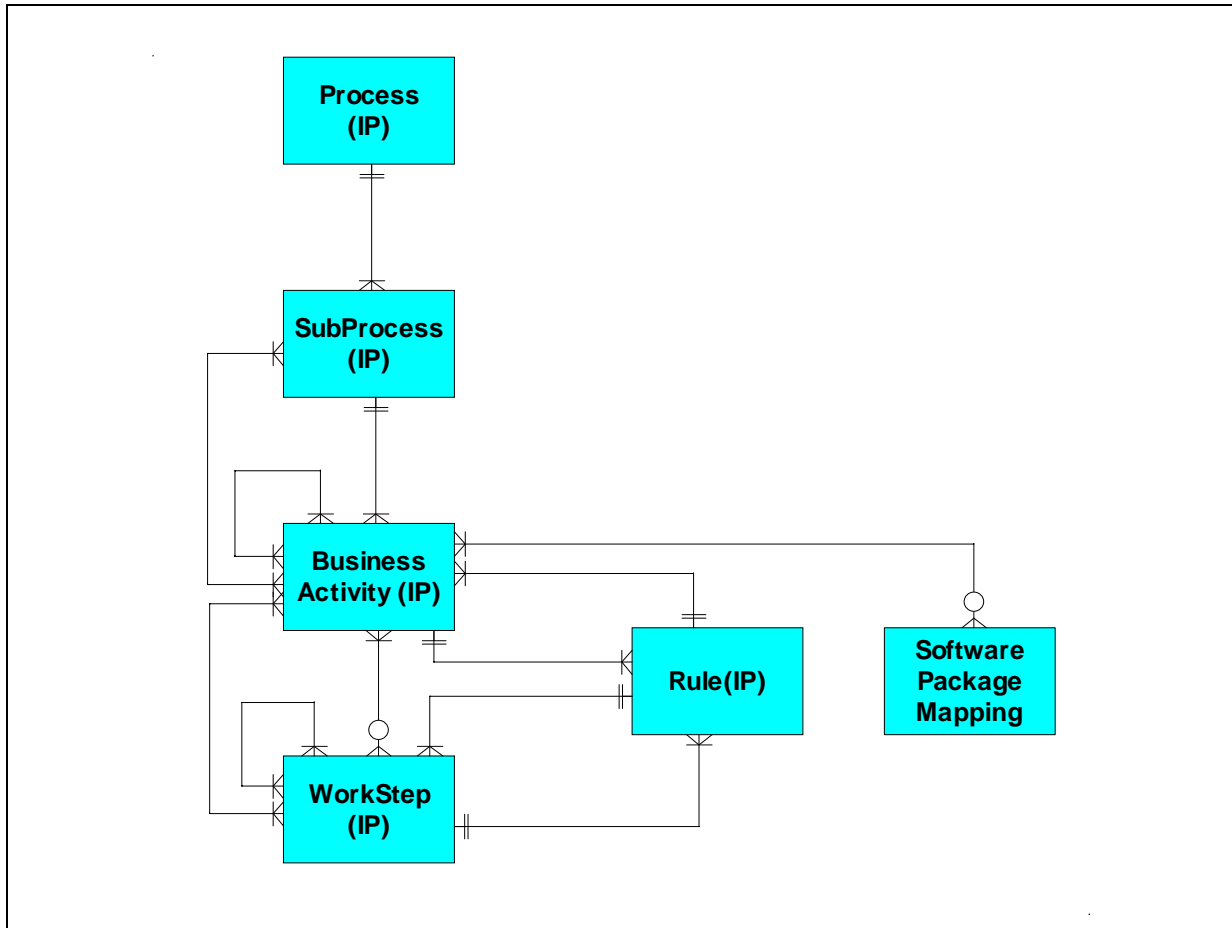


Figure 5.4: IndustryPrint meta-model

The IndustryPrint relationships are created either between Business Activity (third level) or between Worksteps (fourth level). In order to determine the rules of the business process relationship (decisions), a rule object is included as part of the meta-model. The mapping to software packages is done on the third level, between the Business Activity and the Software Package, but the relationship is optional.

Figure 5.5 is a proposed simplified and denormalised meta-model for the SAP Solution Manager BPR meta-model. The decomposition hierarchy for the SAP Solution Manager BPR reference model is:

- a *Business Scenario* is decomposed into one or more *Business Processes*;
- a *Business Process* is decomposed into one or more *Process Steps*;

- a *Process Step* is enabled by none, one or more *Transactions*; and
- a *Process Step* is dependent on the inclusion of a *Component* within the system landscape.

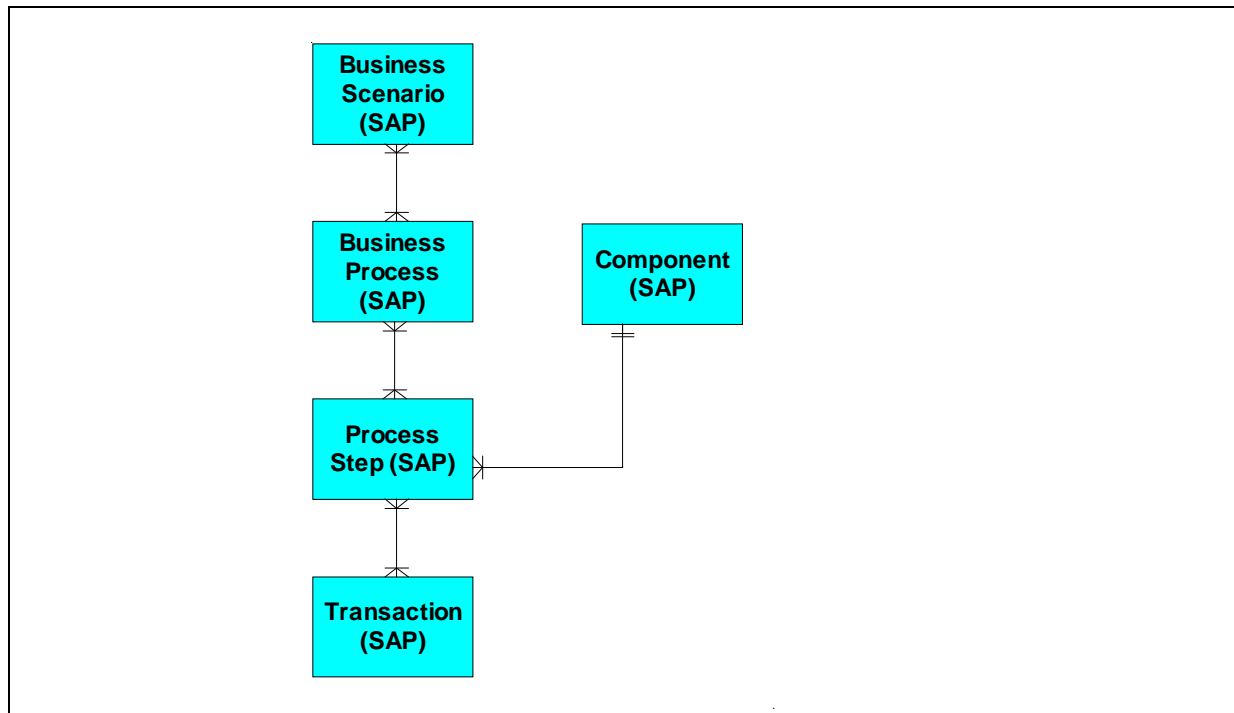


Figure 5.5: SAP Solution Manager BPR meta-model

Figure 5.3, Figure 5.4 and Figure 5.5 are the results of the meta-model creation step. The meta-models are defined for the SCOR reference model, the IndustryPrint reference model and the SAP Solution Manager BPR reference model.

5.3.2.2 Mapping of a Meta-Model

For the purpose of the example, a subset of the mapping of the meta-model is included (Figure 5.6 Mapping of a meta-model), focusing on the relationships between the different business process levels of the business process reference models. The output is a consolidated metadata mapping model.

The mappings are as follows:

- Mapping 1 is the creation of a relationship between the Process Level 3 (SCOR) entity and the Business Activity (IP) entity from the IndustryPrint meta-model. This is an example of vertical integration.
- Mapping 2 is the creation of a relationship between the Business Activity (IP) entity from IndustryPrint and the Process Step (SAP) entity from the SAP meta-model. This is an example of horizontal integration.

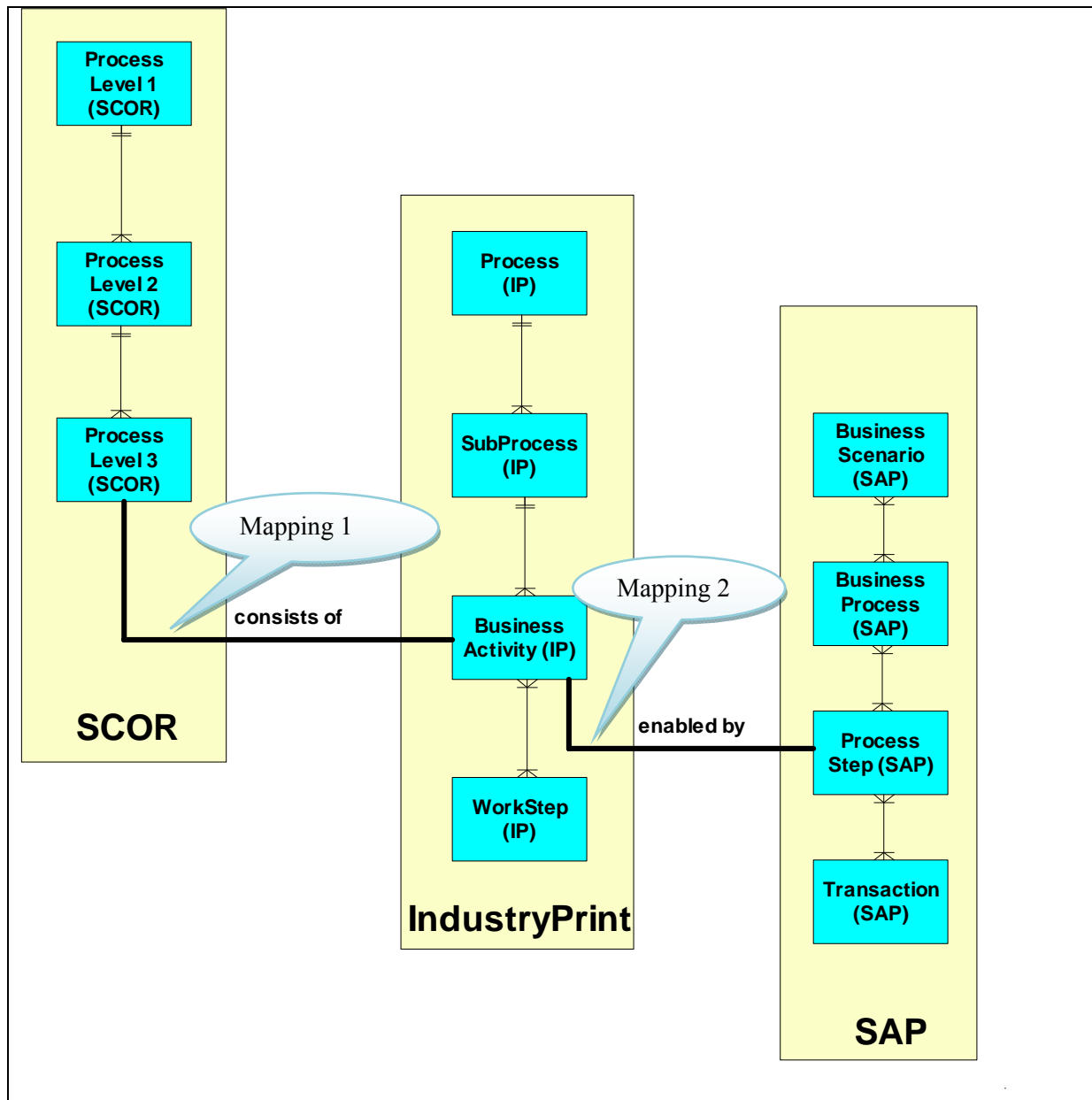


Figure 5.6: Mapping of a meta-model

Figure 5.6 is the result of the mapping of a meta-model. The mapping is dependent on the mapping of the content and, although the meta-model for the mapping is not complex, doing the actual mapping of the content could be a time-consuming activity requiring the input of subject matter expert.

5.3.2.3 Extraction Process

As defined as part of the mapping of the meta-model model (Figure 5.6), it is important to identify the required content of the objects per set of business process reference model for the example. Based on the given extracts as part of Figure 5.7 SCOR content example, the following values are selected:

- SCOR Process_Level_One = *Deliver*

- SCOR Process_Level_Two = *D1 Deliver Stocked Product*
- SCOR Process_Level_Three = *D1.2 Receive Enter and Validate Order*

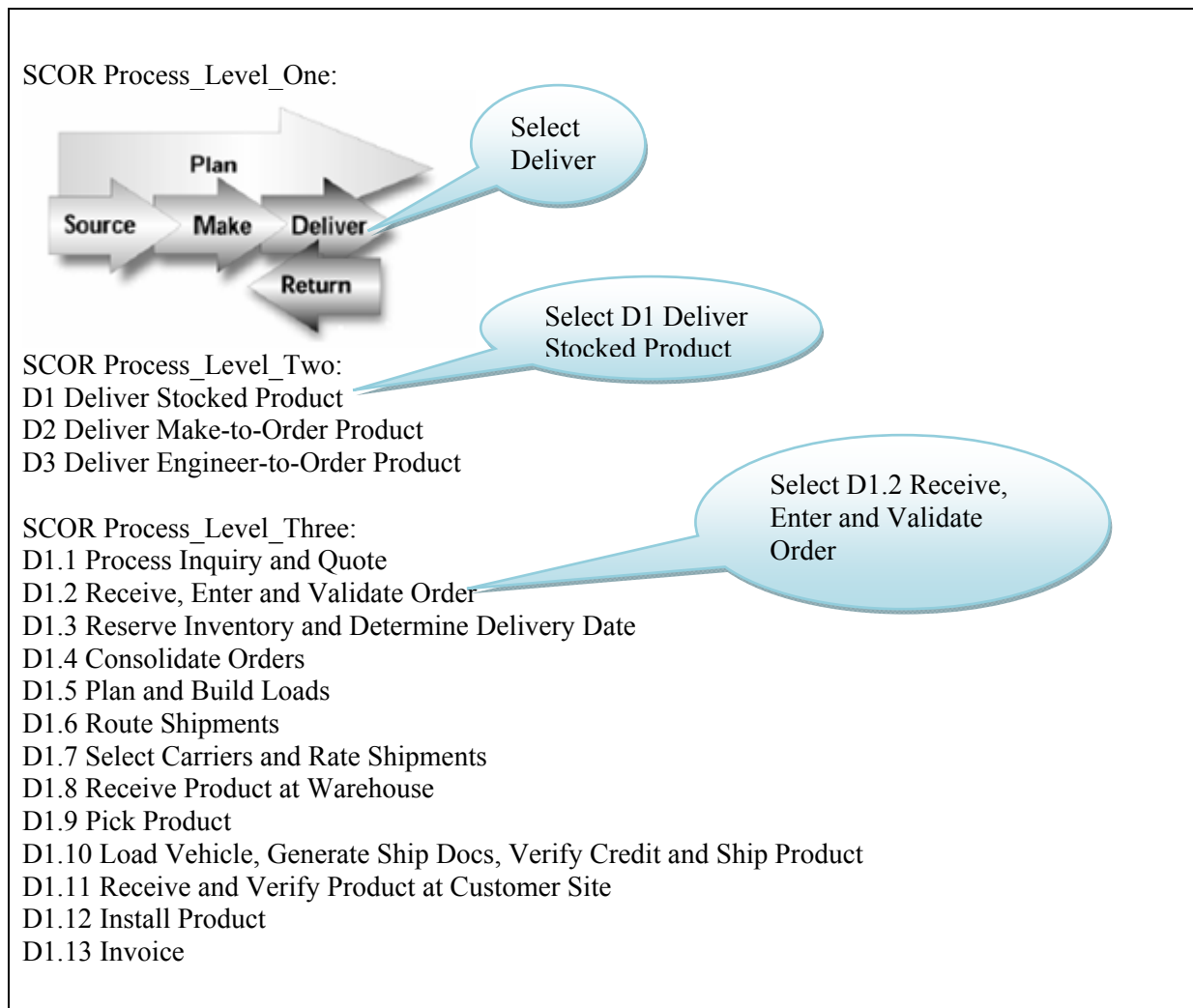
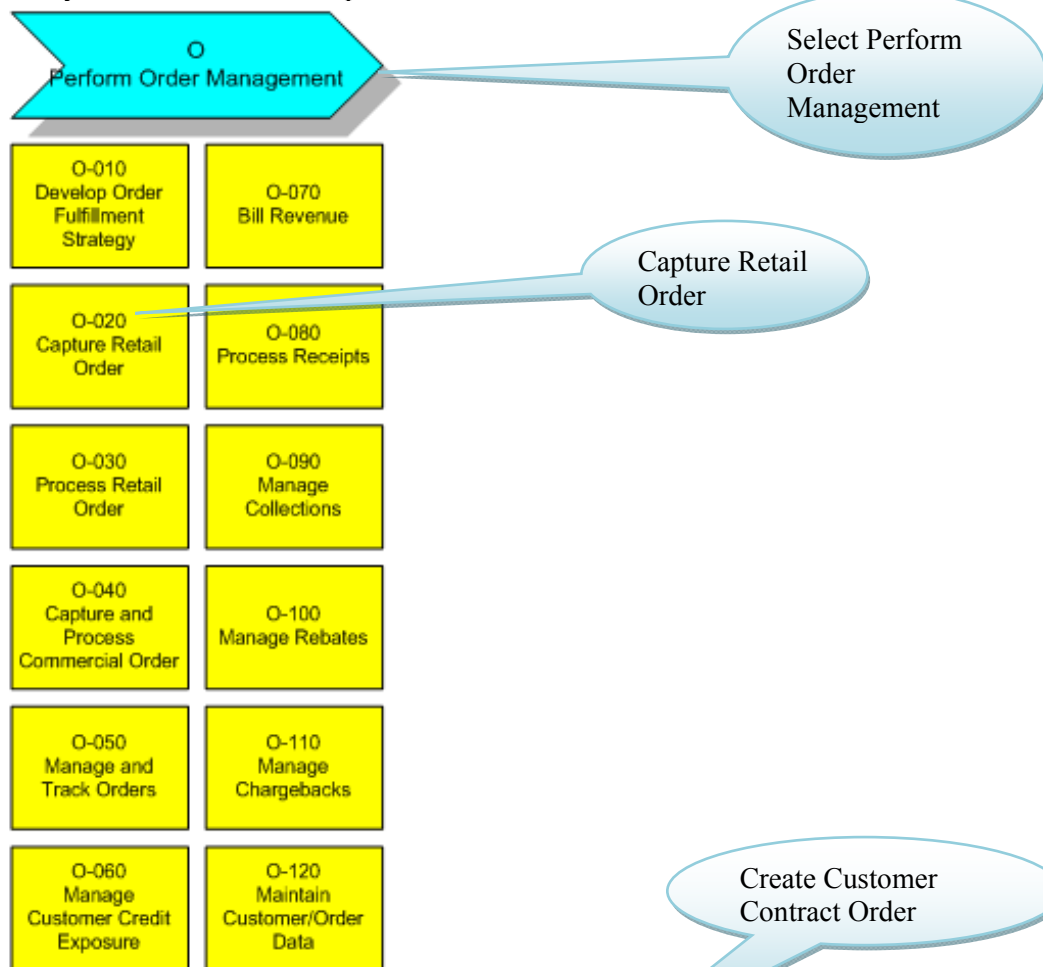


Figure 5.7: SCOR content example © Copyright 2004 Supply-chain Council, Inc, May 2004

Based on the given extracts as part of Figure 5.8 IndustryPrint content example, the following values are selected:

- IndustryPrint Process = *Perform Order Management*
- IndustryPrint Sub-process = *Capture Retail Order*
- IndustryPrint Business Activity = *Create Customer Contract Order*

IndustryPrint Process and Sub-process:



IndustryPrint Business Activity (Subset):

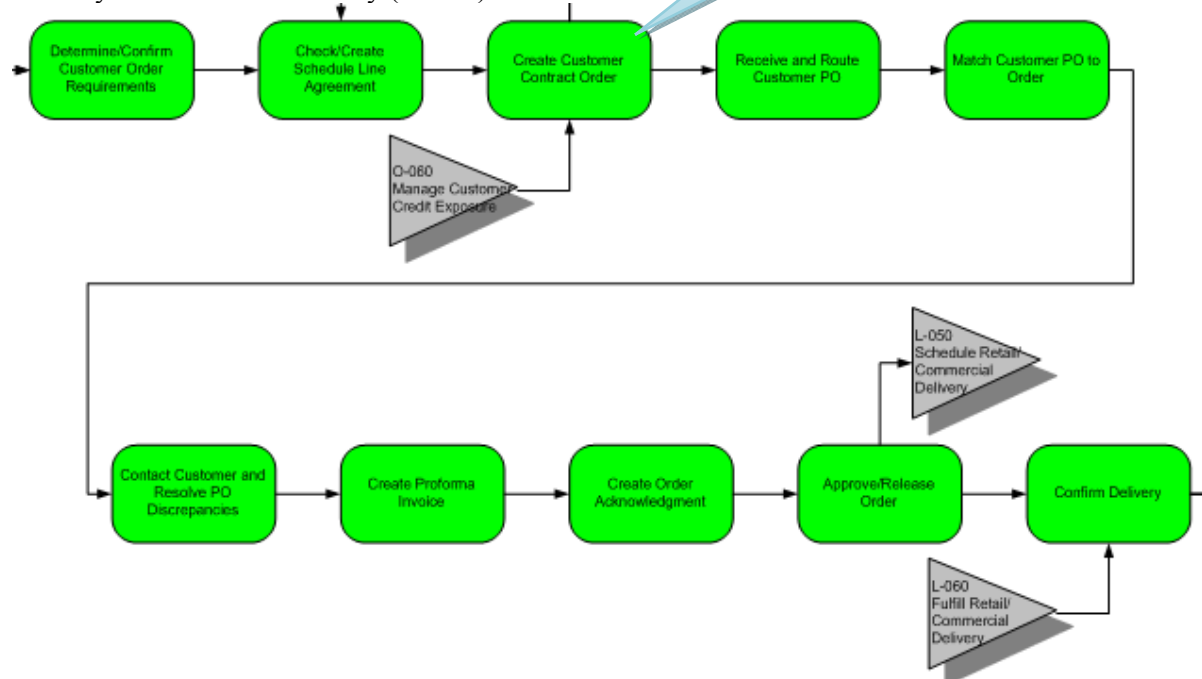


Figure 5.8: IndustryPrint content example © Copyright 2004 Deloitte Consulting

Based on the given extracts as part of Figure 5.9 SAP Solution Manager BPR reference model content example, the following values are selected:

SAP Business Scenario = Quotation and Order Management
 SAP Business Process = Sales Order Processing
 SAP Process Step = Create sales order
 SAP Transaction = VA01 Create Sales Order

The screenshot shows the SAP Solution Manager BPR content selection interface. The left pane displays a hierarchical tree of content. The right pane shows the selected content. Callouts point to specific selections:

- Select Quotation and Order Management**: Points to the 'Quotation and Order Management' folder in the left pane.
- Select Sales Order Processing**: Points to the 'Sales Order Processing' folder in the left pane.
- Select Create Sales Order**: Points to the 'Create sales order' folder in the left pane.
- Select VA01 Create Sales Order**: Points to the 'VA01 Create Sales Order' transaction in the table below.

SAP Transactions enabling Create Sales Order

VA01	Create Sales Order
VA02	Change Sales Order
VA03	Display Sales Order
VA05	List of Sales Orders

Figure 5.9: SAP Solution Manager BPR content example

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The selected content as indicated on Figure 5.7, Figure 5.8 and Figure 5.9 is the content to be loaded into the interim repository. This is the result of the extraction process.

5.3.2.4 Loading Process

Within the context of a business process model warehouse, the first step is to create a temporary repository, and the second step is to populate the temporary repository with the extracted data. The selected data is indicated by a red circle, but the complete business process model is loaded into the

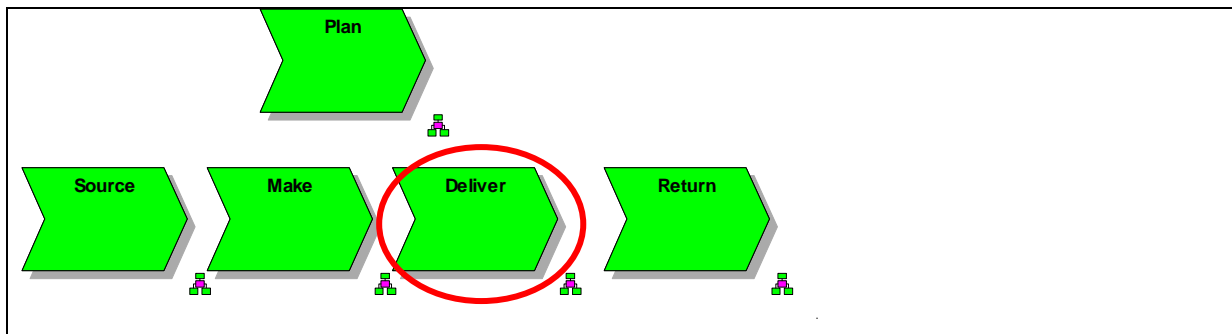


Figure 5.10: Process Level 1 (SCOR) Deliver

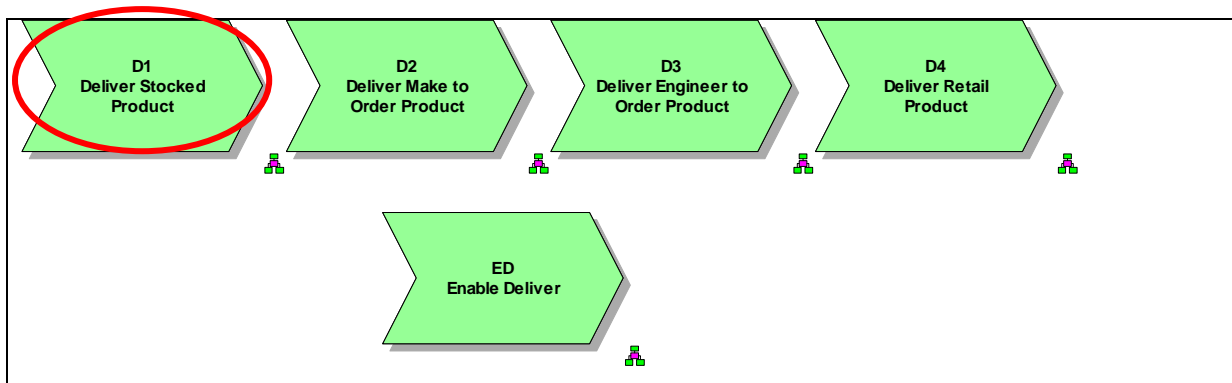


Figure 5.11: Process Level 2 (SCOR) D1 Deliver Stocked Product

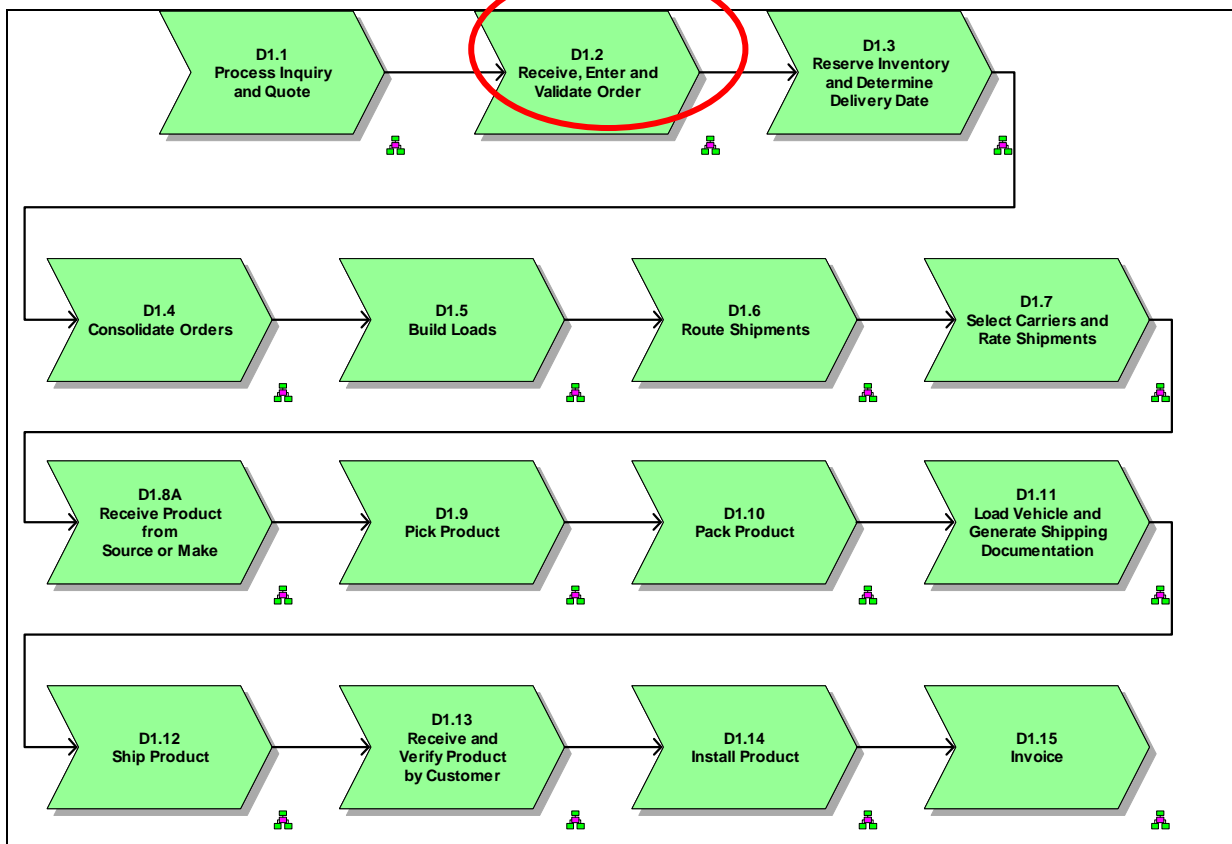


Figure 5.12: Process Level 3 (SCOR) D1.2 Receive, Enter and Validate Order

repository. For this example, the subset of the SCOR reference model (Figure 5.10 to Figure 5.13), the IndustryPrint reference model (Figure 5.14 and 5.15) and the SAP Solution Manager BPR reference model were populated each in a separate ARIS repository (Figure 5.16 to Figure 5.19).

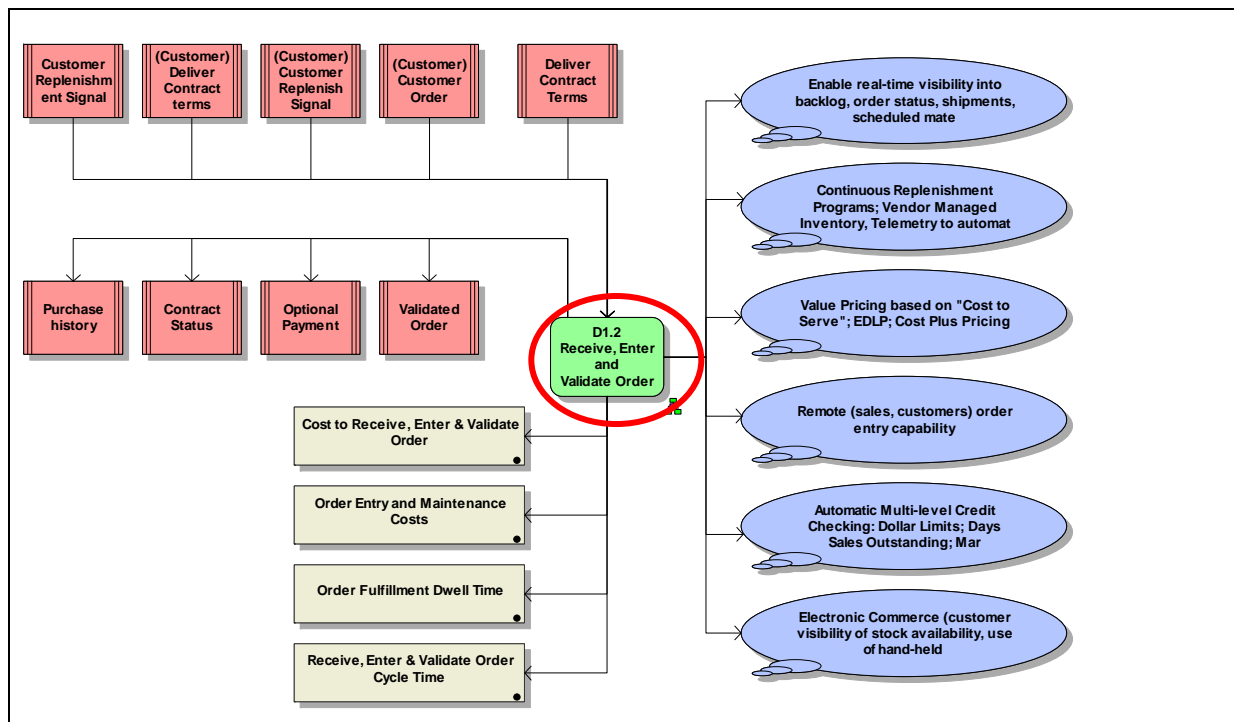


Figure 5.13: Input, Output, Metrics, Best Practices (SCOR) for Receive, Enter and Validate Order

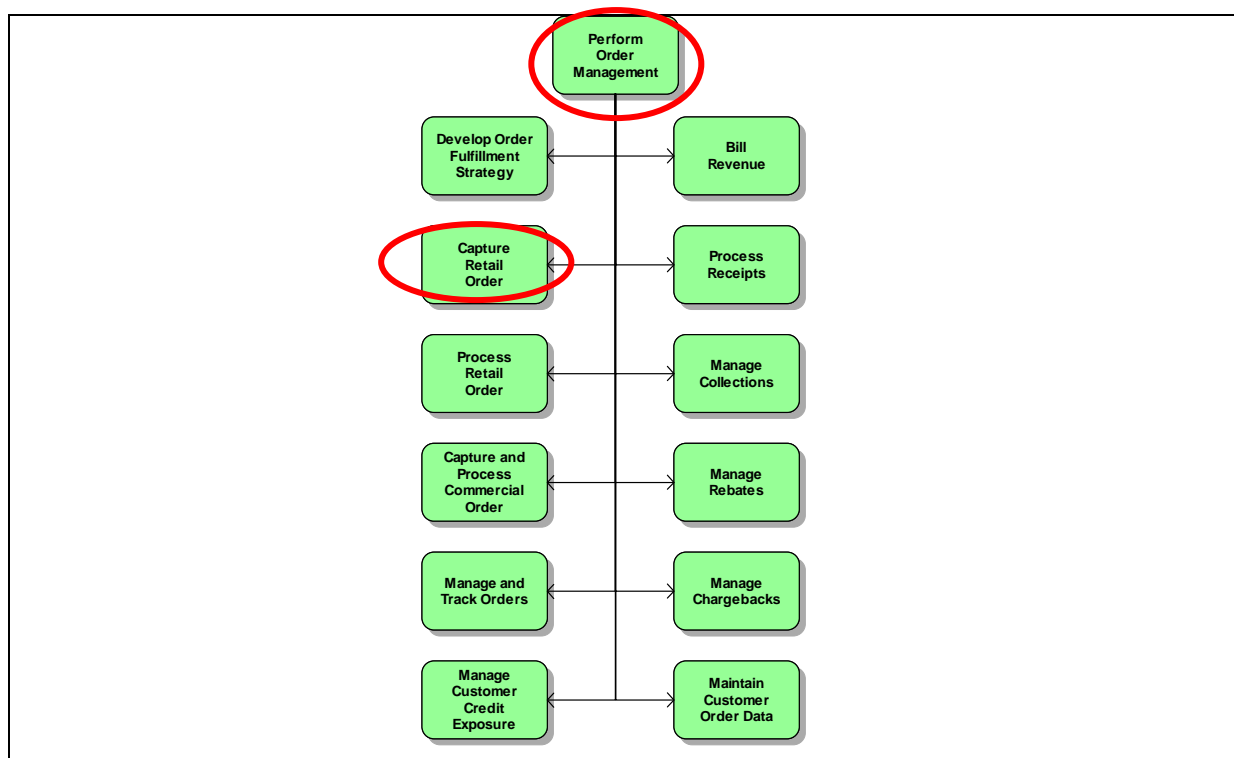


Figure 5.14: Process and Sub-process (IndustryPrint)

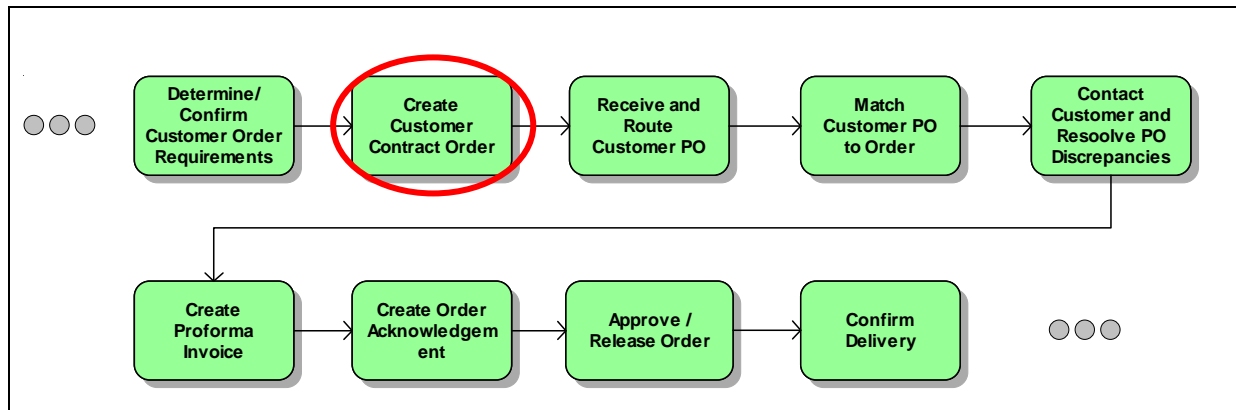
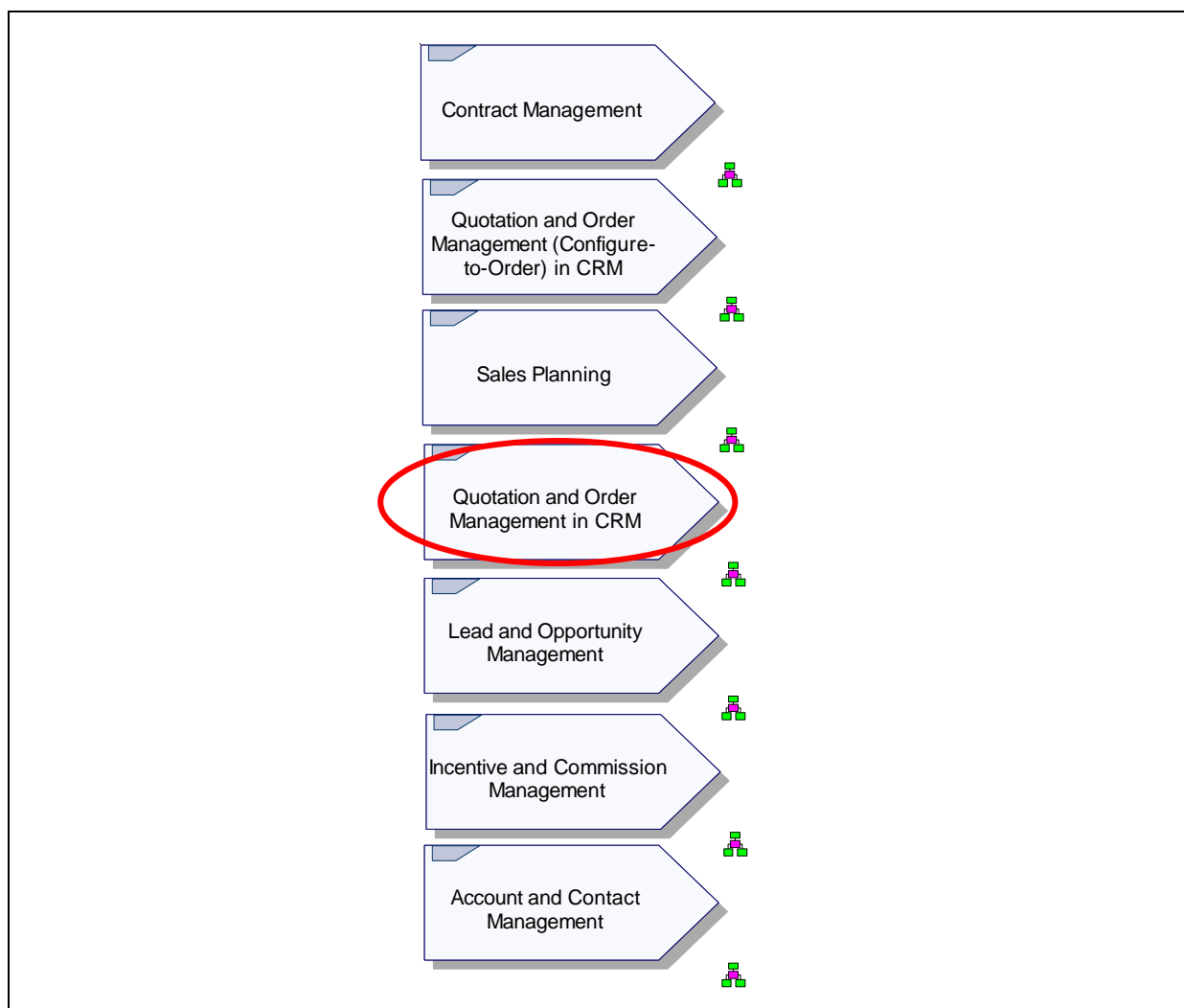


Figure 5.15: Business Activity (IndustryPrint) Create Customer Contract Order



**Figure 5.16: Business Scenario (SAP Solution Manager BPR)
Quotation and Order Management**

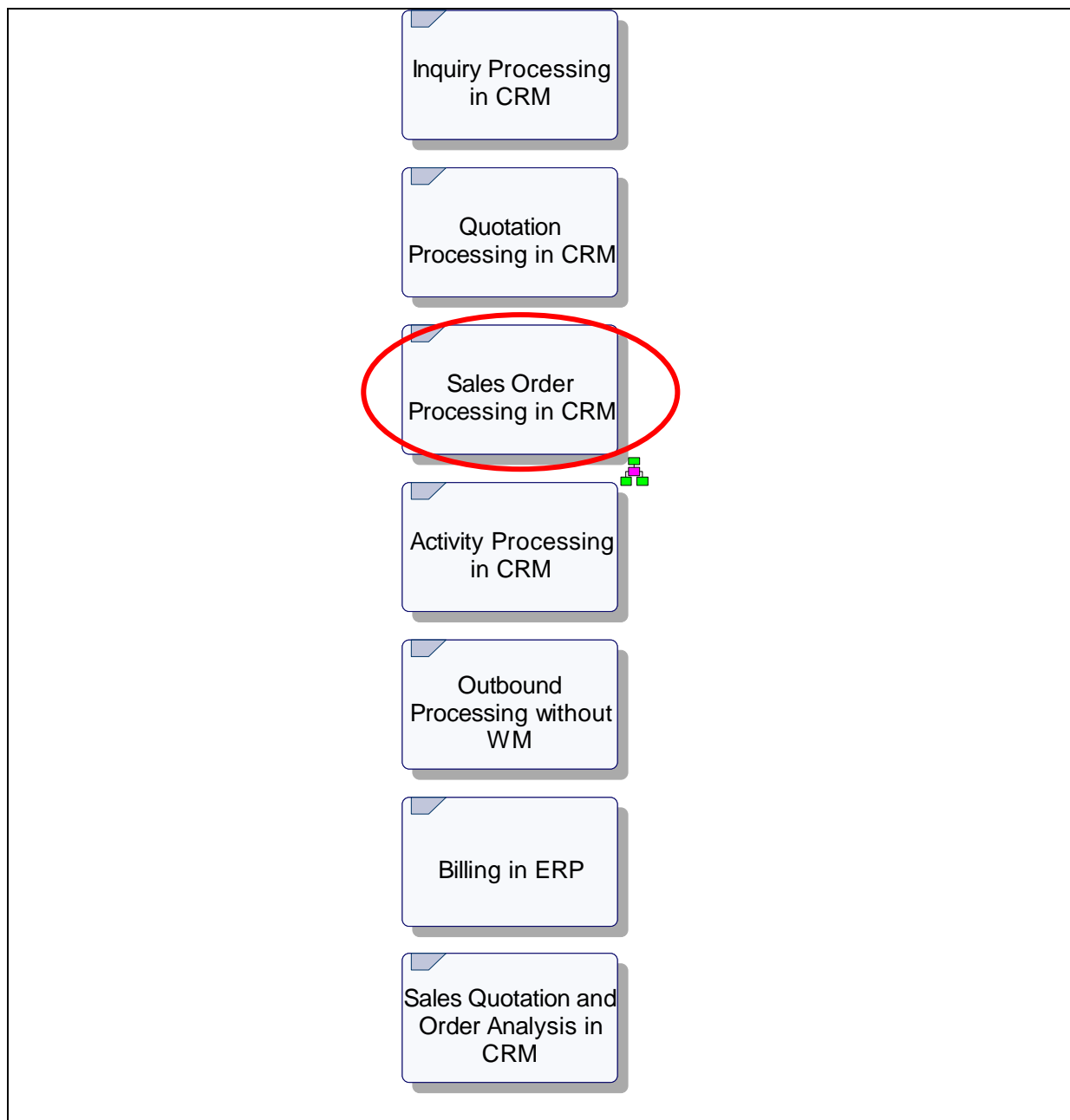


Figure 5.17: Business Process (SAP Solution Manager BPR) Sales Order Processing in CRM

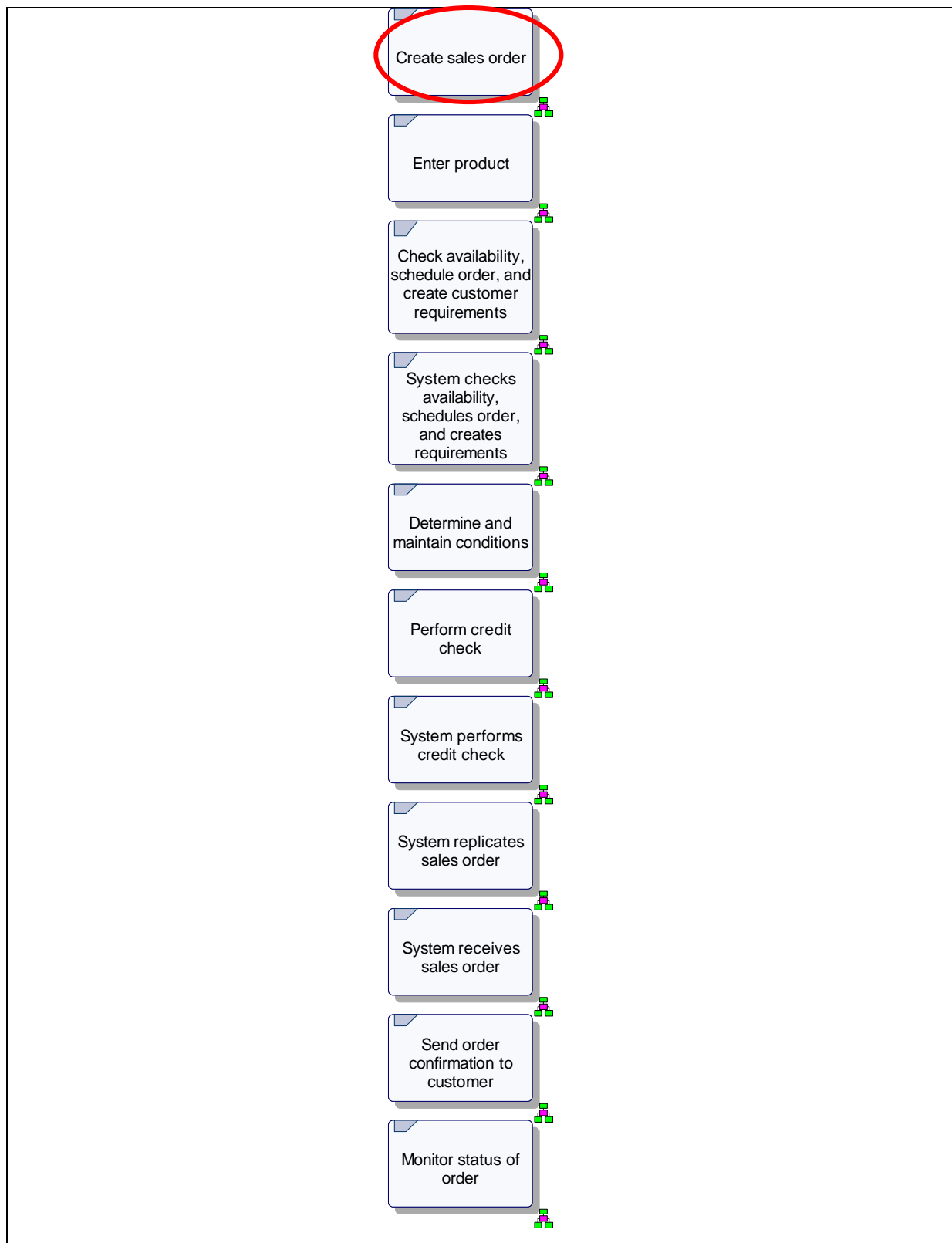


Figure 5.18: Process Step (SAP Solution Manager BPR) Create Sales Order

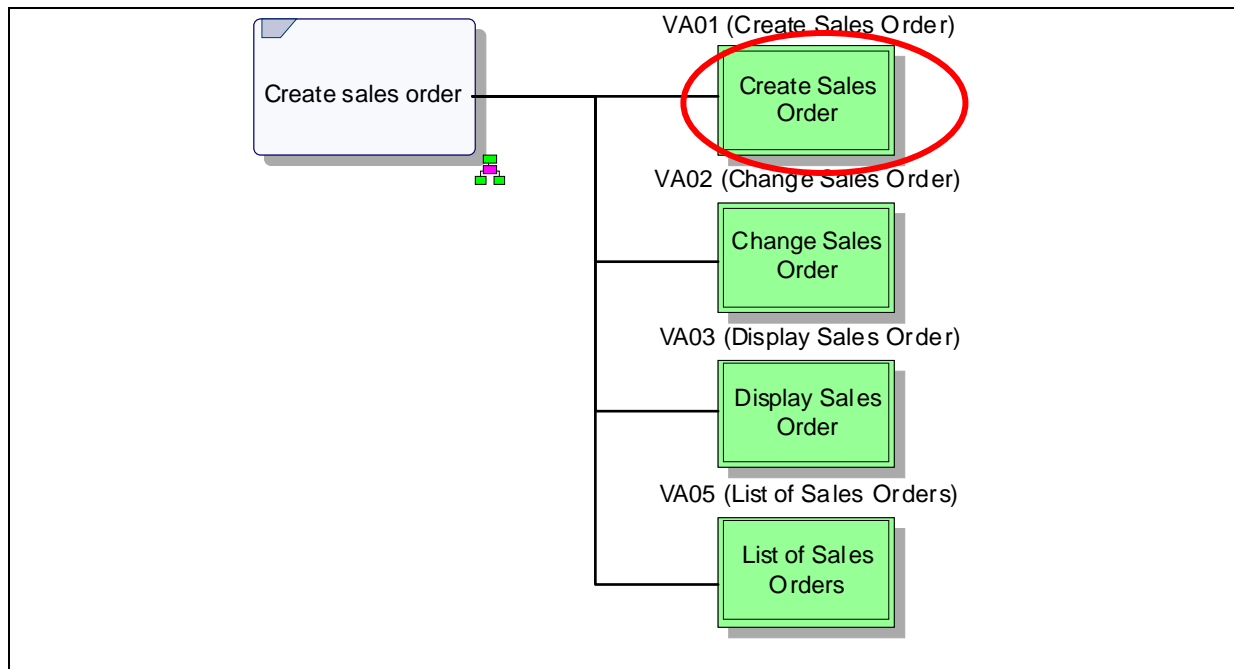


Figure 5.19: Transaction (SAP Solution Manager BPR) VA01 Create Sales Order

The outcome of the loading process is the set of business process models, representing the extracted data captured, into the temporary repository.

5.3.2.4 Transformation Process

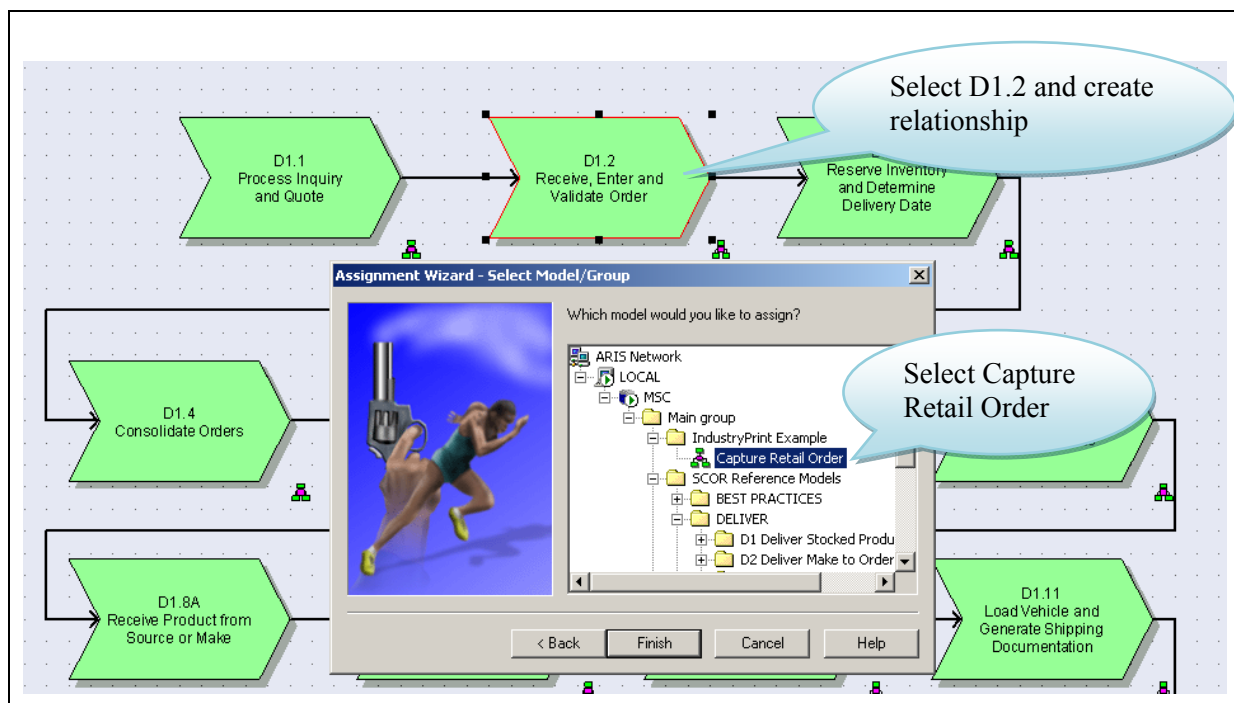


Figure 5.20: Relationship from Process Level 3 (SCOR) to Business Activity (IndustryPrint)

The transformation process is a human-intensive task and it is about the creation of relationships between the different sets of business process reference models based on the meta-model mapping.

To illustrate the transformation process, the relationship between the Process Level 3 (SCOR) object and the Business Activity (IndustryPrint) object is created. Refer to Figure 5.20 for the practical example. The SCOR instance is D1.2 *Receive, Enter and Validate Order* and the IndustryPrint object is on the model *Capture Retail Order* and the specific Business Activity, which is selected as variant is *Create Customer Contract Order*.

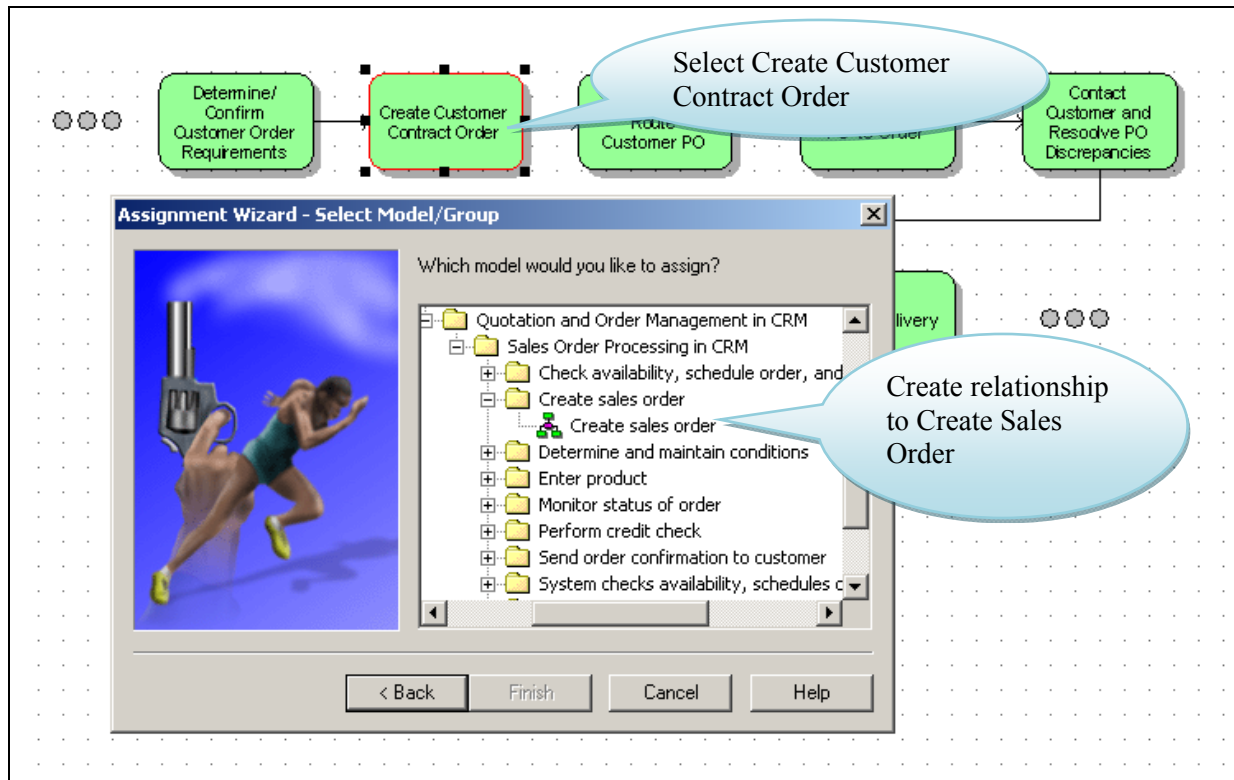


Figure 5.21: Relationship from Business Activity (IndustryPrint) to Process Step (SAP Solution Manager BPR)

The second relationship to be created according to the meta-model mapping (Figure 5.6) is the relationship between the Business Activity (IndustryPrint) and the Process Step (SAP Solution Manager BPR). Refer to Figure 5.21 for the specific example. The IndustryPrint instance is *Create Customer Contract Order* and the SAP instance is *Create Sales Order* (Figure 5.19).

The value of building these relationships is that it allows the user to navigate between the different sets of business process reference models. (Refer to Chapter 7 for a discussion on the application of the business process reference models to define comprehensive business process requirements by re-using objects from multiple business process reference models.)

The three sets of reference models are available in the repository as individual sets, but the consolidated model makes it possible to create relationships between the SCOR Process_Level_Three object and the IndustryPrint Business Activity object to ensure vertical integration. For horizontal

integration, the relationship between the IndustryPrint Business Activity object and the SAP Solution Manager BPR Process Step is included in the meta-model.

5.3.3 Reflection on Example

Section 5.3.4 is a reflection on the outcome of the application of the proposed ELT method. For illustrative purposes, three sets of business process reference models were successfully integrated in a business process warehouse following the proposed process:

Metadata model creation: <ul style="list-style-type: none"> Analyse each business process reference model. Create a metadata model for each business process reference model.
Mapping of meta-model: <ul style="list-style-type: none"> Mapping of a consolidated meta-model.
Extraction process: <ul style="list-style-type: none"> Identify the needed entities and relationships from the source business process reference models.
Loading process: <ul style="list-style-type: none"> Create a temporary repository. Merge the selected entities and relationships to the temporary repository.
Transformation process: <ul style="list-style-type: none"> Merge the content of the temporary database into the business process warehouse repository. Create relationships between the entities of the different business process reference models.

The conclusion is that the proposed ELT method can be used to consolidate multiple business process reference models into a business process model warehouse.

The second outcome is to comment on the potential value of multiple business process reference models to address the issue of inadequate business process requirements:

- The content of the selected business process reference models are at least considered, thereby minimising inadequate business requirements gathering and improving the quality of the business requirements. A single set of business process reference models is preferable to a clean sheet approach, but multiple sets of business process reference models may identify potential gaps or perspectives not identified with a single set of business process reference models.
- Instead of redefining the subset of business process models used in the example the business process models were consolidated from the three sets of business process reference models pre-populated in the repository. Re-use of pre-populated business process reference models

accelerates part of the business requirement definition, thereby mitigating the availability constraint of customers.

- The example includes subsets of three sets of business process reference models. The customer can refer to the set of business process reference models with which he/she is familiar to provide context to the other sets of business process reference models. Presenting the business requirements within the context of multiple business process reference models, improves the understanding of the business requirements by the customer.

5.4 Conclusion

The focus of Chapter 5 was to derive a business process model warehouse ELT method based on the data warehouse ELT framework. The proposed method was tested and the example is described in section 5.3. The example also illustrates the potential value of using multiple business process reference models to address the argument (thesis) of inadequate business requirements.

The specific research question that was addressed in Chapter 5 is:

Which component(s) lacking in the current references to multiple business process reference models should be addressed by the business process model warehouse framework?

Both the method for ELT and the method for the integration of multiple business process reference models into a business process models warehouse were lacking. These aspects were both successfully addressed in Chapter 5. The value contribution of Chapter 5 is therefore more than just the description of the ELT example; it is also the development of an ELT method as part of the business process model warehouse framework.

The engine room of a business process model warehouse is a repository, as depicted in the context diagram of the business process model warehouse framework in Figure 5.1. The repository will be described in more detail in Chapter 6. As further mentioned in Chapter 6, it is important to have an understanding of the differences between a database and a repository. The merge functionality associated with a repository plays a critical role in the transformation part of the ELT method for a business process model warehouse.

CHAPTER 6: REPOSITORY

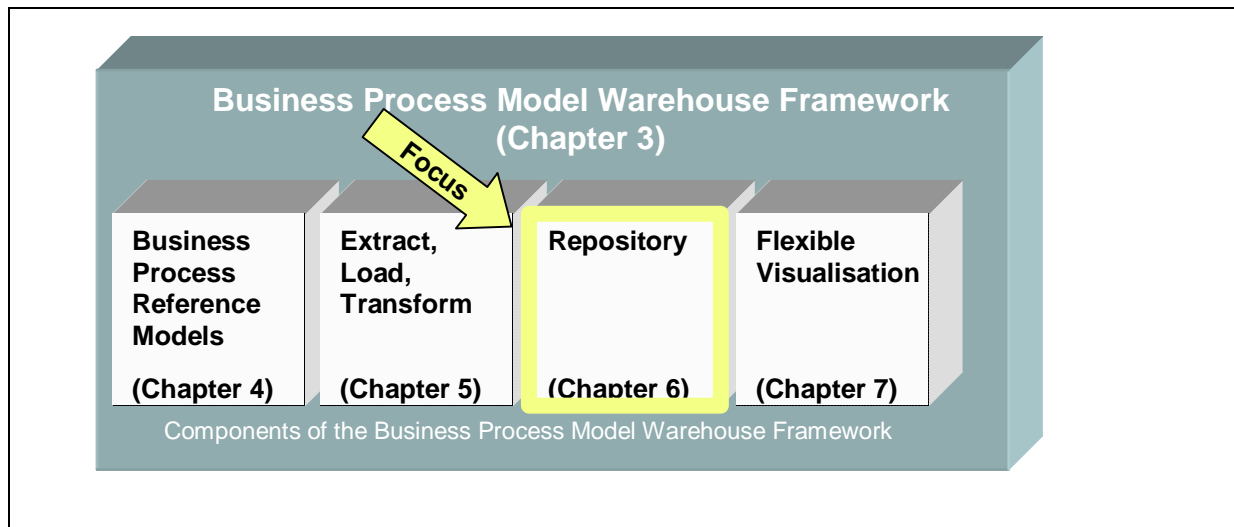


Figure 6.1: Context diagram with focus on repository

From the business process model warehouse framework, the component that is addressed in Chapter 6 is the repository. An acknowledged term for a database storing the business process models is a *repository* (Bernstein, 1998). The component known as a data warehouse, as part of the data warehouse framework in Chapter 3, is replaced with the repository component in the business process model warehouse framework (Figure 6.1).

The research question is whether it is possible to use a data warehouse for a business process model warehouse taking into account that there is a good fit between the two frameworks. The approach for Chapter 6 is not to compare and learn from a data warehouse but rather to look at the unique content and the unique functionality of a repository as described in literature in order to answer the research question.

According to Blechar and Sinur (2006), *business process analysis* is the term that defines the business process modelling space where business professionals and information technology designers collaborate on business process designs and architecture frameworks. Therefore business process analysis tools help define the business architecture portion of the enterprise architecture as described in Chapter 2. It states clearly that most business process analysis tools have a shared repository.

In order to describe the content and functionality of a repository, it is important to note the difference and similarities between a repository, a knowledge base and a library within the context of business process analysis. Business process reference models are also referred to as *a library of business process models* or *a knowledge base of business processes*, independent of whether the business

process reference models are stored in a repository or only published in text format. Technically, the functionality provided by a library, a knowledge base and a repository differ:

- A *repository* is a shared database of information about engineered artefacts (Bernstein, 1998) with specific functionality enabling the definition and management of such artefacts.
- A *library* is a collection of information resources in print or in other forms that is organised and made accessible for reading or study (Britannica Concise Encyclopedia, 2006). The term *library* has itself acquired a secondary meaning, namely that of a computerized facility containing a collection of organised information used for reference (Sci-Tech Dictionary, 2003).
- A *knowledge base* is a special kind of database for knowledge management. It provides the means for the computerised collection, organisation and retrieval of knowledge. The primary benefit of such a knowledge base is to provide a means to discover solutions to problems that have known solutions, which can be re-applied by others who are less experienced in the problem area (Wikipedia, 2006). It is important to note that it does not refer to specific functionality enabling the definition and management of engineered artefacts associated with the Bernstein (1998) definition of a repository.

Considering the fact that *repository*, *library* and *knowledge base* are being used interchangeably within the context of business process reference models, Chapter 6 will describe the functionality of a repository as defined by Bernstein (1998).

As part of Chapter 6 the concept of a repository is defined by:

- Differentiation of the content of a repository with the typical content of a database.
- A description of the critical repository management functionality required to support the proposed BPMW ELT method, described in Chapter 5, to populate a business process model warehouse.

6.1 Content of a Repository

In order to get a better understanding of a repository the definition of a database is essential. A database is defined as a collection of stored operational data used by the application systems of some particular enterprise (Date, 1981). Operational data includes both the entities (example customer and product data) as well as the relationships (linking the entities together). According to Date (1981), a database, in general is both integrated and shared. *Integrated* implies that the database may be thought of as a unification of several otherwise distinct files, with any redundancy among those files partially or wholly eliminated. The implication of *shared* is that individual pieces of data in the database may be shared among several different users, in the sense that each of such users may have

access to the same piece of data (and may use it for different purposes). *Concurrent sharing* is the ability for several different users to be actually accessing the database – possibly even the same piece of data – at the same time. One of the similarities between a database and a repository is that both should make provision for integration and concurrent sharing.

One of the differences between a repository and a database is the type of data being stored in the repository and the database. Operational data is stored in a database and not in a repository. A repository is defined by Simon (1993) as “a database in which data used by the information system itself, rather than user applications, are stored”. Bernstein (1998) broadens the content of a repository by referring to the repository as “a shared database of information about engineered artefacts”. The repository content is still limited to the software development domain. Bernstein states that the goal of the repository is to store models and contents of these engineered artefacts to support the software tools being used in designing such artefacts. Within the context of this paper this definition is acceptable as the business process is indeed one of the engineered artefacts that should play a role in the development of software. A similar definition is given by Blaha, LaPlant and Marvak (1998) who rephrase the definition of a repository as “a database that holds information about models (including business process models), implementation artefacts and their mappings”. Friedrich (2005) extends the definition of the repository to include metadata configuration management capabilities as a fundamental design concept. The argument is that for information technologies, such as computer-aided software engineering tools (including business process analysis tools), ELT engines and warehouses, the metadata often drive much of the tool’s functionality. The repository plays a major role as part of the metadata management environments, and related functionality will be included as part of section 6.2.

6.2 Repository Management Functionality

Within the context of this dissertation, the focus is on the re-use of the content of the repository. Justo (1996) listed the following three objectives to enable the re-use of repository content:

- To facilitate (business process) requirement modelling, providing the user (analyst and/or requirements engineer) with re-usable conceptual components, organised in a hierarchy of different levels of abstraction. The levels of abstraction are emphasised by Peters, Szczurko, Jarke and Jeusfeld (1995), who assert that the repository approach allows in the business process reengineering context the modelling of the relations between information and the environment in which the information is used at various levels of abstraction.
- To improve the productivity of the (business process) requirement engineering process, shortening the formalisation time-effort, adapting and tailoring suitable parts to a given project.

- To improve the quality of the (business process) requirement specification, providing well-defined, tested, re-usable conceptual components.

Other motivations for a repository include the role of the repository as organisation memory, including the publishing and communication of the content to ensure common understanding, ensuring consistency and correctness of integrated content, and enabling analysis of the content of the repository to support continuous improvement (Blaha et al., 1998). The functionality associated with the repository is discussed with these objectives in mind.

According to Bernstein (1998), the main functions of the repository engine are:

- Object management.
- Dynamic extensibility.
- Relationship management.
- Notification.
- Version management.
- Configuration management.

A brief description of each of the main functions is based on information from Bernstein (1998), Blaha et al. (1998), IDS Scheer AG (2002); Kolsch and Witte (2003) and Friedrich (2005).

6.2.1 Object Management

Every object in the repository has a type, attributes and methods associated with it. The values of the populated attributes are stored in the repository. The object management facilities are similar to the facilities of an object-oriented database. It should be possible to run database queries and to navigate in the repository based on the properties defined per object. Managing occurrence and definition copies of objects is a functionality that could provide solutions for the configuration management challenges.

There is some similarity to retrieving components from software component repositories as discussed by Henninger (1996). In order for the re-use approach to be useful, the repository should contain enough components to support the developers, but when many examples are available, finding and choosing an appropriate component becomes troublesome. The structure of a repository is generally regarded as a key to obtaining good retrieval results. Up-front investment in structuring a repository results in a proportional increase in the ease with which components can be re-used. The MIT

Process Handbook Process Compass (Malone et al., 2003), as discussed in section 2.1.3, is an example of a structure enhancing navigation in the repository.

6.2.2 Dynamic Extensibility

The repository's data structure (information model) consists of type definitions and classes that implement them. It must be easy and efficient to add new types definitions and classes and to modify existing ones. Tools often limit the extensibility to maintain the integrity of the repository. Some of the repository engines allow for the definition of new tables and attributes, but others only allow for the definition of variants of existing objects and the renaming of attributes that are predefined.

6.2.3 Relationship Management

A relationship is a connection between objects. A key function of the repository engine is to define and manage relationships between objects. It is also referred to as *mapping*, where mapping is described as “a simple binding between two objects in the repository database” (Blaba et al., 1998). The integrity rules are based on the definition of the relationship rules, for example the cardinality constraint (such as one-to-one or one-to-many) of the relationship between objects. The relationship should also be an object in the database with attributes associated with it. An important functionality is to propagate operations based on the specified rules. For example, if an object is deleted, all relationships to that object should also be deleted.

6.2.4 Notification

An operation on an object may need to trigger operations on other objects. Internal notifications are similar to impact analysis, ensuring for example that a change to an object is reflected on all occurrences of that object on models. External notifications should also be forwarded based on completeness checking, integrity and consistency checking and compliance exceptions. The mechanism and level of notification vary depending on whether an action is prohibited (for example to maintain the integrity of the repository content), whether it is a pro-active warning or a re-active exception report, for example a comparison report.

6.2.5 Version Management

Engineering design information is usually developed according to some engineering process that relies on versions to manage the evolution of designs. Some repository engines provide version

management as part of the functionality, while others only make provision for attributes to reflect the status. Each change potentially creates another version of the artefact.

The repository should also record the source of the data, including the source and version of imported objects. An extended functionality for import of information is also known as *merging*. The objective is to merge the contents of different databases without creating redundant items. Model merging is an exploratory process in which the goal is to discover the exact nature of the relationship between models as much as to combine the models. Model merging is facilitated by a number of related operations on models and objects, including comparing models and objects, checking consistency and finding matches. To achieve this, identical items are detected in the databases so that the user may decide which item to transfer and whether the attributes of the two identical items are to be merged. A challenge of merging is that the version of both source objects may not be imported and as a result reconstructing the version history and impact and lineage analysis will be an almost impossible task. Sabetzadeh and Easterbrook (2005) and Brunet, Chechik, Easterbrook, Nejati, Niu and Sabetzadeh (2006) discuss the challenges of global (business process) model management in more detail.

The emphasis of most repositories has been on the development of a single enterprise architecture and the concept of a single version of the truth. However, both Kolsch and Witte (2003) and Friedrich (2005) argue that for metadata configuration management and re-engineering projects there is a need to handle both precise and imperfect (uncertain, vague, inconsistent, in fact was/should/will/might) information. Therefore the representation of knowledge ought to be modelled in a way that reflects its quality, origin and credibility.

6.2.6 Configuration Management

A user of a tool normally works within the narrow context of the objects that are relevant to the problem at hand. Similarly, a component or product model usually contains only some of the objects in the repository. This requires grouping the objects of a similar version into configurations, which are versioned as well.

Key configuration management concepts based on the configuration management of software engineering (Friedrich, 2005; Appleton, 2006) but relevant for configuration management of repository content include:

- The need to track multiple versions (states in time) and statuses of configuration items (discrete artefacts).
- Management of changes through the lifecycle of the artefact.

- Impact analysis due to actual or proposed changes. Lineage analysis requires that one can navigate backward to determine the sources, transformations, interfaces and relationships to create an artefact.
- An understanding and analysis of traceability through the lifecycle, interfaces, exchanges or merges.
- Management of concurrent engineering/designing activities.

However, configuration management requires not only a repository but also a repeatable configuration management process, appropriate resources and full conformance with the configuration management process and full integration with the environment by all stakeholders.

6.3 *Repository for Business Process Reference Models*

The features of a true repository can be summarised as the focus on the management of objects and properties, the rich relational semantics, the support for extensibility and versioning (Musick and Miller, 1998). From the perspective of the integration of multiple business process reference models into a single repository, the functionalities discussed in section 6.2 are relevant. Dynamic extensibility is a critical functionality as it may be necessary to extend the meta-model (information model) of the repository to accommodate the requirements of the various business process reference models. Due to the fact that new versions of business process reference models are released over time it is also important that the repository provides for configuration management.

Consider the following contributing factors to the complexity of managing a repository, if multiple business process reference models are made available for re-use, to ensure more comprehensive business requirements:

- Multiple projects running simultaneously increase the complexity.
- Multiple business process reference models increase the complexity.
- Vertical integration of business process reference models has a higher impact on the complexity than only horizontal integration.
- Introducing a new version of existing business process reference models in a repository increases the complexity, and the impact is major if the new release introduced a new structure of the business process reference models as well.

6.4 Conclusion

In Chapter 6, the content and functionality of a repository, the engine room of the business process model warehouse, were discussed. The repository is a key prerequisite to promote the use of multiple business process reference models to address the problem of inadequate business requirements as stated as part of the argument (see section 1.4). The research question is whether it is possible to use a data warehouse for a business process model warehouse. The answer is given in Chapter 6, as the difference between the content and functionality of a repository and a database is a key differentiator between a data warehouse and a business process model warehouse. It is not likely that a data warehouse will be able to provide all the functionality required for a repository. This is however a potential future research issue.

A second part of the argument (see section 1.4) is the promotion of enablement of flexible visualisation of the business processes. The business process model warehouse is addressed in Chapter 7, with the introduction of flexible visualisation of business process models.

CHAPTER 7: FLEXIBLE VISUALISATION

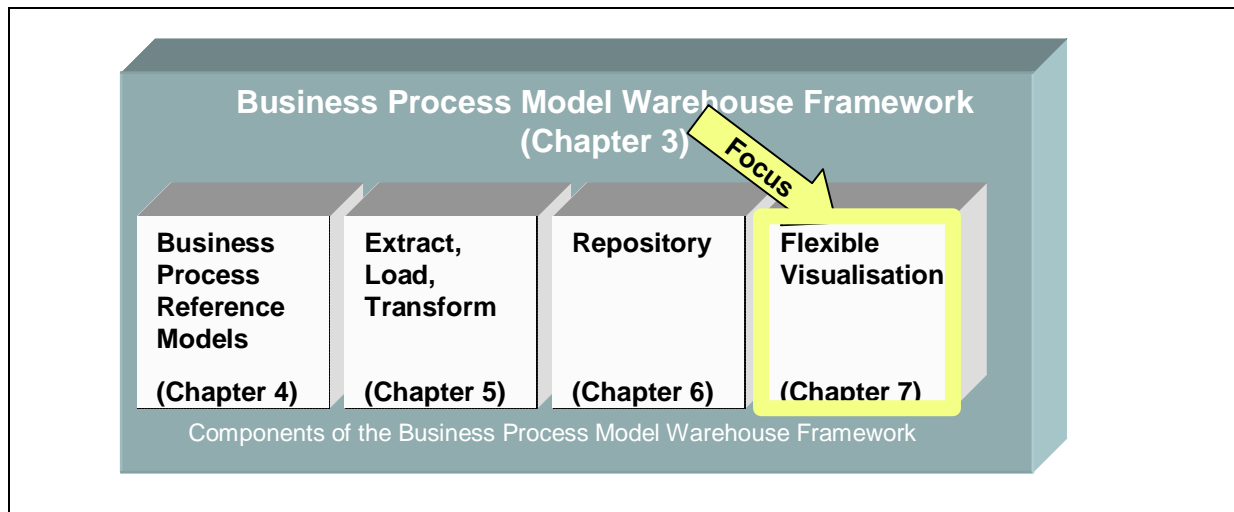


Figure 7.1: Context diagram with focus on flexible visualisation

Chapter 7 focuses on flexible visualisation (Figure 7.1) to enhance the understanding of business requirements, keeping in mind the objective of this dissertation to propose a business process model warehouse framework, promoting the re-use of multiple business process reference models and flexible visualisation. Some research questions to be addressed in Chapter 7 are the following:

- Is it possible to motivate the value of flexible visualisation to minimise to some extent the causes contributing to inadequate business requirements?
- Is it possible to include examples to explain the concept of flexible visualisation of business process models?

The first part, section 7.1, focuses on the motivation for flexible visualisation and the second part, section 7.2, focuses on some examples and guidelines to implement flexible visualisation.

Both Online Analytical Processing (OLAP) within the data warehouse perspective and flexible visualisation in the business process model warehouse perspective are based on an analytical component. Within the data warehouse framework, the analytical component, i.e. OLAP, is described as “By exploiting multi-dimensional views of the underlying data warehouse, users can drill down or roll up on hierarchies, slice and dice particular attributes, or perform various statistical operations such as ranking and forecasting” (Dehne et al., 2001). In order to get a better understanding of the requirements for the drill down, roll up and slice and dice of business process models, Chapter 7 focuses on flexible visualisation examples. There are various concepts to explore as part of future research such as:

- Storing materialised views and computing required views from the source data.

- Maintenance of materialised views similar to the maintenance of views for the data warehousing domain (Wang, Orłowska, Liang, 1999).

7.1 Motivation for Flexible Visualisation

One of the main challenges in the modelling of business requirements is to provide the modeller and the user with meaningful visual tools. The business model is usually presented by different types of flow charts and diagrams. If the business process modelling process is simplified in the way it is represented to the user, it improves understanding and helps to interpret the result of the analysis (Virine and Rapley, 2003). The concept of multiple views or viewpoints to improve understanding is well positioned in literature.

Considering the various applications of business process models it is not surprising that a single view does not satisfy the various objectives for business process models. Business process models potentially play a role in business requirement definition, business process optimisation, role clarification, role-based training, system-based training, testing of systems and compliance initiatives. The required representation of the business process model content potentially varies for each of these different deliverables based on the purpose of the business process model.

Different views of the same business process may also be driven by the level of granularity, preference of notation or different representations (similar to the architectural representation discussed in Chapter 2). An example is a manager only interested in high-level business process views whereas engineers or technicians need detailed information about the business processes in which they are involved. Some users may prefer a graphical representation of the business process while others may prefer a textual or tabular description of the business process (Bobrik et al., 2005).

7.2 Examples of Flexible Visualisation

Section 7.2 illustrates the concept of flexible visualisation, using examples classified as follows:

- Enterprise architecture views.
- Viewpoint-based development.
- Swim lane-based views.
- Notation-based views.
- Scenarios.
- Aggregation and reduction of views.

Each of these views is briefly explained in sections 7.2.1 to 7.2.6.

7.2.1 Enterprise Architecture Views

The enterprise architecture frameworks as discussed in section 2.1.2 make provision for various views to achieve a complete representation of the enterprise. These different enterprise architectural views are useful to answer multiple questions about the enterprise (Whitman et al., 2001). As concepts, these different views as defined by an enterprise architecture framework are complementary to one another without major overlaps. As example an enterprise architecture view could be a data model (Figure 7.2), an organisation chart (Figure 7.3) or an integrated view with objects from the data view, organisations view and the business process view (Figure 7.4).

In Figure 7.2 the data model includes a data cluster consisting of entities, the entities and the relationship between the entities.

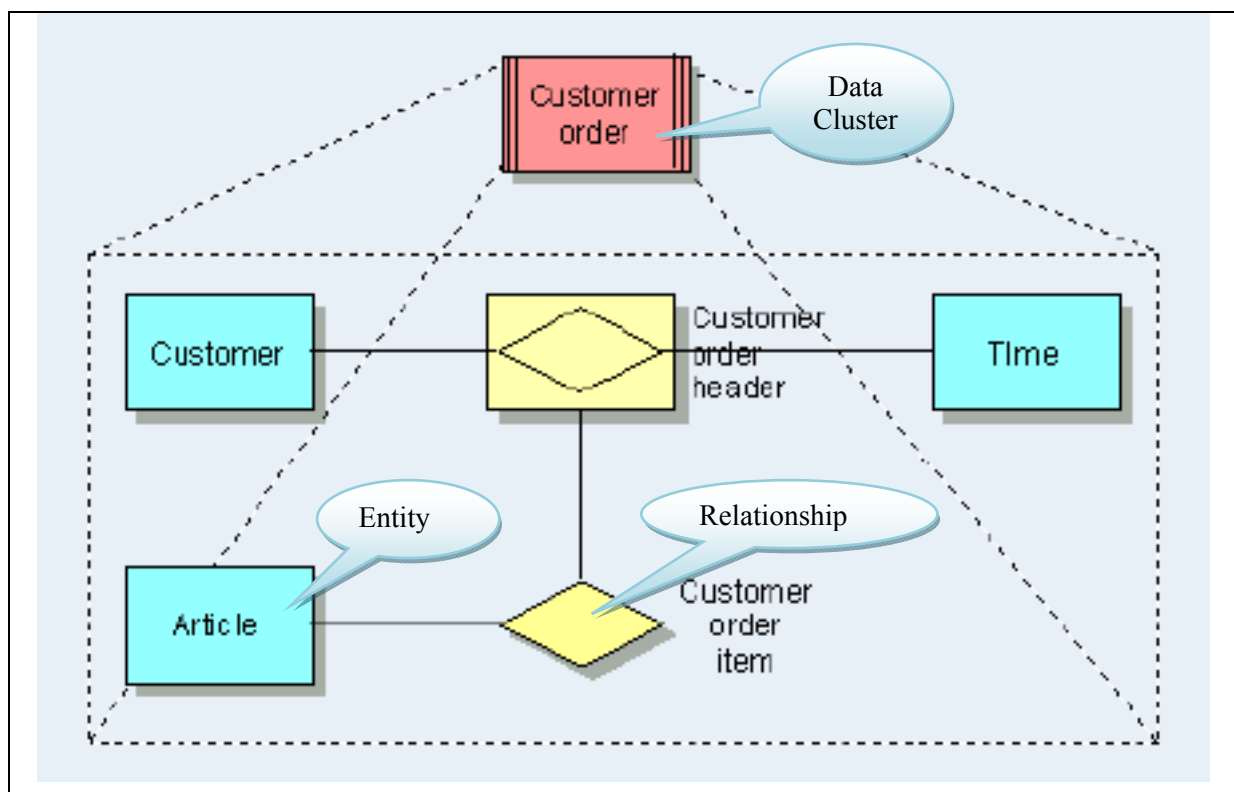


Figure 7.2: Data view (IDS Scheer AG, 2002)

In Figure 7.3 the organisational units are included as part of the organisational hierarchy.

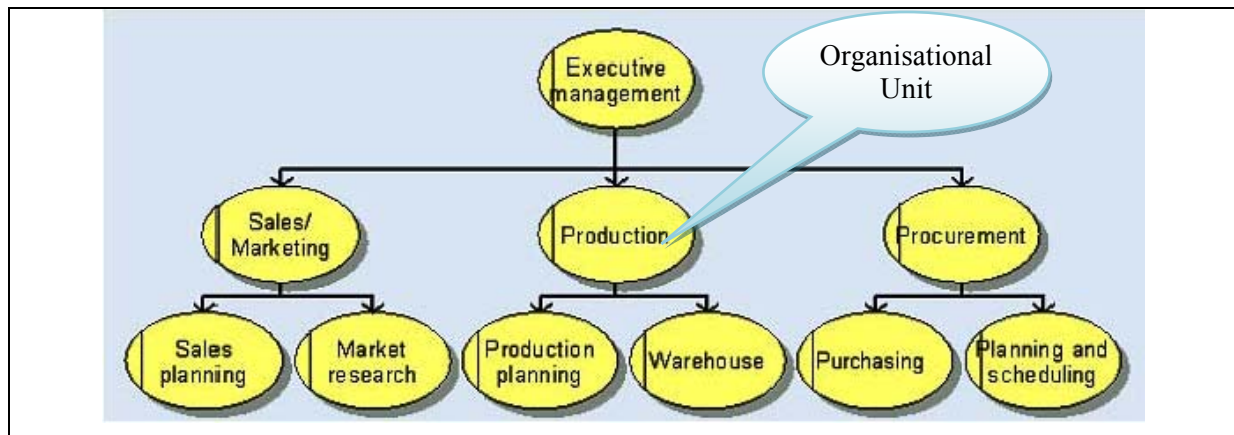


Figure 7.3: Organisational view (IDS Scheer AG, 2002)

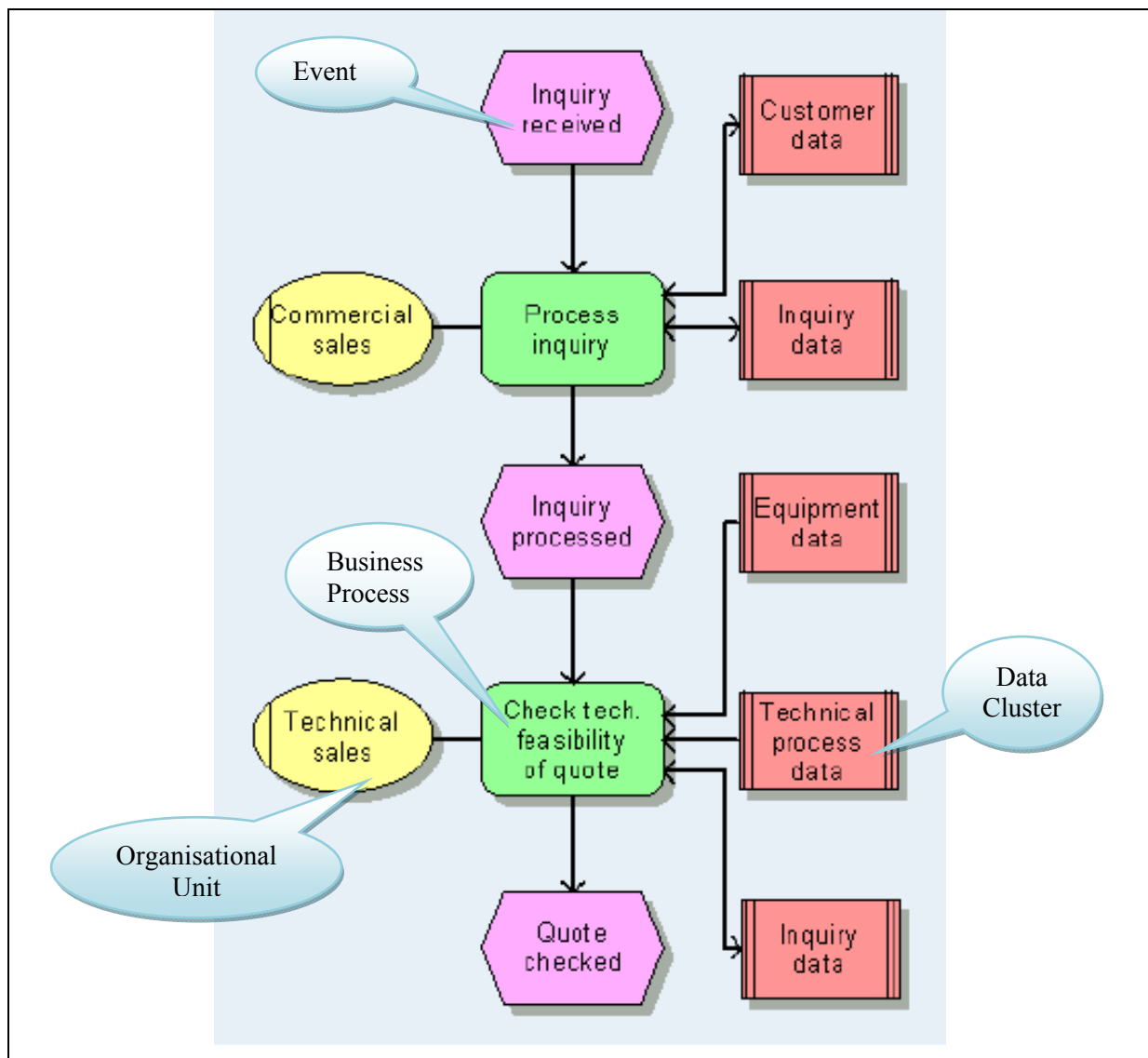


Figure 7.4: Integrated view (IDS Scheer AG, 2002)

In Figure 7.4 the business process, the events that are initiating a business process or which are the result of the business process, and the data clusters, which are either input or output for the business processes are combined in one view.

Another popular approach is to map the content of the different cells in the enterprise architecture frameworks in matrix format. Figure 7.5 is a representation of the technique proposed by Arao et al. (2005) to assist customers to understand the relationship between the business process and system/software functions.

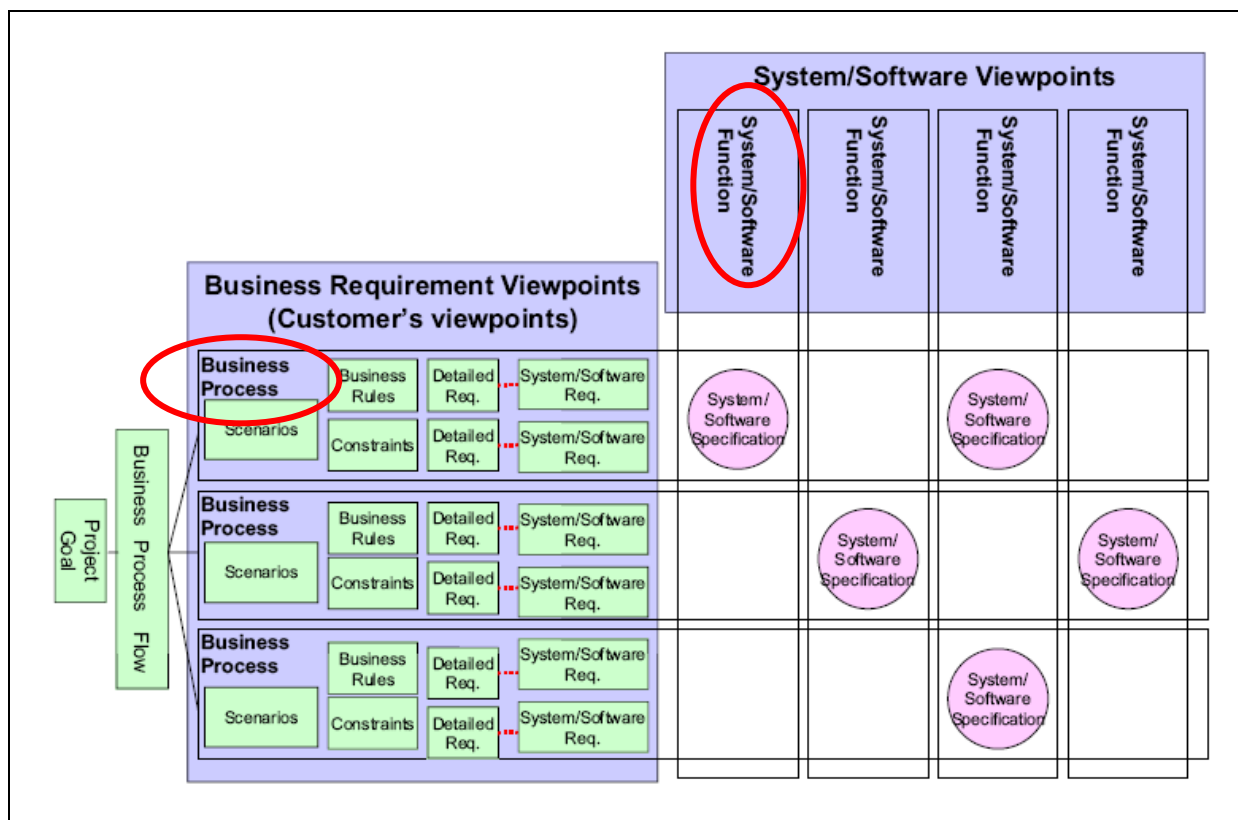


Figure 7.5: Business requirement/system requirement matrix (Arao et al., 2005)

7.2.2 Viewpoint-based Development

Sabetzadeh and Easterbrook (2005) explore viewpoint-based development with major overlaps between the different viewpoints. Viewpoints may be employed to specify different aspects of a problem, to model competing perspectives on a single aspect, or to describe various concerns as to how different problem constituents can interact. Hickey et al. (1999) also promote the use of views to define individual user requirements. However, once viewpoints are merged, it is important to be able to determine how the merged viewpoint represents each viewpoint, and to track the assumptions involved in the merge. This requirement is thus very much about starting with various viewpoints and

consolidating or merging these into a single view. The example included in Figure 7.6 as documented by Sabetzadeh and Easterbrook (2005) refers to multiple entity relationship diagrams that are merged into a single entity relationship diagram (ERD). Refer to section 2.2.2 for a definition of the ERD notation. The introduction of viewpoint interrelations enables origin and assumption traceability. As viewpoints evolve over time and merged views become more complex, identifying the assumptions related to unifications may no longer be trivial. A detailed discussion of the viewpoint merging framework and the discussion of viewpoints and mappings are found in Sabatzadeh and Easterbrook (2005).

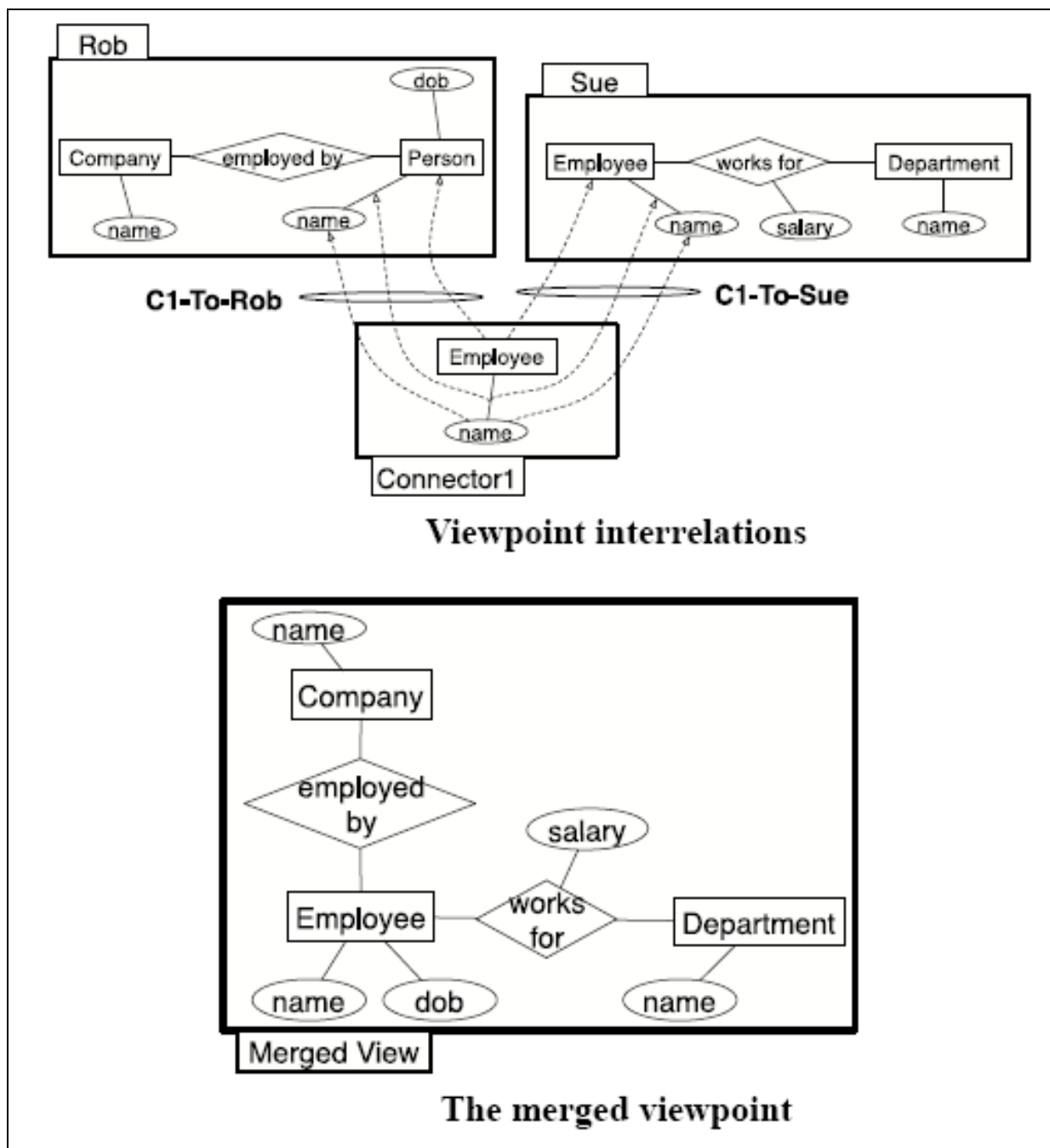


Figure 7.6: Individual and merged viewpoints (Sabetzadeh and Easterbrook ,2005)

7.2.3 Swim Lane-based Views

Swim lane-based views are a preferred technique for role clarification and role-based training. An example of a role-based swim lane is included in Figure 7.7. The role is responsible for the business processes indicated in the same column. However swim lane-based views are not limited to role-based columns or rows. Application-based swim lanes, indicating the application enabling the business process is also well known. The swim lane is to some extent similar to the matrix approach explained in section 7.2.1 and illustrated in Figure 7.5. The swim lane technique is not well suited for complex branching and multiple or cross-allocation of roles as part of the business process model.

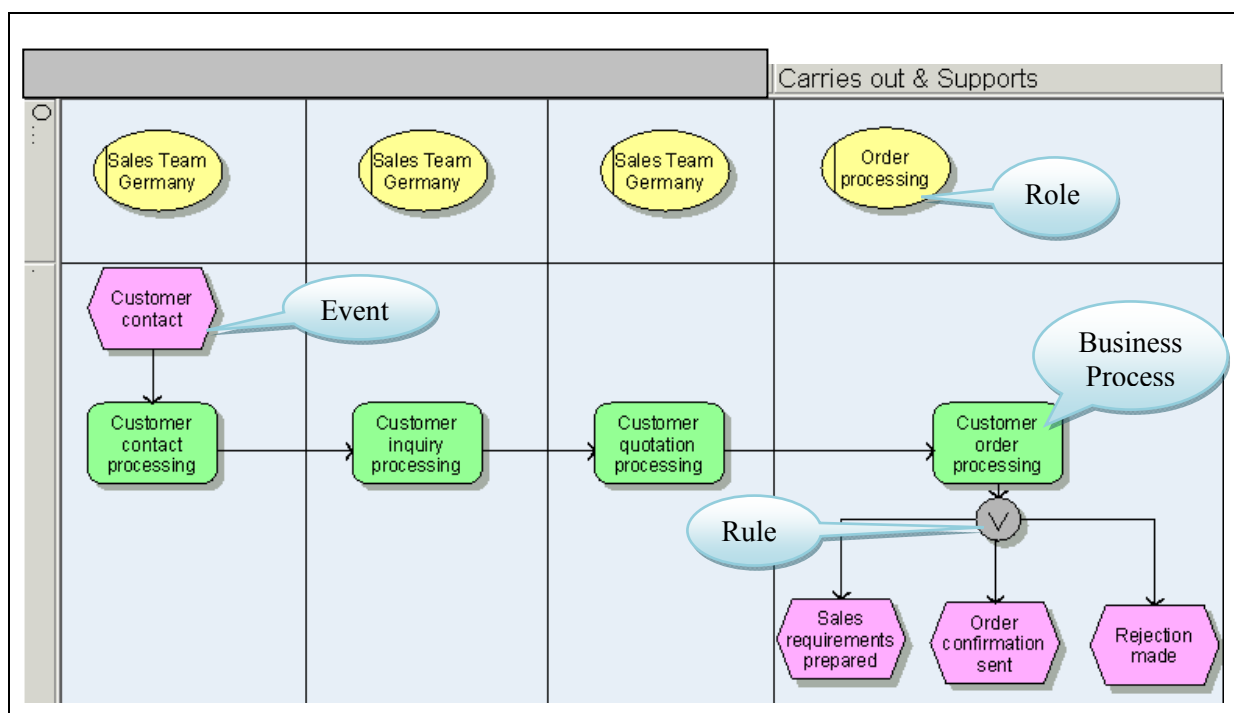


Figure 7.7: Role-based swim lane (IDS Scheer AG. 2002)

7.2.4 Notation-based Views

The requirement for a specific notation is often the result of a personal preference. However, because business process models play a major role as communication medium for change management, the importance of specific notations to get buy-in should not be underestimated. As example, a symbol-based notation variation is included in Figure 7.8. A second notation-based view is the result of the various business processing modelling languages or techniques as listed in section 2.1.3. This is a very relevant concern when re-using business process reference models, as there no standard technique/notation is used for the development of business process reference models. The different

notations used for the documentation of the SCOR models, IndustryPrint business process reference models and the SAP Solution Manager BPR reference models are illustrated in Appendix A, B and C.

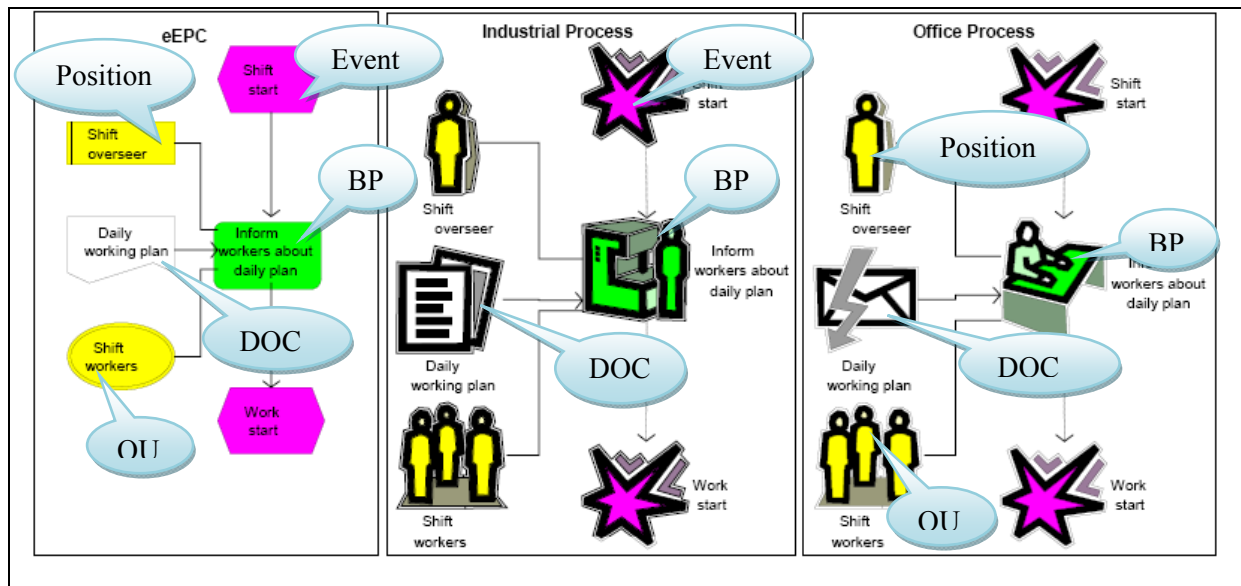


Figure 7.8: Various notations (IDS Scheer AG. 2002)

The import or export of business process models between different tools and transformation between notations are more feasible if the models are repository-based. In Figure 7.8 various symbols are used per model type for the following object types: business process (BP), event, position, organisational unit (OU) and document (DOC). The model types are the extended Event Process Chain (eEPC), Industrial Process and Office Process.

7.2.5 Scenarios

A scenario is a specific path through a set of business process models. Figure 7.9 illustrates the recording of a path from three different business process models. (Figure 7.9 is for illustrative purposes and detail content is not readable) Conceptually, the three business process models are combined in a single model. The selected objects are recorded and a new model is created to represent the scenario. The source models are the *acquisition*, *supply* and *maintenance* models. The recorded objects indicated by the red line will be used to generate a new model. The objects that are not recorded will not be part of the new model.

Figure 7.10 is a variation of a diagram by Bobrik et al. (2005) to illustrate the visualisation of system-spanning business processes in a complex enterprise environment. The difference is that Bobrik et al. (2005) is sourcing the information from different systems, thus a bottom-up approach based on business activity monitoring, business process diagnosis and log data. In Figure 7.10 a top-down approach based on the re-use of multiple business process reference models is illustrated.

Such a top-down and bottom-up approach should be seen as complementary and not as contradictory. The business process reference models could provide context to the tasks executed by the systems as well as the manual activities.

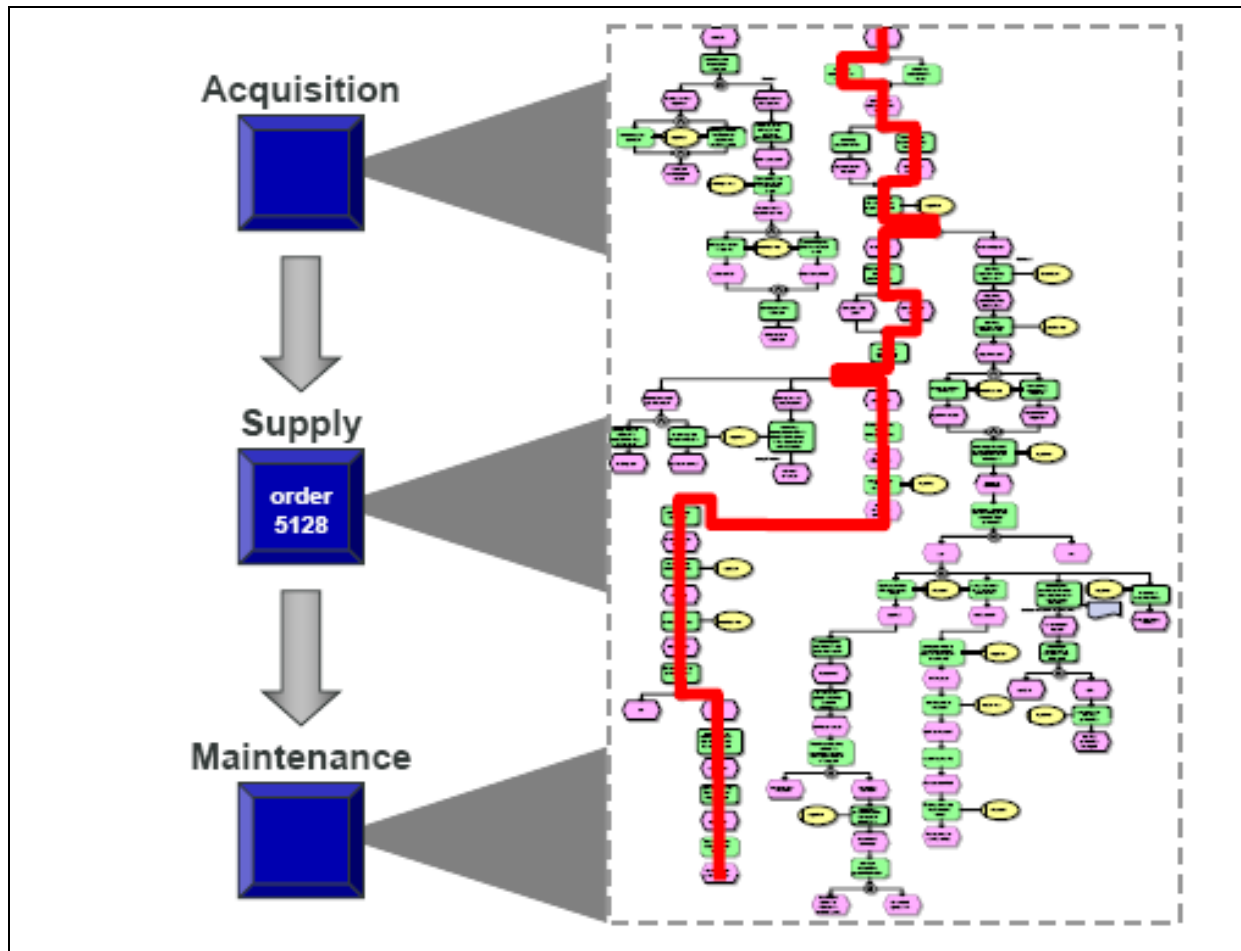


Figure 7.9: Scenario (IDS Scheer AG. 2002)

The scenario in Figure 10 is designed by re-using components from three different business process reference models. Gaps are closed by modelling missing activities from scratch, for example F, G, H, I and J. Overlaps between the business reference models, for example N, are resolved to ensure an integrated scenario.

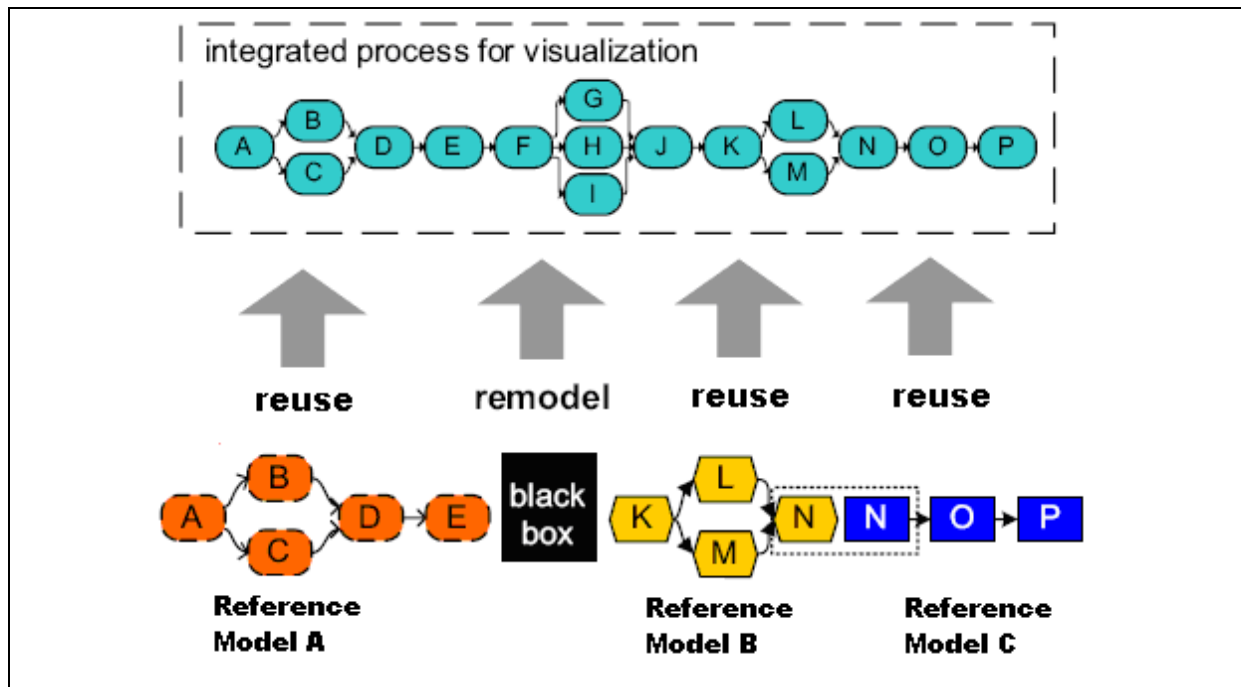


Figure 7.10: Mapping of scenario from reference models

(Variation of example from Bobrik et al., 2005)

7.2.6 Aggregation and Reduction

Bobrick et al. (2005) admit that a more flexible way to visualise business process models is needed. In order to hide or remove business process detail, a concept similar to a generic view, like the one known from relational database systems is considered. Such concept should permit one to aggregate or remove parts of a business process, filter the elements according to their types and attributes, or combine several business processes in a single representation. Two fundamental techniques for building such views on business process models are *graph aggregation* and *graph reduction*, as indicated in Figure 7.11. The aggregation is combining for example B, C, and D resulting in the business process N. With reduction the detail for example B, C and D are not represented in the reduced view.

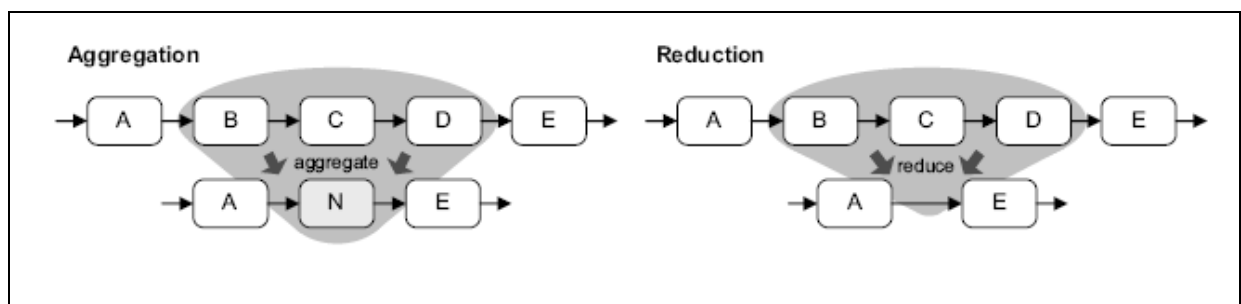


Figure 7.11: Aggregation and reduction of business processes (Bobrik et al., 2005)

7.3 Conclusion

Chapter 7 motivates the need for flexible visualisation of business processes, and various examples are included to illustrate different perspectives. Although the realisation of flexible visualisation of business process models is excluded from the scope of this dissertation it is certainly a major future research topic to consider. Entirely manual recapturing of business process models to provide flexible visualisation should be avoided. Some of the challenges are the algorithms for the automatic layout of the business process models, update frequency, security and access control, support of multiple languages, impact on repository management functionality, viewing technologies, maintainability, availability and response time.

Addressing the issue of flexible visualisation contributes to resolving some of the causes for the misunderstanding by the customer of what the business requirements really mean. The motivation for flexible visualisation of business process models is strongly related to the challenge to ensure that the end user understands the meaning of the business process models. The variety of the examples that were included gives an indication of the complexity associated with the flexible visualisation of business process models.

Chapter 7 focuses on the inclusion of flexible visualisation as component to the proposed business process model warehouse framework. If the repository, as discussed in Chapter 6, is the engine room of the business process model warehouse, then Chapter 7 is the end user experience that can make or break the feasibility of the business process model warehouse concept.

With the last component of the proposed business process model warehouse framework introduced in Chapter 7, it can be concluded that it is possible to propose a business model warehouse framework, promoting the re-use of multiple business process reference models and flexible visualisation of business process models, thereby minimising to some extent the causes of inadequate business requirements stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the business requirements really means.

In Chapter 8 the findings regarding the proposed business process model warehouse framework as defined from Chapter 3 to Chapter 7 are summarised. The outcome of the research questions is revisited and the value contribution of the research is reflected.

CHAPTER 8: OVERALL FINDINGS

The findings of the dissertation are positioned within the context of the enterprise architecture domain. Enterprise architecture, including the business architecture, which in turn includes business process models, is about bridging the gap between the business requirements and the information systems. Bridging the gap between the business process requirements and information system enablement is a challenge. One of the contributing factors to the failure of an information system project is inadequate business process requirements.

To recap, the argument (see section 1.4) is that a framework for a business process model warehouse can be developed. The aim of the business process model warehouse is to promote –

- The re-use of multiple business process reference models.
- The flexible visualisation of business process models.

The critical success factor for such a business process model warehouse is that it should contribute to minimising to some extent the causes of inadequate business requirements as stated by Verner et al. (1999), namely:

- inadequate (business) requirements gathering;
- a lack of user input because the customer would not make the time available; and
- misunderstanding by the customer of what the (business) requirements really mean.

Within this context, the findings of the research are briefly summarised in Chapter 8.

8.1 Finding 1: Research Topic

One of the initial findings was that the argument (see sections 1.4) is a valid research topic. Based on the reference to literature in section 1.3, it was possible to conclude that it is a valid statement to say that comprehensive business process requirements contribute to the success of an information project. It was also found in section 1.3 that *business process requirements* as concept is an active research topic.

8.2 Finding 2: Research Method

The primary research method was analogical reasoning. The target domain in this dissertation was the business process model warehouse framework and the general matching domain was the data

warehouse framework. The intent was to find related items between the data warehouse framework and the business process model warehouse framework and to propose a business process model warehouse framework. A prerequisite for the analogical reasoning was to get a definition for a data warehouse framework. No representative data warehouse framework definition could be found in literature. However, it was possible to derive a data warehouse framework from a number of data warehouse frameworks. Analogical reasoning as research method was dependent on the definition of a data warehouse framework. Deriving a data warehouse framework made it possible to continue with analogical reasoning as research method.

8.3 Finding 3: Business Process Model Warehouse Framework

The derived data warehouse framework consists of the following components:

- Operational databases or external sources.
- Extract, load and transform (ELT) method.
- Data warehouse.
- Online analytical processing (OLAP).

No framework for a business process model warehouse was found in the reference to published research as reflected in Chapter 4. It was, however, possible to find references to the concept of a business process model warehouse, to the characteristics of a data warehouse and a similar analogy between a data warehouse and a design warehouse. These sources were all considered together with the analogy to the data warehouse framework as input in the development of the proposed business process model warehouse framework.

The key finding was that it is possible to propose a business process model warehouse framework with the following components:

- Usage of multiple business process reference models as source models.
- Conceptual design of a process to extract, load and transform multiple business process reference models into a repository.
- Description of repository functionality for managing enterprise architecture artefacts.
- Motivation of flexible visualisation of business process models to ensure more comprehensive business requirements.

The findings related to the various components of the business process model warehouse framework will be discussed below per component. There will be cross-referencing to the argument and the research questions stated in section 1.4.

8.4 Finding 4: Business Process Reference Models

The finding regarding the use of multiple business process reference models is that there is a reference in the body of knowledge to the use of multiple business process reference models. With references to the specific sources referring to the use of multiple business process reference models, two areas that were not addressed by the sources were identified. From the perspective of proposing a business process model warehouse framework it was important to address the following two gaps related to the use of multiple business process reference models:

- It was important to define a method to extract, load and transform (ELT) multiple business process reference model into a repository.
- It was also important to select the business process reference models in such a way that it allowed the testing of the proposed ELT method both for the horizontal and vertical integration of business process reference models. (It can also be stated that the integration is not only limited to decomposition of an element from one set of business process reference models to another. The ELT method should make provision for the integration of two sets of business process reference models when the content is overlapping.)

The finding related to the argument (see section 1.4), namely that the business process model warehouse framework should promote the use of multiple business process reference, with the specific qualifier that it should minimise to some extent the causes of inadequate business process requirements, can be summarised as follows:

- One approach to verify the quality of business requirements is to compare the business requirements with a predefined set of business requirements to measure consistency, completeness and integration. Business process reference models are available to use as predefined business requirements to mitigate the risk of inadequate business requirements gathering.
- Business process reference models can be used as accelerator with the definition of business requirements resulting in more value-adding work sessions and less time required from the customers, mitigating the risk of the customer not making the time available to provide input.
- Various sets of business process reference models are available, giving the customer the opportunity to select the most understandable and applicable variant. An additional benefit is that information is available to enhance a better understanding of the business processes.

8.5 *Finding 5: Extract, Load and Transform (ELT) Method*

A key value contribution of this dissertation to the body of knowledge is that it not only proposes a business process model warehouse framework, but also the conceptual design of an ELT method for multiple business process reference models. Not only is the conceptual design considering the vertical and horizontal integration of multiple business process reference models, but the conceptual design is also tested with a proof of concept example.

8.6 *Finding 6: Repository*

One of the research questions is phrased as: “Why not use the data warehouse as solution for the business process model warehouse if the frameworks are such a good fit?” The answer can be found in the functionality required to manage enterprise architecture artefacts. As stated in section 2.2.1, it was necessary to extend the database functionality to a repository for enterprise artefacts. A similar extension is required to the data warehouse in order to provide the repository management functionality required to manage the business process model warehouse.

8.7 *Finding 7: Flexible Visualisation*

The argument (see section 1.4) is also referring to the promotion of the use of flexible visualisation of business process models to minimise to some extent the causes of inadequate business process requirements. As illustrated with the various views in Chapter 7, the flexible visualisation of business process models enable a better understanding of the business process requirements by the end user. However, as stated in Chapter 7, it is not a feasible option if the generation of the different views is not automated. The finding is therefore that it is an important area for future research, but for the immediate future the focus is on creating an awareness of flexible visualisation.

8.8 *Conclusion*

The positive finding related to the argument (see section 1.4) did add value to the enterprise architecture domain but also to the information management discipline in general. The quality of the business requirements is important from an information management perspective for two reasons:

- Improving the quality of the business requirements should reflect an increase in the success rate of information system implementations.

- This research is also particularly concerned with the positive role that a repository (an information system) can play in enabling the business requirements process.

None of the concepts are totally new, but proposing a business process model warehouse framework contributed to the enterprise architecture domain by giving context to a number of concepts and providing a foundation for further discussion.

CHAPTER 9: CONCLUSION

9.1 *Summary of Chapters*

Chapter 1 described the background to the argument (see section 1.4) and motivations based on references to literature that it is a valid research question. The layout of the dissertation and the content of each chapter is summarised in the subsections of section 9.1

9.1.1 Chapter 2 – Context and Domain Description

The objective of Chapter 2 is to ensure common definition of key concepts relevant to the dissertation. The key domains that are included in the content of Chapter 2 are the enterprise architecture and the data domains. Key concepts described as part of the enterprise architecture domain are business architecture, business process, business process model, business process reference model as well as flexible visualisation of business process models. As part of the data domain, the differences and similarities between a database, repository, data warehouse, process warehouse and business process model warehouse are highlighted.

9.1.2 Chapter 3 – Business Process Model Warehouse Framework

Chapter 3 is a key chapter as this is the chapter where the business process model warehouse framework is proposed. The intent of Chapter 3 is to derive the business process model warehouse framework based on the description of a data warehouse framework, as found in literature.

The proposed business process model warehouse framework includes components to use multiple business process reference models as source data, to extract, load and transform the multiple reference models into the repository, to manage the content of the repository and then to provide flexible visualisation of the business process models based on the content in the repository.

9.1.3 Chapter 4 – Business Process Reference Models

From the perspective of the argument (see section 1.4), the promotion of the re-use of multiple business process models is the focal point of Chapter 4. However, from the perspective of the

business process model warehouse framework proposed in Chapter 3, the focus of Chapter 4 is the multiple source models for the warehouse, known as business process reference models.

Two sources, Gullledge et al. (2001b) and Kirchmer et al.(2002), referring to the use of multiple business process reference models are referenced in Chapter 4, confirm that there is reference in the body of knowledge to the use of multiple business process reference models. There are two areas of relevance for this dissertation that are not addressed by either of these sources. These areas are the description of the method to extract, load and transform (ELT) more than one business process reference model into a repository, and the integration of models from both the horizontal and vertical sectors as defined by the Gartner nine architectural sectors of metadata (refer to Figure 4.2) .

9.1.4 Chapter 5 – Extract, Load, Transform

The focus of Chapter 5 is to derive a business process model warehouse ELT method based on the data warehouse ELT framework. The proposed method is tested and the example described in Chapter 5. The example also illustrates the potential value of using multiple business process reference models to address the argument related to inadequate business requirements.

The selection criteria for the selection of business process reference models for the proof of concept are included in section 5.3.1.4. The background, analysis, abstraction and logical design of the selected business process reference models are described in more detail for the following business process reference models:

- Supply-Chain Operations Reference-model (SCOR).
- IndustryPrint 3.0 reference model.
- SAP Solution Manager BPR reference model.

9.1.5 Chapter 6 – Repository

Chapter 6 addresses the repository component of the proposed business process model warehouse framework. The content and functionality of a repository, the engine room of the business process model warehouse, are discussed. The repository is a key prerequisite to promote the use of multiple business process reference models to address the problem of inadequate business requirements as stated as part of the argument. From a technology enablement perspective, the repository is a critical success factor to integrate and configure multiple business process reference models.

9.1.6 Chapter 7 – Flexible Visualisation

Chapter 7 focuses on the flexible visualisation component of the proposed business process model warehouse framework. The concept *flexible visualisation of business process models* is motivated and requirements are defined based on the inclusion of various examples. Addressing the issue of flexible visualisation contributes to resolving some of the causes for the misunderstanding by the customer of what the business requirements really mean. The motivation for flexible visualisation of business process models is strongly related to the challenge to ensure that the end user understands the meaning of the business process models. The variety of the examples that were included gives an indication of the complexity associated with the flexible visualisation of business process models.

9.2 Reflections

9.2.1 Challenges

Part of the objective of a dissertation is to learn from and to build on the existing body of knowledge. Therefore it is a disappointment if limited sources of information are available to be used as reference material. As an example let us refer to the data warehouse framework constraint. The research method was based on analogical reasoning and with the research design it was assumed that it would be possible to find a predefined representative data warehouse framework. This was not to be, resulting in the additional challenge to derive a data warehouse framework.

A second challenge was the inconsistent usage of terminology. Alignment of terminology, both the use of a similar terminology for different meanings, or different terminology for the same meaning, was such a concern that it was specifically addressed by introducing a notation in the Preface.

Another concern was that it should be possible to find various sources referring to terms such as *process warehouse*, but on further investigation it was clear that sources often are not referring to the process warehouse in the same context. Differentiation was important to ensure that concepts are clearly defined as in or out of scope of the dissertation. It became apparent that an additional descriptor was to be added to differentiate terms. The initial term *process warehouse* was first extended to *business process warehouse* and then to *business process model warehouse*.

9.2.2 Method

Analogical reasoning played an important role as research method. The research design was to use analogical reasoning between the data warehouse framework and a business process model warehouse framework. The finding was that this worked well as key research method. In addition, as part of the domain description in Chapter 2, analogical reasoning between the architectural deliverables for the construction world and enterprise architectural domain was used. The resultant stating and mapping of the principles assisted in clarifying a number of concepts. This was not an initial expectation and therefore it was considered an additional bonus. Just a note on the quality of the architectural prints as this was a concern. As we are discussing the role of analogical reasoning, it was interesting to find that in the article by Zachman (1987), the illustration was a rough drawing by hand. My conclusion was that if that diagram was good enough for Zachman to communicate the concept, then one does not need a work of art to explain a concept.

Clarifying the relationship between a database, a repository (for enterprise architecture artefacts) and a data warehouse, an analogy was a similar positive moment. The question that remains is whether one needs to extend a repository with data warehouse functionality, or whether it is necessary to extend a data warehouse with repository functionality. Within this dissertation, the approach was to extend the repository functionality with data warehouse functionality.

9.2.3 Value Contribution

Considering that there is an opportunity to contribute to the body of knowledge from the business process model warehouse perspective, this dissertation is providing context for and clarifies a number of concepts. This may provide a jump start for any further research regarding the definition of the milieu.

The conceptual design of the extract, load and transform (ELT) method of multiple business process reference models into a single repository is acknowledged as a new contribution since no similar reference was found to date. The selection of a set of business process reference models that address both the challenge of integration and overlapping gives an additional value contribution flavour to the ELT part of the dissertation.

9.3 Recommendation for further research

The potential for further research related to this dissertation is not limited to one or two topics. From work regarding the impact of business process requirements on the success rate of the implementation of information systems to the automation of flexible visualisation are all feasible research topics.

There are a number research questions that come to mind:

- Would there be value in an analogy with another information system subject area, for example a geographical information system (GIS)?
- What would the impact be if the source information is extended from the business process reference models to include any other business process models?
- Is it technically possible to enable flexible visualisation with technology?
- What would the role of expert systems be as part of the flexible visualisation solution?
- Is it possible to promote the concept of a business process model warehouse by doing an empirical study on the value of business process reference models and flexible visualisation?
- What would the impact be of extending the multiple business process reference models to incorporate the enterprise services repository?

9.4 Conclusion

The argument of this dissertation originated in the practical experience related to the definition of business process requirements. The intent was to learn from a theoretical foundation. The proposed business process model warehouse framework is based on such a theoretical foundation. By formalising the practical experience the concept was extended to a broader framework. The proposed business process model warehouse framework is giving direction to explore solutions within a structured context.

Appendix A: Supply-chain Operations Reference-model (SCOR)

The purpose of this section of the document is to analyse and understand the structure of the content of the Supply-chain Operations Reference-model (SCOR). The content and the method to apply the SCOR model are excluded from this study. The content of Appendix A is based on the information available on the Internet at the following address, www.supply-chain.org as published by the Supply-Chain Council (Supply-chain Council, 2003). Appendix A will reflect the SCOR

- Content.
- Structure.
- Documentation notation.

SCOR Model Content

The SCOR model spans all customer interactions, all physical material transactions and all market interactions. The SCOR model can be used to describe supply-chains whether simple, complex, from different industries, site specific or global.

The SCOR model describes (business) processes and not functions, and the person or organisation element that performs the activity is not included in the SCOR model. It is necessary to extend the SCOR model to accommodate organisation-specific detail (business) process element descriptions (Figure A.1 level 4) as well as enablement of the (business) processes with technology.

The SCOR model does not address wall-to-wall business processes and some of the well-known (business) processes not included are:

- Sales and marketing.
- Product development.
- Research and development.
- Human resource management.
- Quality management.

SCOR Model Structure

SCOR is a hierarchical model with three levels as indicated in Figure A.1. (Please note that level 4 indicated on Figure A.1 is not included in the scope of SCOR). Level 1 differentiates between the five basic management (business) processes (Plan, Source, Make, Deliver, Return) as well as three (business) process types (Planning, Execution, Enable).

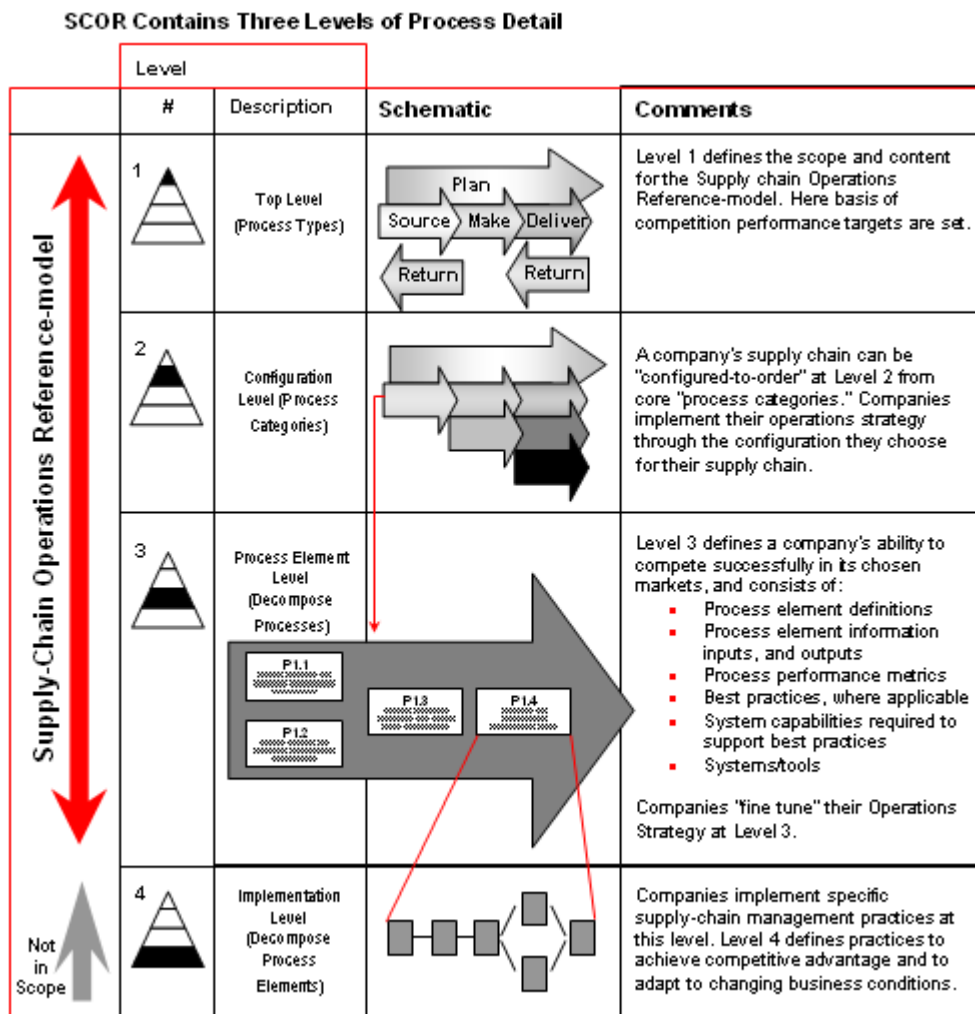


Figure A.1: SCOR is a hierarchical model © Copyright 2004 Supply-Chain Council, Inc, May 2004

The SCOR model is composed of a number of sub-structures:

- Refer to Figure A.2 for a visual representation of the process elements, their relationships to each other, and the inputs and outputs that are relevant to each process element.
- Refer to Figure A.3 and A.4 for examples of the Level 2 Text Table and Level 3 Text Table consisting of:
 - The standard name for the Process Category/Process Element.
 - The notation for the Process Category/Process Element.

- The SCC's "standard" definition of the Process Category/Process Element.
- Performance attributes that are associated with the Process Category/Process Element. The metrics are intended to be hierarchical.
- Best practices, which are associated with the process (not necessarily an exhaustive list).
- Features (generally technologically related) that can contribute to better performance of the process.
- The related inputs and outputs for Level 3, provided in table format.
- Refer to Figure A.5 and A.6 for the Glossaries differentiating between Process Terms and Metric Terms.

SCOR Documentation Notation

SCOR 6.0 is published by the Supply-Chain Council in MS Word format and in Adobe Reader format. Formulating a visual understanding of the relationship between the various elements is difficult in text format. Without database support it is a challenge to understand the inputs and outputs flowing from (business) process to (business) process.

A number of companies addressed this constraint by populating the SCOR models as part of a database. These database versions are often offered as products to the market and the logical and physical designs of these databases are not published as open domain information. The information, as indicated in the following table, was accessed on 2 October 2004 at the internet address indicated per product:

Product	Reference and Overview
e-SCOR	http://www.gensym.com/supplychain/escor_overview.shtml
	Based on SCOR, Gensym's e-SCOR is a powerful software application for the graphical design, simulation and management of complex supply- chains. E-SCOR assists in modelling supply-chain structures and strategies so that alternatives can be tested (e-SCOR, 2004).
SCORWizard	www.mi-services.com www.scorwizard.com
	SCORWizard is a powerful tool automating the SCOR Model and then putting it to work in the business. SCORWizard includes Balanced Strategic Measurement, End-to-End Visualisation, Powerful Analysis and Compelling Results (SCORwizard, 2004).

Phios	http://repository.phios.com/SCOR/
	Most process-mapping techniques (including the current SCOR model) analyse business processes using one dimension, namely breaking processes into their subparts. The Phios Process Repository organises business knowledge using two dimensions: the different <i>parts</i> of business processes and the different <i>types</i> of business processes (Phios, 2004).
EasySCOR	http://www.ids-scheer.com/sixcms/detail.php/23684
	ARIS EasySCOR is a supply-chain design and analysis tool, developed by IDS-Scheer, that combines the business process modelling software, ARIS Toolset with the SCOR model, as defined by the Supply-chain Council. With ARIS EasySCOR, one can easily define and document existing processes and evaluate various future supply-chain scenarios before implementation (EasySCOR 2004).
ProSCOR	http://www.proformacorp.com/solutions/supplychain.asp
	ProSCOR® contains all of the information from SCOR in more robust, extendable and manageable format. It also includes the leading enterprise modelling tool ProVision (ProSCOR 2004).
StreamlineSCM SCOR	http://www.streamlinescm.com/solutions/streamsub.htm
	StreamlineSCM SCOR is a robust analytical and execution tool that converts the SCOR text documentation to an application database. The StreamlineSCM SCOR database is a single user modelling and execution tool that allows the user to visualise the input/output elements, best practices and metrics. The tool has built-in reporting capabilities and graphics representations generated from data entered into the database (Streamline, 2004).

In order to do a SCOR database conversion, as indicated in the previous table, several abstractions should be available although not published in the public domain. In order to bring to the attention of the Supply-chain Council's membership the opportunity to integrate the existing SCOR model into a structure that creates a more functional business application tool. A paper, *SCOR Model Database Conversion* was published by StreamlineSCM on the Internet, providing a detailed description of the SCOR data definition and the conversion (Figure A.7). To view this paper, see <http://www.streamlinescm.com/solutions/streamsub.htm> accessed on 2 October 2004.

The StreamlineSCM abstraction of SCOR is included as part of this section to give an indication of the complexity of a normalised data view of the content of SCOR. The following definitions describe the data model included as Figure A.7:

- Level One Process Elements (Process_Level_One) defines the scope and content of the SCOR Model (Plan, Source, Make, Deliver, Return)
- Level Two Process Elements (Process_Level_Two) comprise Process Categories that can be configured to represent a company's competitive environment.
- Process Type (Process_Type) indicates the type of the Level Two Process (Planning, Executing, or Enabling).
- Level Three Process Elements (Process_Level_Three) are used in different configurations to define the operational aspect of a supply-chain.
- Input is the movement of information or material/energy between process elements, or from the environment into a process element. Each input, which is received from another process element or external process element, is utilised in some way by a process. Output is the resultant information or material/energy from an element that has been processed. Each output is sent from a process element to one or more other process elements or external element for their use (Inputs_Outputs)
- Metrics is a business process measurement represented in a unit of time, money quantity, or as ratios thereof. The Attribute Metrics are associated with the Level Two Processes and are typically calculated from the "base metrics", which are related to Level Three Processes.
- Best Practices define successful standard operating procedures for a given business type.
- Best Practice Feature was redefined as the technology elements that are associated with best practices.
- Performance Attributes define the characteristics of the supply-chain that permits the supply-chain to be analysed and evaluated against other supply-chains with competing strategies.

S1: Source Stocked Product

- (P2.4) Sourcing Plans
- (ES.2) Source Execution Data
- (ES.6) Logistics Selection
- (M1.1, M2.1, M3.2) Production Schedule
- (M1.2, M2.2, M3.3, D1.3) Replenishment Signals
- (DR1.4, DR2.4, DR3.4) Return Inventory Transfer Data
- (DR1.4) Defective Products
- (DR2.4) MRO Products
- (DR3.4) Excess Products
- (Supplier) Sourced Products
- (DR2.4) MRO Products

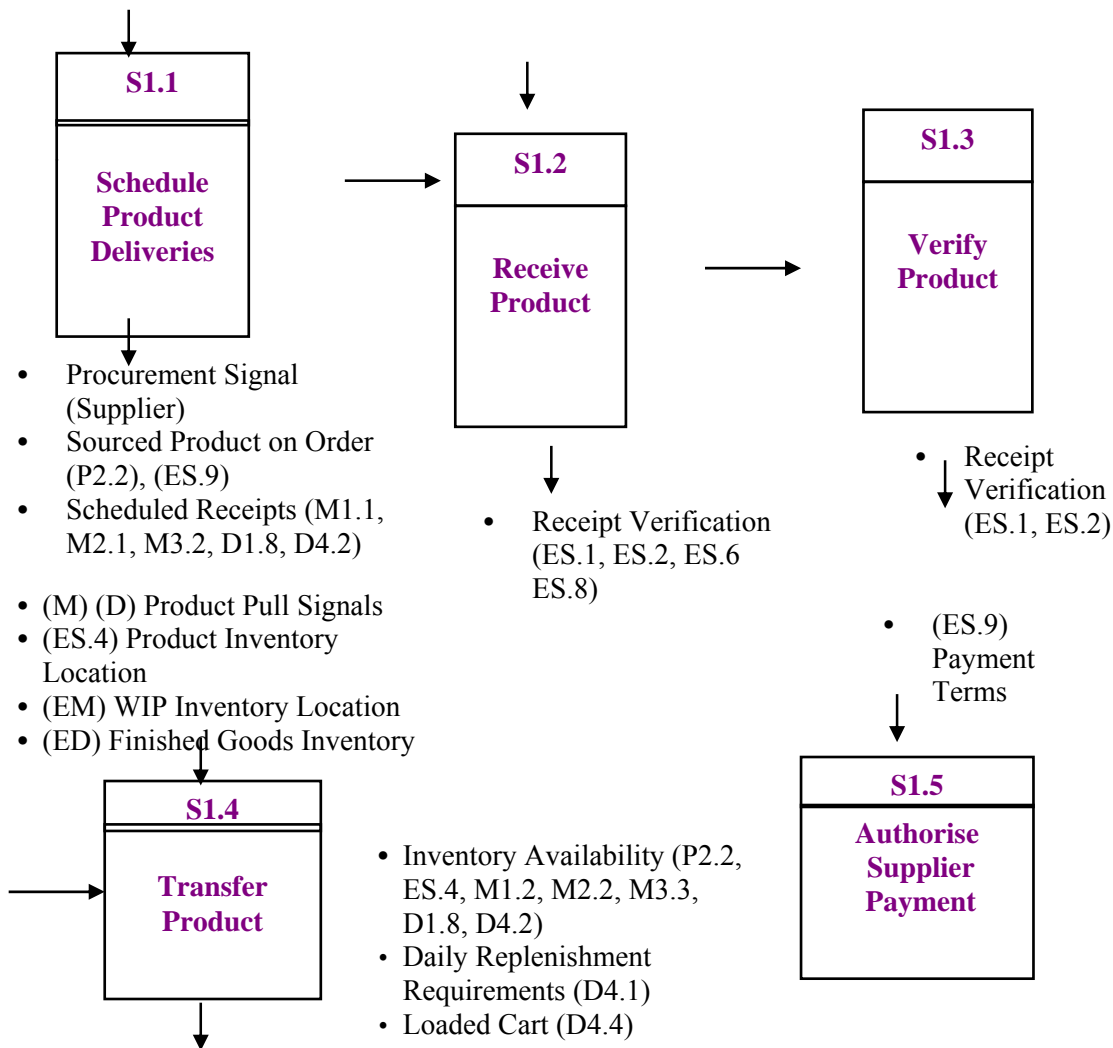


Figure A.2: SCOR visual representation © Copyright 2004 Supply-chain Council, Inc, May 2004

Process Category: Source Stocked Product		Process Number: S1
Process Category Definition		
The procurement, delivery, receipt and transfer of raw material items, subassemblies, product and or services.		
Performance Attributes	Metric	
Reliability	% Orders/lines processed complete	
Responsiveness	Total Source Cycle Time to Completion	
Flexibility	Time and Cost related to Expediting the Sourcing Processes of Procurement, Delivery, Receiving and Transfer.	
Cost	Product Acquisition Costs	
Assets	Inventory DOS	
Best Practices	Features	
Joint Service Agreements	None Identified	
Alliance and Leverage agreements		

Figure A.3: SCOR level 2 text table © Copyright 2004 Supply-chain Council, Inc, May 2004

Process Element: Receive Product		Process Element Number: S1.2			
Process Element Definition					
The process and associated activities of receiving product to contract requirements.					
Performance Attributes		Metric			
Reliability	% Orders/ lines received damage free % Orders/ lines received complete % Orders/ lines received on-time to demand requirement % Orders/ lines received with correct shipping documents				
Responsiveness	Receiving Cycle Time				
Flexibility	% Receipts Received without Item and Quantity Verification				
Cost	Receiving costs as a % of Product Acquisition Costs				
Assets	None Identified				
Best Practices		Features			
Supplier certification programs are used to reduce (skip lot) or eliminate receiving inspection		Skip lot / sampling inspection logic			
Bar coding is used to minimize handling time and maximize data accuracy		Bar code interface for data collection devices Generate bar coded receiving documents			
Deliveries are balanced throughout each working day and throughout the week		None Identified			
Supplier delivers directly to point of use – (dock to line or end destination)		Electronic Tag tracking to Point of Use (POU) destination			
Supplier (Carrier) Agreements		See Glossary			

Inputs	Plan	Source	Make	Deliver	Return
(Supplier) Sourced Products					
MRO Products					DR2.4

Outputs	Plan	Source	Make	Deliver	Return
Receipt Verification		ES.1, ES.2, ES.6, ES.8			

Figure A.4: SCOR level 3 text table © Copyright 2004 Supply-chain Council, Inc, May 2004

TERM	TYPE	DEFINITION	From Process Category/ Element #:
		support maintenance of internal Outbound Transportation equipment – CAPITAL ASSETS) and 2) the management of transporters.	
Material Availability	Input/Output	Availability of a product by location that is reserved, scheduled or available for sale.	D2.3
MRO Product Return Capabilities	Input/Output	The capability to manage the administration and physical transfer of returned products for maintenance, repair or overhaul	P5.2, ER.2 ER.5
MRO Products	Input/Output	Products being returned for Maintenance, Repair, or Overhaul	S1.2, S2.2, DR2.4
Order Backlog	Input/Output	Orders that have been received and entered into the order processing system and are in a queue waiting to be processed and shipped.	D2.3, M2.1
Outsource Plan	Input/Output	A plan that describes how a company will utilize third party business partners to provide products and services which the company chooses not to provide with internal capacity. Outsource Plans can vary in detail from simple policy statements to highly detailed plans with specifics about the third party business partners, specifications for products and services, performance expectations, and contract considerations.	EP.4, EP.5, EP.6
Package	Process Element	The series of activities that containerize completed products for storage or sale to end-users. Within certain industries, packaging may include clearing or sterilization.	M1.4 M2.4 M3.5

Figure A.5: SCOR glossary process terms © Copyright 2004 Supply-chain Council, Inc, May 2004

TERM	TYPE	DEFINITION	From Process Category/ Element #:
% Of Potential Suppliers Selected which Become Qualified	Metric	The number of suppliers who become "qualified" divided by the total number suppliers who were selected for qualification in the measurement period	S3.1
% Of Qualified Suppliers which Meet Defined Requirements	Metric	The number of qualified suppliers who meet defined requirements divided by the total number of qualified suppliers used as sources in the measurement period	S3.1
% Of Receipts Received without Item and Quantity Verification	Metric	# of receipts with Quantity variance requiring corrective actions (outside industry standard tolerance) divided by total number of receipts.	S1.2, S2.2, S3.4
% Of Receipts Received without Quality Verification	Metric	# of receipts with Quality variance requiring corrective actions divided by total number of receipts.	S1.3, S2.3, S3.5
% Of Single and/or Sole Source Selections	Metric	# of Single and/or Sole Source selections divided by the total number of awards	S3.2
% Of Supplier Contracts Negotiated Meeting Target Terms and Conditions for Quality, Delivery, Flexibility and Cost	Metric	The number of contracts negotiated meeting all business requirements divided by the total number of contracts processed in the measurement period	S3.2
% Of Time Data Available When Needed	Metric	The amount of time that data is accessible by applications during those time periods when it is scheduled to be available. Data availability is often measured as a percentage of an elapsed year.	EM.3
% Orders/Lines Processed Complete	Metric	The number of orders / lines that are processed complete divided by the total orders / lines processed within the measurement period	S1, S2, S3
% Orders/Lines Received Complete	Metric	The number of orders / lines that are received complete divided by the total orders / lines received in the measurement period	S1.2, S2.2, S3.4

Figure A.6: SCOR glossary metric terms © Copyright 2004 Supply-chain Council, Inc, May 2004

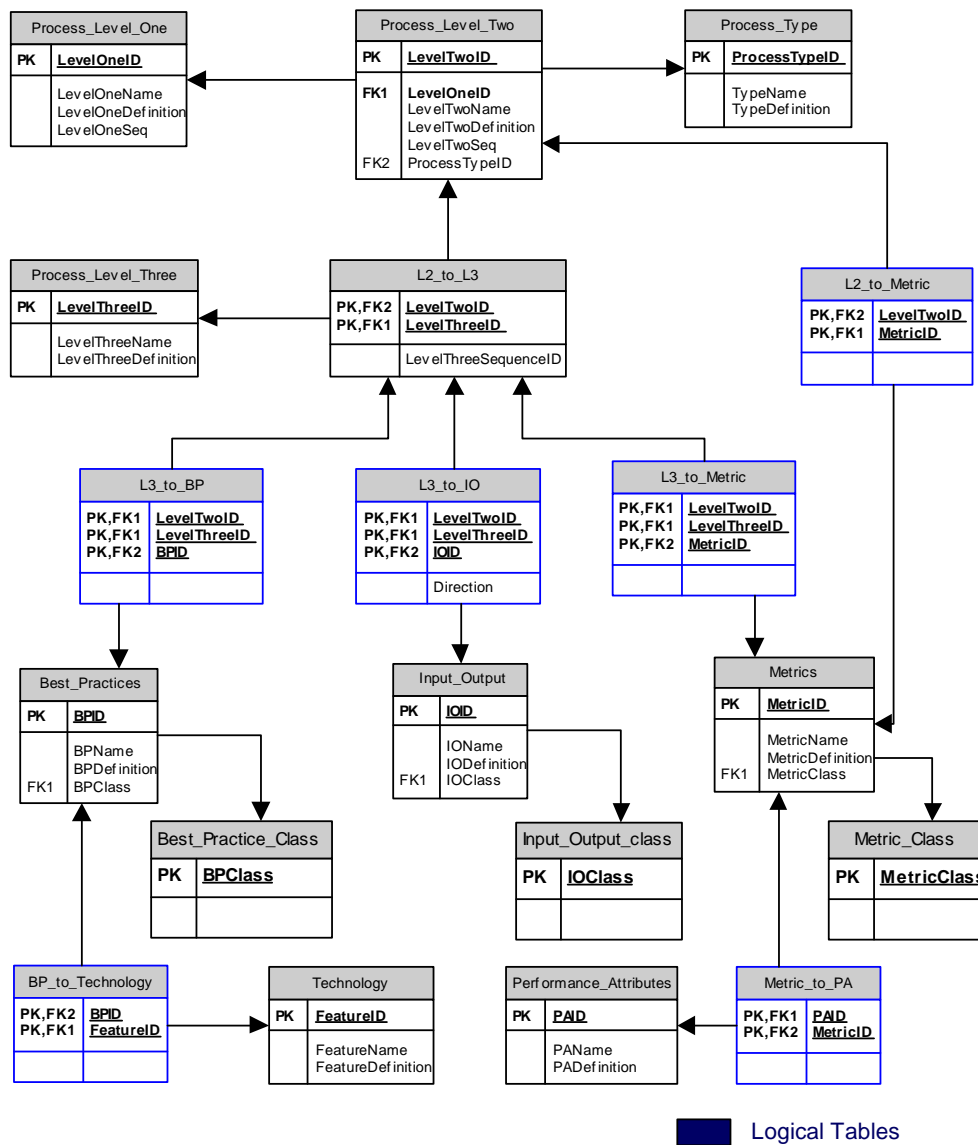


Figure A.7: SCOR StreamlineSCM database mapping

Appendix B: IndustryPrint 3.0 Reference Model

The purpose of this section of the dissertation is to analyse and abstract the structure of the content of the IndustryPrint 3.0 Reference-model © 2004 Deloitte Consulting LLP (Deloitte Consulting LLP, 2004). The content and the method to apply the IndustryPrint 3.0 Reference-model are excluded from this study. Please note that due to the proprietary nature of the information no detailed references are included in the reference list. The information was communicated by E. de Klerk from Deloitte Consulting during 2004 and the request is that readers should contact the local Deloitte Consulting branch for detailed information. Appendix B will explore the following components of the IndustryPrint reference model:

- Content.
- Structure.
- Documentation notation.

IndustryPrint Content

The IndustryPrint models span enterprise-wide business processes and are not limited to customer interactions, as all physical material transactions and all market interactions are included. The IndustryPrint models describe business processes and not functions, and the person or organisation element performing the activity is not included in the IndustryPrint models. IndustryPrint models are depicted in four levels of detail. The business processes are mapped to enterprise software packages to assist in technology-enabled business transformation.

There are a number of IndustryPrint variants, but the business processes are categorised as follows:

- **Infrastructure business processes:** these business processes represent internal operations of the business and do not vary greatly from one industry to another. Examples:
 - Human Resources.
 - Information Technology.
 - Business Planning.
- **Operational business processes:** these business processes represent external operations of the business. These business processes are industry-specific and can vary greatly from one IndustryPrint to another. Examples:
 - Product Research and Marketing.
 - Customer Billing.
 - Customer Service.

- **Collaborative business processes:** these business processes occur between two or more trading partners, such as the Supplier or Channel Partner. Examples:
 - Commerce.
 - Indirect eProcurement.
 - Sales Support.

There is a large portfolio of IndustryPrint variations that are differentiated by industry and industry segments and enabling technology. There are eight different industries and 33 different industry segments, and 14 packages are mapped to the relevant business process models. Due to the proprietary nature of the IndustryPrint business process models, the detail will not be discussed as part of this report.

The IndustryPrint business process models add value to the project deliverables throughout the life cycle of a project, for example contributing to the following deliverables:

- The As-Is business process model.
- Project scope.
- Documentation strategy.
- Enabled vision.
- Business case.
- Gap analysis.
- Security definition.
- Detailed To-Be design.
- Communication.
- Configuration.
- Integration Test Plan.
- End-User Learning.

The basic steps to create a client-specific set of business process models based on the Industry Print business process models are:

- Select the best fit variant from the IndustryPrint portfolio for the specific client.
- Delete the objects (Process, Sub-process, Activity, Workstep) that are not applicable to the client.
- Add new objects as required to the decomposition diagrams.
- Create and revise the business process models.
- Add relationships to software packages and roles as desired.
- Develop descriptive detail as desired.

IndustryPrint Model Structure

The essence of an IndustryPrint is a business process model, usually constructed in three levels (process-sub-process-activity). The fourth level (workstep) is most commonly used when customising an IndustryPrint for an individual client (Figure B.1).

Process:

A process is a representation of time-related actions and dependencies that transfer a set of inputs into a set of outputs.

Sub-process:

A sub-process is a segment of a process covering a single business area.

Business Activity:

A business activity is a breakdown of a sub-process that produces a measurable result.

Workstep:

A workstep is a single step in a business activity.

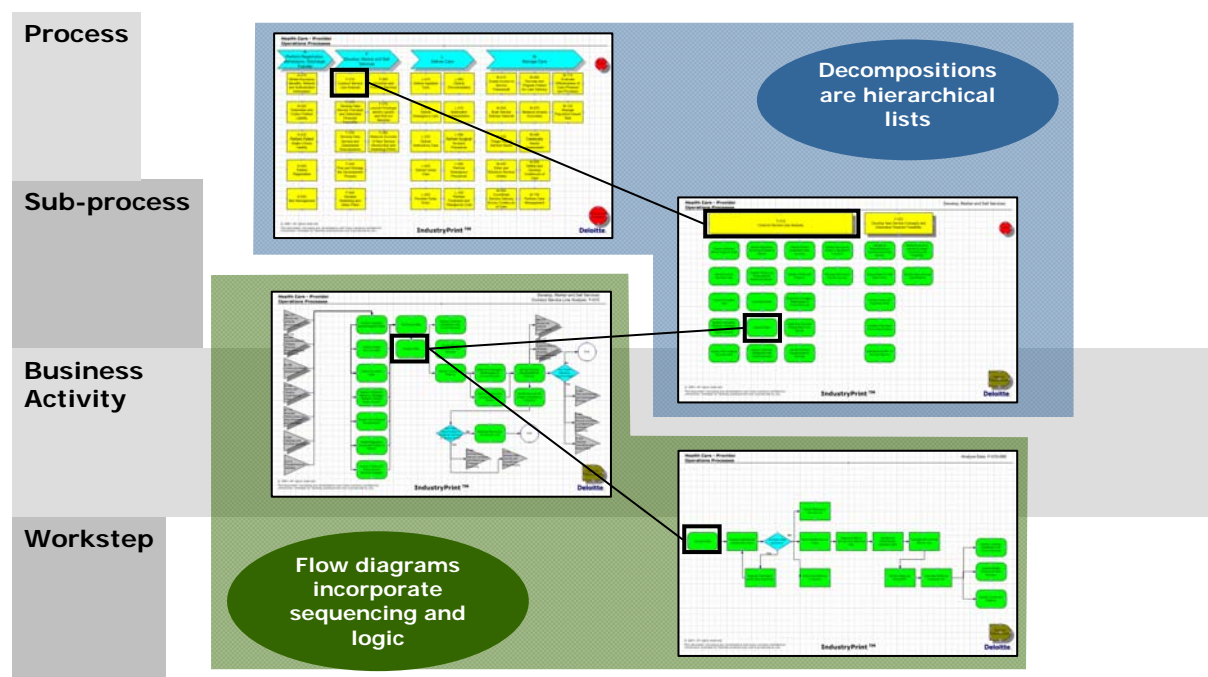


Figure B.1: IndustryPrint models and hierarchical decompositions © Copyright 2004 Deloitte Consulting LLP

In order to support technology-enabled business process design, a number of software packages are mapped to the Business Activity (third level) of IndustryPrint variants.

IndustryPrint Documentation Notation

IndustryPrint is delivered in Microsoft Visio and Microsoft Access. Microsoft Visio Drawings are the “front end” of IndustryPrint. The decomposition and business process models are contained in Microsoft Visio. The business process object hierarchy, software package mappings, collaboration relationships and the role relationships are stored in a MicroSoft Access database. An IndustryPrint-specific software package enables information stored in the database to be displayed in the business process models.

Appendix C: SAP Solution Manager BPR Reference Model

The purpose of this section of the dissertation is to analyse and abstract the structure of the content of the SAP Solution Manager Reference Model published as part of the ARIS for SAP NetWeaver product developed by IDS Scheer. The content and the method to apply the SAP Solution Manager Reference model are excluded from this study. The content of this section is based on the article by Scholz and Volmering (2004) and material from the following two product sets:

- The IDS Scheer AG product ARIS for SAPNetWeaver Copyright © 2004(IDS SCHEER AG, 2004).
- The SAP AG product SAP Solution Manager Copyright © 2004 (SAP AG, 2004).

Appendix C will reflect the following components of the SAP Solution Manager BPR reference model:

- Content.
- Structure.
- Documentation notation.

SAP Solution Manager Reference Model Content

Reference material is available for both the Process Configuration Model and the Process Execution Model. The scope of this special topic report is limited to the Process Configuration Model. Reference models are available for at least the following scenarios (the list is extended continuously):

- Customer Relationship Management.
- Supplier Relationship Management.
- Supply-chain Management.
- Human Resources.

Reference models are also available for the following business processes:

- Accounting.
- Business Intelligence.
- Cross Applications.
- Customer Relationship Management.
- Human Resources.
- Inventory Management.

- Production.
- Production Planning.
- Purchasing.
- Retail.
- Sales and Distribution.
- Service Management.
- Supplier Relationship Management.

The content of the SAP Solution Manager BPR repository model is a technical oriented view to the business process and it is presented in a swim lane diagram. The application systems are presented at the top of the columns. The process components are positioned within the columns and it is consequently possible to view the business process model running across the different applications.

SAP Solution Manager BPR Reference Model Structure

The content of the SAP Solution Manager BPR reference models (Figure C.1) is:

Business Scenarios decomposed into –

- Business Processes decomposed into
 - Process Steps decomposed into
 - Transactions.

SAP Solution Manager BPR Reference Model Documentation Notation

The content of the SAP Solution Manager BPR Reference models is available in the SAP Solution Manager and the ARIS Business Process Management Tool. It is possible to synchronise the content of the models between the different tools. Within ARIS, it is possible to map the technical view to the business process view. Within the SAP Solution Manager, it is possible to navigate from the technical view to the configuration of the system. Within the ARIS Business Process Management tool, two model types (refer to Figure C.2) are used to present the content, namely

- eEPC (Column Display – extended Event Process Chain) on the left-hand side. The SAP Components and the Process Steps are included as part of the model.
- FAD (Functional Allocation Diagram) on the right-hand side. The Process Step and the Transactions enabling the Process Steps are included on this model.

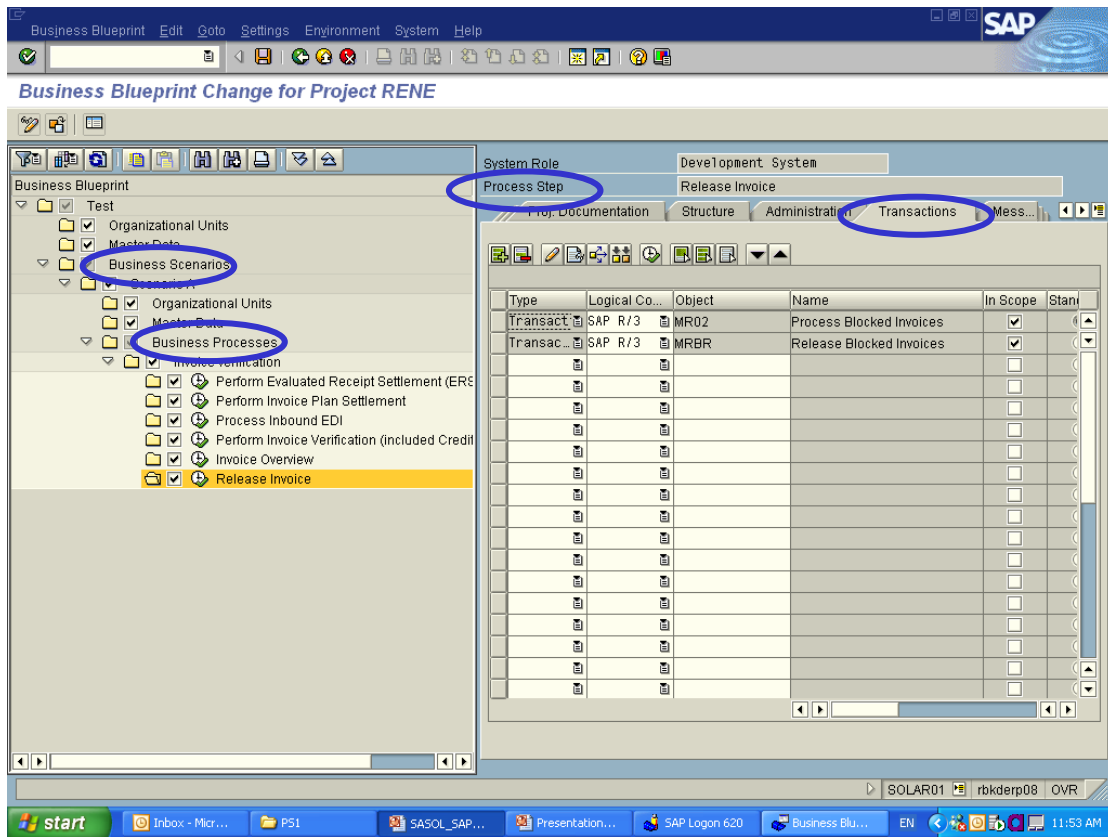


Figure C.1: SAP Solution Manager BPR structure © Copyright 2004 SAP AG

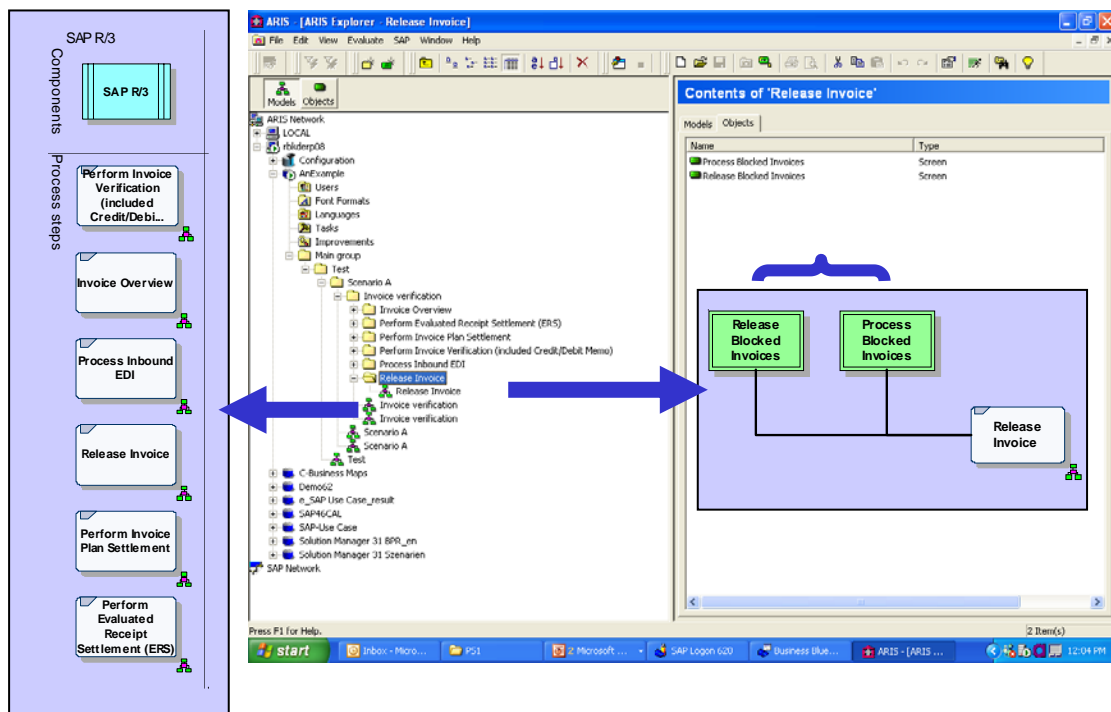


Figure C.2: Event Process Chain and Function Allocation Diagram IDS Scheer AG Copyright © 1997-2002

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