# The Impact of Conceptual Structures on Transaction and Enterprise Architecture Practices

Richard Lindsay Fallon

A thesis submitted in partial fulfilment of the requirements of

Sheffield Hallam University

for the degree of Doctor of Philosophy

May 2021

# Candidate Declaration

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.
2. None of the material contained in the thesis has been used in any other submission for an academic award.
3. I am aware of and understand the University's policy on plagiarism and certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.
4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy.
5. The word count of the thesis is 40,000.

| | |
|---|---|
| Name | Richard Lindsay Fallon |
| Date | May 2021 |
| Award | PhD |
| Faculty | Department of Computing |
| Director of Studies | Dr Simon Polovina |

# Abstract

This research hypothesises is Conceptual Structures using the Resource Event Agent (REA) ontology adds value when defining a Transaction Oriented Architecture (TOA) for Enterprise Systems.

Enterprise Systems drive global economic growth through well-designed implementations that provide organisations with multiple benefits, including streamlined business processes, increased efficiencies, improved productivity and decreased costs. Conversely, poorly implemented Enterprise Systems can lead to poor operating results. Most Enterprise Systems still use traditional methods of storing economic data mirroring the double-entry bookkeeping system, which can cause several problems, including data loss and repetition. Enterprise Systems must capture transaction data in a format available to multiple business processes to fulfil their goals.

This thesis provides an overview of the currently available frameworks for Enterprise Architecture design. It details the problems that are observed and experienced during the completion of real-world Enterprise System development projects. The basis of the Transaction Concept is then presented as the general solution, leading to a TOA for Enterprise Systems. The Transaction Pyramid describes TOA through three layers of transactions: Enterprise, Business, and Database.

The Design Science Research Methodology (DSRM) is used as the primary research methodology to provide a framework to this research. Together with the secondary research method of Action Research to provide a more granular basis for DSRM Step 3 : "Design and development", which required multiple minor iterations of the cyclical process of Action Research to produce the required artefacts. The case study approach is used also as a secondary research method for empirical inquiry and investigation required for DSRM step 4: "Demonstration".

A Knowledge Management System is defined to validate TOA, and artefacts are implemented for an Automated REA (AREA) based on Protégé Frames to underpin TOA as a Proof of Concept. AREA provides a fully-fledged, TOA design tool for Enterprise Architecture using the REA ontology. AREA's Knowledge Repository uses Conceptual Structures through a) the ISO Common Logic standard's Conceptual Graph Interchange Format (CGIF) to store and transmit the TOA using an REA ontology, and b) Formal Concept Analysis (FCA) for validation. AREA is then demonstrated and evaluated using two industrial case studies as exemplars. These findings support the research's hypothesis and its contribution to knowledge.

# Preface

Having worked within the IT industry since 1987 in different sectors (Product Development, Research, Manufacturing, Banking and Consumables) working in different roles (hardware developer, software developer, project manager, consultant) like others in the industry, I have always been aware of inadequacies of the current solutions for analysing, defining and developing software systems.

Since 2008 my work has been primarily in the design and implementation of Enterprise Systems (ES) solutions, specifically using SAP software.

Through my Master of Science studies in Technical Consulting at Sheffield Hallam University I completed my first research looking at the REA Ontology.

Thus my motivation for this research comes from the idea of bringing these two fields together that of the practical industry experience and academic research, to take a fresh look at the observation that although there are already ES software tools which aid the user in design and implementation of ES, these solutions have their limitations.

Using the idea that the design and development process for ES could be enhanced and improved using the REA ontology by capturing the collective exchange of transactions within Enterprise Architecture (EA).

Several authors have previously completed research into this area and the aim is to advance this work further, from a pragmatic viewpoint by finding out "what is available?", "what works?" and "how can it be improved?". In pursuit of the above, I conducted this doctoral research project of which this thesis is a product.

# Acknowledgements

I can not thank enough my Director Of Studies: Dr. Simon Polovina, without his constant insights, support and cajoling, this thesis would never have seen the "light of day".

I would like to also thank Dr. Jacob Habgood for helping to define a clear research strategy and Dr. Babak Khazaei for his assistance in completing this thesis.

I would also like to express my thanks to the following people for assisting in this work and providing information and insights when required: Prof. Mark von Rosing at the LEADing practice, Johnathon Carter at the Essential Project, John F. Sowa and Harry Delugach at the University of Alabama.

Further thanks must go to people who have through their kindness and patience lead down the path to this work.

My parents David and Dorothy Fallon, who had the foresight to invest in a BBC computer, back in the day when this system was on the leading edge of technology.

John Tindle, Emeritus Professor Telecom Engineering at University of Sunderland who guided my final year project of my degree in Bachelor of Engineering in Digital Systems, which then led onto many other projects including this one.

This work was conducted using the Protégé resource, which is supported by grant GM10331601 from the National Institute of General Medical Sciences of the United States National Institutes of Health (*Protege Wiki*, 2021).

And finally of course my wife Margot, who has always provided support whenever it was required.

# Dedication

This work is dedicated to my children Lukas and Mia Fallon.

# Contents

# List of Figures

# Glossary

**ADM** Architecture Development Method. 44

**AI** Artificial Inteligence. 78

**AR** Action Research. 7, 83–85, 93, 168, 190, 216, 217

**AREA** Automated Resource Event Agent. 2–4, 9–11, 33, 50, 94, 107, 119, 144, 189, 190

**ATM** Automated Teller Machine. 141, 143

**BPMN** Business Process Modelling Notations. 59

**CG** Conceptual Graph. 3, 7, 10, 27, 33, 40, 45, 56, 65, 147, 188, 192

**CGIF** Conceptual Graph Interchange Format. 7, 9, 57, 77, 81, 195, 210, 211, 240–245, 248

**CL** Common Logic. 7, 9, 57, 74, 195

**CRM** Customer Relationship Management. 5

**CWA** Closed World Assumption. 7, 9, 45, 58, 64, 99, 116

**DS** Design Science. 88

**DSL** Domain-Specific Language. 52, 53

**DSRM** Design Science Research Methodology. 4, 10, 11, 26, 45, 88, 107, 190

**E2AF** Extended Enterprise Architecture Framework. 13

**EA** Enterprise Architecture. 4, 7, 9, 10, 12, 13, 16, 17, 21, 26, 27, 33, 34, 39, 44, 45, 81, 95, 184, 189

**EAF** Enterprise Architecture Frameworks. 6, 10, 12, 13, 16, 20, 24

**EAM** Enterprise Architecture Modelling. 59, 66

**ERP** Enterprise Resource Planning. 1–5, 37

**ES** Enterprise Systems. 1, 3–5, 12, 26, 36, 39, 49, 51, 189

**FCA** Formal Concept Analysis. 10, 27, 43, 78, 113

**FCL** Formal Concept Lattice. 79

**GERAM** Generalised Enterprise Reference Architecture and Methodology. 13

**HCM** Human Capital Management. 5, 149

**HR** Human Resources. 149

**IS** Information Systems. 1, 37, 87, 193

**ISO** International Standards Organisation. 7, 9, 36, 74, 142, 195

**IT** Information Technology. 12

**JESS** Java Expert System Shell. 114

**KB** Knowledge Base. 58, 61, 63–65

**KMS** Knowledge Management System. 2–4, 7, 9–11, 26, 27, 33, 39, 40, 42–45, 59, 81, 93–95, 106, 107, 119, 144, 189, 190

**KR** Knowledge Repository. 7, 9, 21, 39, 41, 44, 48, 60, 75, 93, 98

**LTA** Learning Teaching and Assessment. 168, 174

**MA** Model Automatisation. 183

**MDA** Model Driven Architecture. 22, 53

**MOF** Meta Object Facility. 23

**MV** Model Visualisation. 183, 241–245, 248

**MVCC** Multi Version Concurrency Control. 6

**OMG** Object Management Group. 22, 53

**OO** Object Oriented. 3

**OWA** Open World Assumption. 7, 58, 64, 66

**OWL** Web Ontology Language. 55, 60, 66

**POC** Proof of Concept. 2, 7, 11, 50, 154, 167, 189

**POS** Point Of Sale. 141, 143

**RDF** Resource Description Framework. 54, 56, 80, 210, 211

**RDFS** Resource Description Framework Schema. 65

**REA** Resource Event Agent. 2–5, 7, 26, 45, 188, 192

**RFID** Radio Frequency IDentification. 31

**RMW** Requirements Management Wheel. 9, 45, 50, 114, 192

**SOA** Service Orientated Architecture. 5

**SP** Dr Simon Polovina. 96

**SQL** Structured Query Language. 6, 58

**SRM** Supplier Relationship Management. 5

**TC** Transaction Concept. 10, 26, 34, 117

**TM** Transaction Model. 33, 144

**TOA** Transaction Orientated Architecture. 2–4, 7, 9, 11, 26, 33, 34, 37, 40, 42, 43, 45, 78, 81, 93, 95, 119, 184, 191

**TOGAF** The Open Group Archietecture Framework. 3, 13–15, 21, 39

**TP** The Transaction Pyramid. 35

**TrAM** Transaction Agent Modelling. 43

**UML** Unified Modelling Language. 3, 22, 23

**XML** Xtensible Markup Language. 54, 80

**ZEF** Zachman Enterprise Framework. 18, 23

# List of Tables

# Chapter 1

# Introduction and Motivation for Research

**Design Science Research Methodology (DSRM) Step 1 - Problem identification and motivation.** Define the specific research problem and justify the value of a solution. Since the problem definition will be used to develop an artefact that can effectively provide a solution, it may be useful to atomize the problem conceptually so that the solution can capture its complexity.

## 1.1 Introduction

This chapter introduces the motivation behind the research and identifies the research hypothesis. Existing current solutions are briefly detailed followed by the aims of this research. Prior work and contributions are presented followed by an overview of this thesis.

## 1.2 Motivation

Enterprise Resource Planning (ERP) systems which are enterprise-wide, integrated Enterprise Systems (ES), assist organisations in managing and coordinating all aspects of the resources, information, and functions of a business using data stored within a shared Enterprise Database. To benefit from these central integrated Information

Systems (IS), organizations have spent billions of dollars on the implementation of ERP systems, whereby the objective has been to focus primarily on improving transaction handling through the standardization of business processes and integration of operations and data (Holsapple and Sena, 2005). SAP is one of the prevalent ERP system vendors and it is understood that 65-70% of the world's transactions involve SAP systems Forbes (LLC, 2011) quoted by Polovina (2013).

The main motivation for this work comes from the personal observation that although there are already software tools available which aid the user in design and implementation of ERP implementations, these solutions have their limitations. Primarily none of these tools provide what could be called a Transaction Orientated Architecture (TOA) perspective or view on ERP data. This lead to the idea that the design and development process for ERP business processes could be enhanced and improved using an Resource Event Agent (REA) ontology to capture the collective exchange of transactions.

Early research (Fallon and Polovina, 2013) which has gained traction in the EA academic community provided the basis of what could be called a Proof of Concept (POC) for the usage of REA ontology to capture business progresses within the (defacto) industry standard (SAP) ERP system architecture and a clear justification for using TOA for modelling ERP.

Further motivation comes from other authors such as Dunn et al. (2016) who have called for further research to be undertaken by encouraging "advancement along two fronts. First, we encourage researchers to use new technological advances and other research areas to further develop and expand the capabilities of REA . Second, we encourage researchers to use REA design theory to enhance and further develop other research areas".

Parts of this research have been already published (Fallon and Polovina, 2016) and detail advancements, by defining and demonstrating the Automated Resource Event Agent (AREA) Knowledge Management System (KMS), tool-set which is presented in this thesis. Briefly, the AREA KMS allows the enterprise expert to follow the design principles of The Open Group Archietecture Framework (TOGAF) and define B: Business Architecture, C: Information System Architecture and D: Technology Architecture using TOA, using Conceptual Graph (CGs), the REA ontology, and subsequently defining an SQL Enterprise Domain Database from within a unified KMS using TOA design principles.

Early personal experience was gained in the mid-90's using early versions of the Rational-Rose Unified Modelling Language (UML) tool to develop ES to process financial transactions to authorise card payments, using C++ and an Object Oriented (OO) design. This move towards OO design provided a paradigm change and a move away from the traditional thinking of functional implementation of software systems.

This experience proved useful, showing how difficult it can be to both capture business knowledge and also to incorporate this information within the completed software system. Round-trip engineering proved to be even more problematic, since although an implemented feature within Rational-Rose, due to the extra effort required, often the result was that the OO designs were rarely updated. Therefore the OO designs became either less useful or, worse still, obsolete.

Thus the motivation for this research is to bring together the practical application gained within 30+ years of industry experience with the theoretical knowledge collected from previous academic work (Fallon, 2012) to answer the call from other researchers to advance the design theory for designing and developing ES.

## 1.3 Hypothesis

The hypothesis of this research is Conceptual Structures using the REA ontology adds value when defining a Transaction Oriented Architecture (TOA) within Enterprise Systems (ES).

The importance of ERP systems in driving global economic growth is undisputed, ERP systems provide organisations with multiple benefits including increased efficiencies, improved productivity, decreased costs and streamlined business processes. To follow these goals ERP systems must capture data in a transaction structure so that the information is available to each individual business process. Most ERP systems still use traditional methods of storing economic and other transaction data, mirroring the double entry book keeping system used by accountants. This is detrimental to ERP solutions since the complex transactional information transfers stored in the enterprise database using traditional (double-entry) methods can cause several problems including data repetition and loss of data (Fallon and Polovina, 2013). ERP systems must complete a multitude of repetitive and bespoke business transactions to fulfil the organisations goals. Several authors have shown previously, that storing the transactions using what could be called a TOA based on the REA ontology offers a theoretical solution to these problems and can be useful in capturing the semantics of ERP systems (Polovina, 2013; Launders, 2011; Fallon and Polovina, 2013).

Thus the aim of this thesis is to advance this work further using a pragmatic viewpoint of TOA, by finding out "what is available?", "what works?" and "how can it be improved?". Thus bridging the gap between Enterprise Architecture (EA) theory and practice by demonstrating how TOA can be used to improve the processing and understanding of transactions processed by ES.

Using the Design Science Research Methodology (DSRM) to provide a regimented framework, artefacts are identified and developed which fulfil the goal of providing the AREA KMS, which allow for the capture and development of transactions using TOA.

## 1.4 Current Solutions

Over the last years enterprises have all moved to using ES to store the details of their economic transactions. To enable these organisations to process these sometimes complex economic transactions, EA has been developed which is commonly built along the lines of large “functional silos”. Some examples of these silos are; ERP, Customer Relationship Management (CRM), Supplier Relationship Management (SRM) and other solutions. Each solution or silo covers a specific range of business processes from a specific business perspective (Customer, Supplier etc..). Additional to these silo’s, software vendors also offer specific industries solutions (the so-called “verticals” applications) such as Oil and Gas, Banking, Consumer products etc. One of, if not arguably the leading enterprise software provider SAP has clearly shown the importance of enterprise software, “76% of the world’s transaction revenue touches an SAP system and SAP touches $16 trillion of consumer purchases around the world” (Fox-Martin, 2016).

SAP’s enterprise solutions are partially based on a Service Orientated Architecture (SOA) where a differentiation is made between generated Web and enterprise services. SOA attempts to recognise the limitations of existing enterprise applications that have been built along the lines of the large functional silos detailed above. The use of an SOA interface enables an operational architecture which makes component based software development realistic for ES through presenting a set of Service interfaces. SOA development distinguishes from object-orientation in that each component is centred on providing a service based on a composite element of business semantics. SOA adds value to the enterprise application, meaning that the technical nature of each component is encapsulated by its business meaning (Polovina, 2013).

We have however shown that relying on the schematics used in traditional relational database management systems, the enterprise data can often miss the recognition of the semantic meaning (Fallon and Polovina, 2013). Whereby using the concept of a database made up from REA as introduced by McCarthy (1982) can provide a semantic view of business transactions and be used successfully for modelling SAP business processes (e.g. Human Capital Management (HCM)). Further we have shown that through non-compliance with the REA ontology, how data can be lost or stored again (repeated) within the SAP (relational) database. This leads to the confirmation of one McCarthy's original theories that led to the REA ontology, since he identified that using conventional data storage techniques (such as double entry), would lead to inconsistency of data, information gaps and overlaps in data or data spread (Fallon and Polovina, 2013).

SAP is currently in the process of moving away from the previously used relational database management architecture (using 3rd party database solutions, Oracle, Microsoft Structured Query Language (SQL) Server etc.) to a new database management system developed and marketed internally by SAP as SAP HANA which is an in-memory, column-oriented, relational database. SAP HANA manages concurrency through the use of Multi Version Concurrency Control (MVCC), which gives each transaction a snapshot of the database at a point in time, thus when transactional data is updated the old data is not over written with new data, but instead the old data is marked as obsolete and the newer version is added (Lee et al., 2013). Although improvements have been made, the new SAP HANA database has inherited also the old disadvantages of the previous relational database scheme, in that data can be lost or more often repeated within the database. In Chapter 2 the existing Enterprise Architecture Frameworks (EAF) environment and current solutions are described in more detail.

## 1.5 Research Objectives

Using the Pyramid Principle introduced by Minto (1987), to structure a top down thought process by looking at the three basic Sections of the pyramidal structure shown in Figure 1.1, by framing what is known, summarizing logical reasons for action, and ordering the arguments through answering the questions of "what", "why", and then "how" when looking at the research objective of "Conceptual Structures using the REA ontology adds value when defining a Transaction Oriented Architecture (TOA) within Enterprise Systems (ES)".

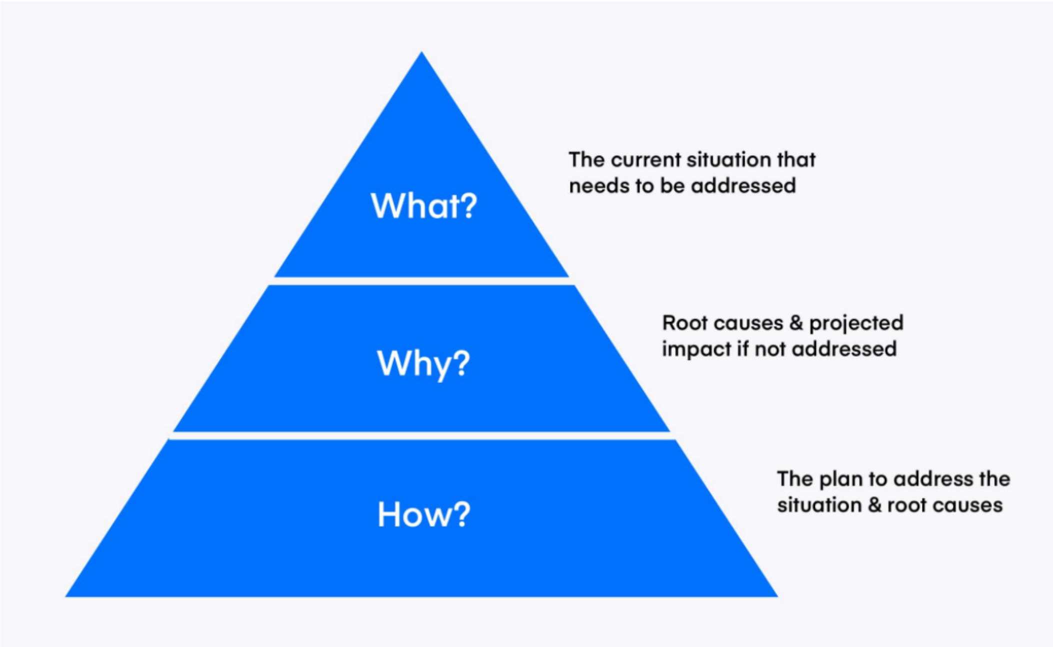


Figure 1.1: The Minto Pyramid (Minto, 1987)

This research uses the pyramid principles of What?, Why? and How? to identify the key factors which provide a solution and fulfil the objectives of this research presented below:

1. How can REA/TOA ontology design be improved?

2. What is the best-practice for storing CGs in a KR?

3. Which Knowledge Repository (KR) structure: Closed World Assumption (CWA) or Open World Assumption (OWA) would provide best-practice for supporting a TOA EA?

4. How can the International Standards Organisation (ISO) Common Logic (CL) Conceptual Graph Interchange Format (CGIF) standard be used to support type hierarchies?

5. Through a process of Action Research (AR) produce a POC for an KMS TOA tool based solution, using currently available open source software together with

artefacts developed to specifically solve the problems which are encountered and identified.

## 1.6 Ethics

Whilst completing this thesis ethics were primarily considered for the students partaking in the modules and for using the designs which they produced within this research. This research followed the guidelines in accordance with Sheffield Hallam University's research ethics policy. Each student was presented with the statement contained in Appendix E for subsequent approval. Explicit permission was granted to use the students designs and models and the students were informed that their work was being used for this research both during lectures and in feedback as part of the module review process.

## 1.7 Prior Work

Elements of this thesis have been previously published as follows:

### 1.7.1 Conference papers

- Fallon, R. L. and Polovina, S. (2013), REA analysis of SAP HCM; some initial findings, in "Proceedings of the 3rd CUBIST (Combining and Uniting Business Intelligence with Semantic Technologies) Workshop co-located with the 11th International Conference on Formal Concept Analysis", CEUR-WS.org.
- Fallon, R. L. and Polovina, S. (2016), Automated REA (AREA): a software toolset for a machine-readable Resource-Event-Agent (REA) ontology specification, in "CEUR Workshop Proceedings", Vol. 1637, Tilburg University, pp. 10

### 1.7.2 Book Chapters

- Scheruhn, H., von Rosing, M. and Fallon, R. L. (2015), Information Modelling and Process Modelling, Vol. 1, Elsevier, pp. 511–550.

- von Rosing, M. & Fallon, R.L. (2015). Business process trends. In The complete business process handbook. (pp. 187-216). Elsevier: http://doi.org/10.1016/B978-0-12-799959-3.00011-2

## 1.8 Contributions

In summary, the primary contributions of this research to the body of knowledge are detailed below:

- *Use of the Transaction Pyramid (TP) detailed in Figure 3.5 which presents the three tiers of transactions which constitute a Transaction Oriented Architecture (TOA):*

- *Use of the Requirements Management Wheel (RMW) shown in Figure 3.9 to define an Enterprise Architecture based on a Transaction Oriented Architecture (TOA) and using Conceptual Graphs:*

- *Use of the ISO CL CGIF standard, for representing a EA based on a TOA:*

- *Use of a CWA KR solution for supporting a TOA EA:*

- *Use of the ISO CL CGIF standard to support type hierarchies in a TOA EA:*

- **AREA, KMS** artefact developed as a fully fledged EA modelling tool based on Protégé, providing evidence that using the Requirements Management Wheel (RMW), aids TOA design for an EA

- **CGImport** artefact developed for AREA KMS (Fallon, 2015*c*)

- **CGImport** artefact developed for AREA KMS (Fallon, 2015*b*)
- **FCATab** artefact integrated into AREA KMS(Jiang, 2016)
- **JESS** artefact integrated into AREA KMS (Eriksson, 2003)
- **3to2** artefact developed, as a stand alone CG to Formal Concept Analysis (FCA) utility (Fallon, 2015*a*)

## 1.9 Overview of this Thesis

The structure of this thesis follows DSRM which is detailed in Chapter 6. At the beginning of each chapter, where appropriate a box highlights which of the 6 steps of the DSRM framework is subsequently addressed in the enclosing chapter, for example this chapter details "DSRM Step 1 - problem identification and motivation".

The thesis is structured as follows:

Chapter 2 introduces the existing environment by looking at currently available **EAFs** through a literature review.

Chapter 3 defines the **Basis of the Transaction Concept (TC)** and looks at the objectives for a possible solution. Through focusing on the basis of what is required to define a TC a qualitative description of the required artefacts is developed.

Chapter 4 explores how **Semantics and Ontology in Enterprise Architecture** are used currently in EA and how they can also provide the basis for a solution for an EA modelling tool.

Chapter 5 looks at the theoretical foundations of **Conceptual Structures in Enterprise Architecture** providing details of how Conceptual Structures can be used to aid EA. First-order logic and CGs are introduced together with possible solutions for the notation of Conceptual Structures.

Chapter 6 presents the **Research Methodology** which underpins the research work completed for this thesis. Detailing the the research methodologies which were considered and explains why DSRM was chosen.

Chapter 7 details how and why each of the artefacts were defined and constructed. The focus being on bringing all of the previous chapters together in a POC through detailing the **Implementation** of the AREA KMS.

Chapter 8 **Demonstrates** the usage of the AREA KMS through case studies and student assignments providing evidence of how the AREA KMS fulfils the design goals.

Chapter 9 provides the results of an **Evaluation** of the artefacts of the AREA KMS, detailing observations and measurements of how the artefacts of the AREA KMS support a solution to the problem of modelling transactions in a TOA.

Chapter 10 provides the **Conclusions**, detailing possible further work and presenting the final communication of this thesis.

# Chapter 2

# Enterprise Architecture Frameworks (EAFs)

## 2.1 Introduction

EAFs provide organisations with a tool to manage Information Technology (IT) infrastructure by assisting in the design of ES. An enterprise can be defined as any collection of organisations which have common goals, for example a whole corporation or a division of a corporation, or partnerships and alliances of businesses working together, such as a consortium or supply chain. The goal of an organisations IT infrastructure is to support the fulfilment of the organisation's business strategy, which includes information, process and technology domains. A well structured EA allows the organisation to develop a framework for conducting enterprise analysis, design, planning and implementation by providing architecture techniques and a set of principles and practices to provide a standard method to manage the change (*TOGAF, Ver. 9.2*, 2020).

EA must provide a pragmatic view whilst at the same time highlighting the central role of the enterprise. To enable architectural transformation close collaboration is required between the different stakeholders involved in the enterprise architecture requiring governance, stakeholder management and an architecture-dedicated implementation team (Desfray and Raymond, 2014).

A well designed EA enables an enterprise to achieve the right balance between business transformation and continuous operational efficiency which will subsequently allow individual business units to innovate safely in their pursuit of evolving business goals and gain competitive advantage (*TOGAF, Ver. 9.2*, 2020).

Through completing a literature review this chapter details first the existing environment of EA frameworks, providing an introduction to the key areas of enterprise modelling. This chapter then concludes through highlighting some of the limitations of current EA frameworks and as a consequence the state of the problem is determined.

## 2.2 The Existing Environment

There are many EAFs available however this Chapter will only analyse or inspect those which are leading the way or which are of specific importance. Each EA framework will be presented briefly, detailed together with the known key advantages and limitations.

The EA frameworks which are reviewed in this Section below were chosen firstly for there coverage and usage and secondly for their relevance to an industrial environment. There are of course other popular EA frameworks, such as; Extended Enterprise Architecture Framework (E2AF), and the Generalised Enterprise Reference Architecture and Methodology (GERAM), but to cover all EA frameworks would go beyond the scope of this thesis.

### 2.2.1 TOGAF

The TOGAF standard presents an EA framework which "provides the methods and tools for assisting in the acceptance, production, use, and maintenance of an Enterprise Architecture and is based on an iterative process model supported by best practices and a re-usable set of existing architecture assets".

TOGAF is developed and maintained by members of The Open Group, working within The Open Group Architecture Forum. Successive versions of the TOGAF standard have been developed, the aim of which is to provide a definition of EA, which is consistent, reflects the needs of stakeholders, employs best practice, and gives due consideration both to current requirements and the perceived future needs of the business. The structure of TOGAF Capability Framework is shown below in Figure 2.1 (*TOGAF, Ver. 9.2*, 2020).

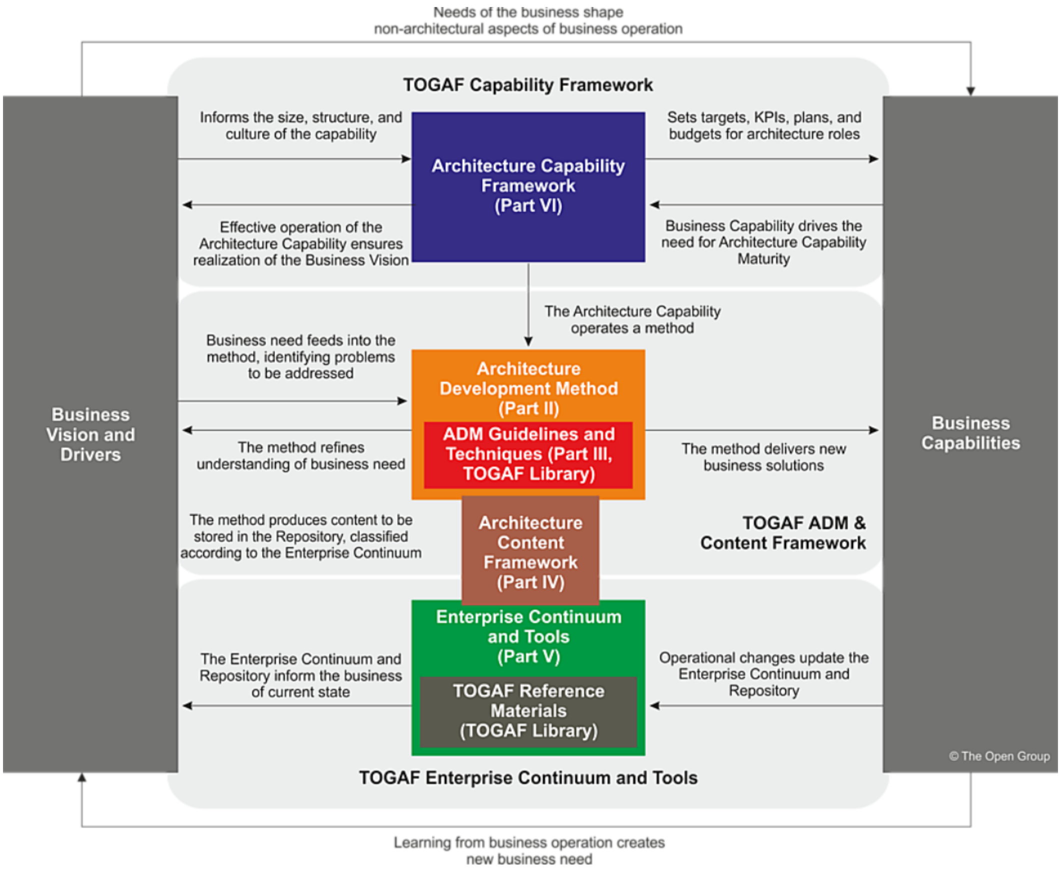


Figure 2.1: TOGAF Capability Framework (*TOGAF, Ver. 9.2*, 2020)

There are three key architecture phases which TOGAF defines as part of the Requirements Management, which is defined as a continuous process which ensures that any changes to requirements are handled through appropriate governance processes and reflected in all other phases when defining the Enterprise Architecture:

- **B: Business Architecture**: defines the business strategy, governance, organization, and key business processes

- **C: Information Systems Architecture**: describes the structure of an organization's logical and physical data assets and data management resources
- **D: Technology Architecture**: describes the logical software and hardware capabilities that are required to support the deployment of business, data, and application services; this includes IT infrastructure, middleware, networks, communications, processing, standards, etc.

The core of the TOGAF framework is a multi-phase, iterative approach to develop, shape and govern business transformation and implementation projects as shown below in Figure 2.2.

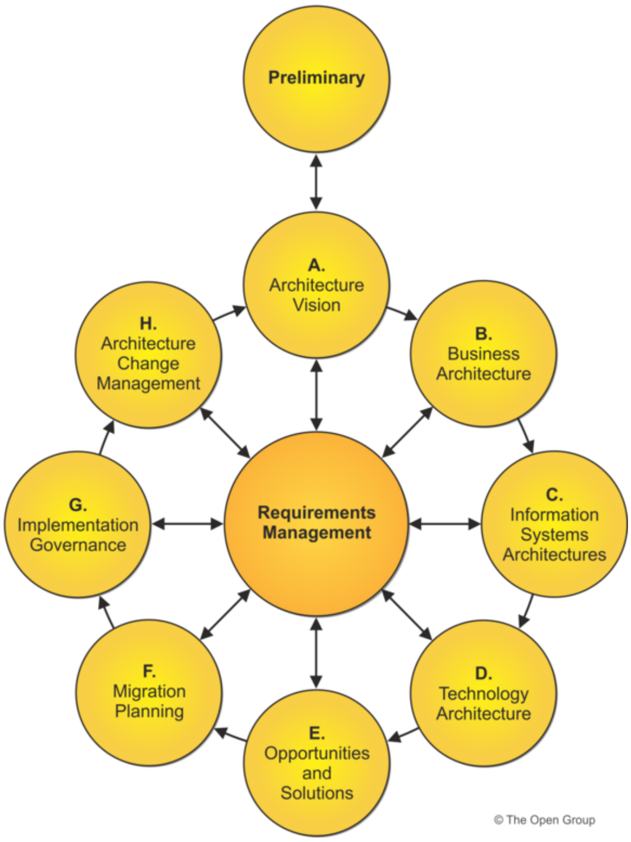


Figure 2.2: TOGAF Architecture Development Cycle (*TOGAF, Ver. 9.2*, 2020)

TOGAF has been developed through the collaborative efforts of a large community of organisations; SAP, Phillips, INTEL, IBM to name only a few and has also proved useful in modelling BPM (von Rosing et al., 2015). However TOGAF also has its critics with some stating that it distracts attention in the EA community away from real EA-related questions, to simply discussing the present TOGAF standards. Meaning that instead of advancing EA education, organisations are led towards TOGAF certification. Rather than asking questions, for instance "What works?" and "What does not work?", many EA practitioners end up wondering "How should TOGAF be properly applied?", "What are the advantages of TOGAF?" or "What is better, TOGAF or Zachman?". The academic EA community tends also to be focused on TOGAF, however this dependence on TOGAF will not lead to a greater understanding of EA, but instead lead to a gap between EA theory and practice. Often new enterprises looking at implementing an EA would ask the question "Can TOGAF be interpreted literally and followed step-by-step to practice EA?", but is often answered with "No, TOGAF is only a framework, it should be modified (somehow) for specific organizations". This of course leads to the conclusion that although it would appear that EA practice is well defined using TOGAF, the opposite conclusion could be made. Since no-one can specify exactly how TOGAF should be used, would imply that we (the EA community) still do not know enough (Kotusev, 2016).

### 2.2.2 SAP Enterprise Architecture Framework (EAF)

SAP EAF and TOGAF can be considered as complimentary to one another since SAP EAF was initially developed through building upon the foundation of TOGAF 8.1 and at the same time added several extensions. During the development of TOGAF 9.0 SAP joined The Open Group thus the contents of TOGAF 9.0 were "enriched by drawing upon notable to significant contributions from SAP" which were subsequently included in TOGAF 9.0. The relationship between the two frameworks TOGAF and SAP EAF can be described as follows: "TOGAF 8.1 served as the foundational source for SAP EAF and subsequently SAP EAF served as one of the key sources for TOGAF

9.0 content" this relationship can be seen below in Figure 2.3 (Rajagopalan, 2010).

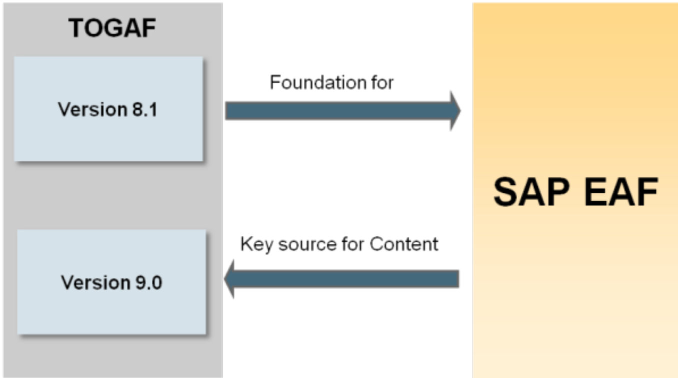


Figure 2.3: TOGAF's relationship to SAP EAF (Rajagopalan, 2010)

Using the SAP EAF based on TOGAF as a structured methodology, SAP has enabled actionable roadmaps, which provide a plan for a successful implementation of EA which is based on the business strategies of SAP customer's. Through this partnership both SAP and the Open Group have mutually benefited (Rajagopalan, 2010).

### 2.2.3 Zachman Enterprise Framework (ZEF)

One of the earliest and most comprehensive EA frameworks was developed by John Zachman, a world-renowned authority in the field. (Zachman, 2008) described the discipline of EA as key to containing enterprise frustration and leveraging technology innovations, thus fulfilling the expectations of enterprises in the information age. Zachman argues that there is a need to define "engineering descriptions" of the architectural components of an enterprise to enable a sound basis for launching change initiatives, he also recognised the problem of how such mechanistic views of the enterprise could underplay the human factors and the reliance on old database structures. Whilst in contrast the use of conceptual structures would provide the influence to change cultural norms, social dynamics and personal agendas on the shape and direction of an enterprise (Mayall and Carter, 2015).

The Zachman Enterprise Framework (ZEF) was originally developed by John Zachman and extended to its current scope together with John Sowa. The aim of the framework shown below in Figure 2.4 is to guide organizations away from the widespread practice of viewing the enterprise through static and disconnected models (Magoulas et al., 2012).

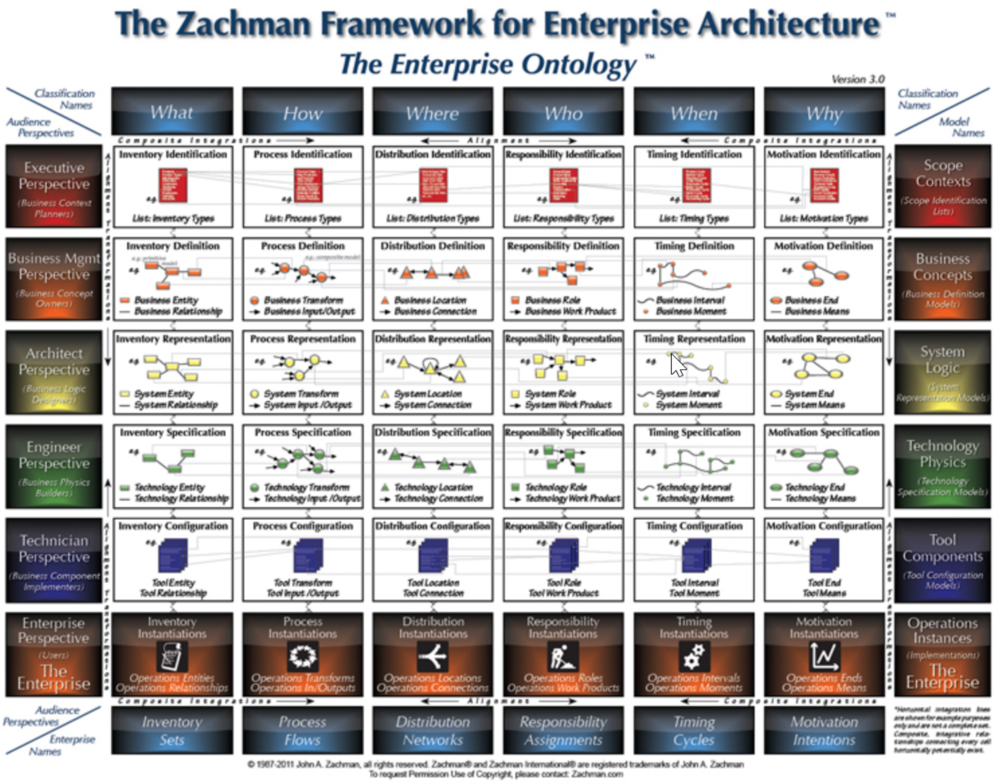


Figure 2.4: The Zachman Framework for Enterprise Architecture (Zachman, 2008)

ZEF provides a structure for helping an enterprise organize and classify the detailed representation of the internal structures, which depict in a visual way the interaction between the stakeholders or agents of the process. ZEF builds the enterprise model, through defining the owner, designer and builder of each process, the setting of the component, the way it works, the location where it is situated, the person who is responsible, the team which does the work and crucially why it matters.

ZEF defines further the EA by defining six main questions: (1) **what** – data needs to be understood and worked with, (2) **how** - function or how the process of changing the aim of the enterprise into a more detailed description of its operations, (3) **where** - network or where the business activities are taking place or will be distributed in the future, (4) **who** - people who are involved in the business processes and into implementing the new architecture, (5) **when** - time and effects of time on the organization and (6) **why** - motivation and formulating the business goals and strategies (Dumitriu and Popescu, 2020).

### 2.2.4 LEADing Practice

Established in 2004, using the acronym LEAD meaning Layered Enterprise Architecture Development, now the organisation is referred to as the LEADing Practice and is a community which develops Enterprise Standards including Enterprise Modelling and Enterprise Architecture.

LEAD is based on an open source community concept and has been used by many of the Fortune 500 and public organizations. It is also integrated into commercial software solutions such as SAP (ASAP Methodology), IBM Rational, IBM System Architect, iGrafx and Software AG (ARIS). Figure 2.5 shows how the LEADing practice define the Enterprise, Engineering and Modelling Architecture.

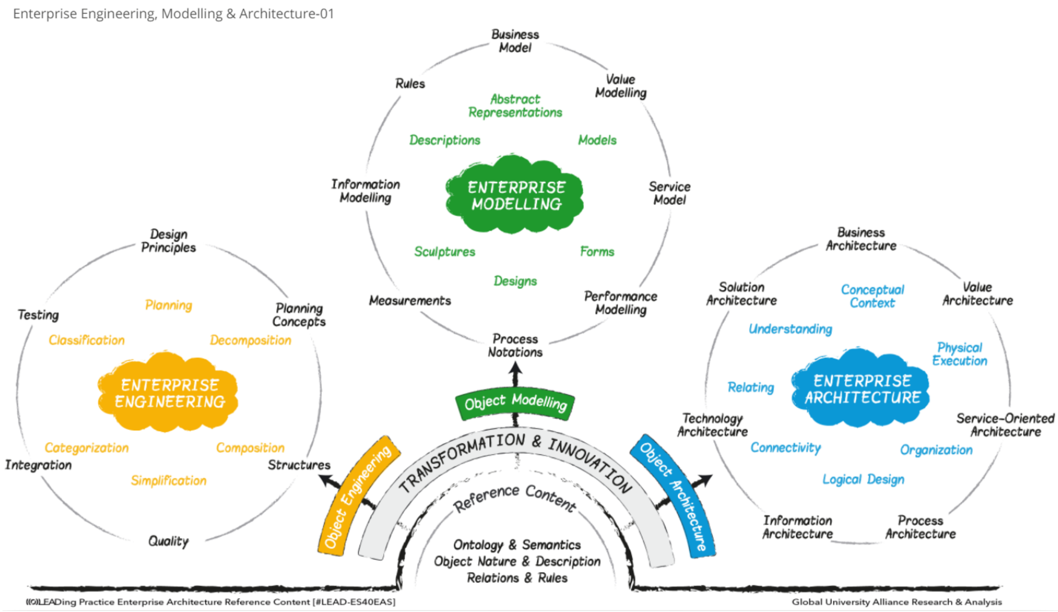


Figure 2.5: Enterprise, Engineering and Modelling Architecture (*LEADing Practice*, 2020)

What makes LEAD different to other EAF, is the fact that it does not only work in domains, but across layers (business, information, and technology) allowing the practitioner to simultaneously work within multiple domains through the use of the decomposition and composition of meta objects, allowing the integration of objects across different layers. Another key feature of LEAD is the inclusion of detailed reference content which connects to many of the major existing EA and other frameworks, methods and approaches, such as TOGAF, Zachman, FEAF, ITIL, Prince2, COBIT and DNEAF. LEAD uses a multitude of reference content which encompasses meta-objects, descriptions, templates and includes the content into Hands-On Modelling rules and tools (Polovina et al., 2014; von Rosing and von Scheel, 2016).

The core of LEAD Enterprise Standards are developed using 4 key pillars:

1. **Researching** and analysing industry best practice and leading practices
2. **Identifying** common and repeatable patterns (the basis of LEAD's standards)
3. **Developing** the Enterprise Standards that increase the level of re-usability and replication

4. **Building** industry accelerators within the standards, enabling the adoption of the best leading practices

### 2.2.5 Essential Project

The Essential Project launched in 2009 by a UK-based EA consulting firm, is the collective name for an open source toolkit designed to support EA activities. This includes an EA meta-model defining the framework and structure of an enterprise and a software product, the Essential Architecture Manager. Essential Project has been deployment by a large number of companies, government agencies and academic institutions across the world. The Essential repository uses a Protégé knowledge base which is a well-established open source ontology KR developed and maintained by Stanford University. Protégé allows relationship between two different (ontological) elements to be easily configured within a knowledge base. The Essential repository uses Protégé Frames (v3.5) for more details on the Protégé frames specification and further details on Protégé, refer to Section 4.3.2.

The Essential meta-model extends a three tier schema concept (Conceptual, Logical and Physical) across the four kinds of "architecture" components which the Open Group claims are commonly accepted as subsets of an overall EA, allowing for all of the elements to be interlinked both vertically and horizontally to establish relationships (Mayall and Carter, 2015). This claim can be justified since these components can be directly related to those of TOGAF's Architecture Development Cycle shown in Figure 2.2: Business Architecture , Data/Information Architecture, Applications Architecture and Technology Architecture.

The Essential Project Meta Model is shown below in Figure 2.6, clearly showing also the four separate layers of Business, Application, Information and Technology seen from TOGAF.

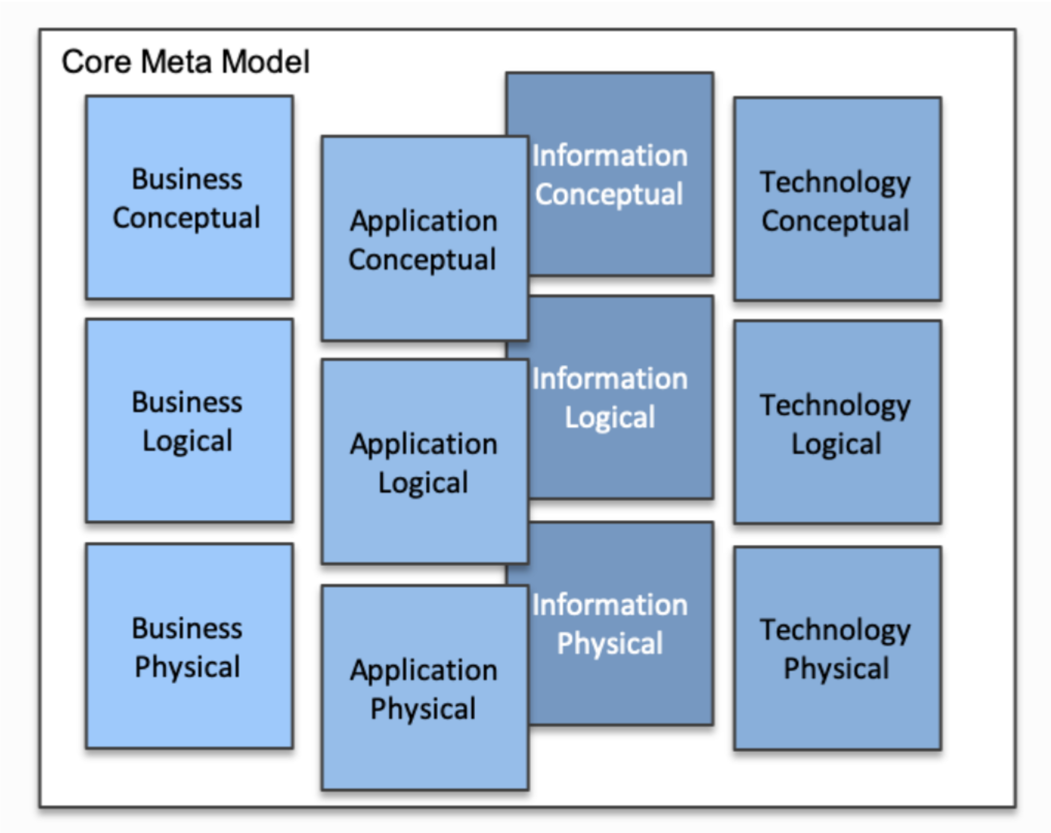


Figure 2.6: Essential Meta Model EssentialProject (2021)

### 2.2.6 Object Management Group (OMG)

The Object Management Group (OMG) is a consortium of organisations (IBM, Boeing, DELL etc.) which develops standards for various aspects of software engineering which are widely used in industry, including UML. Following the movement towards the Semantic Web and the subsequent development of ontology modelling languages like OWL by the World-Wide Web Consortium (W3C), the development of ontologies has become mainstream (Colomb et al., 2006).

Though not specifically an EA framework as defined by for example TOGAF or LEAD, it is important to include the OMG and their definition of a Model Driven Architecture (MDA) approach which represents and supports everything from requirements to business modelling and technology implementations. The primary feature of MDA, is that it allows the practitioner to include the complexity and derive value from models and modelling through defining the structure, semantics, and notations of models using industry standards. The OMG meta-models are developed using the Meta Object Facility (MOF) , which is a subset of the UML class meta-model (*OMG MDA Guide rev. 2.0*, 2014).

## 2.3 Conclusions in Chapter 2

This chapter has provided an overview of current EA frameworks, with the ZEF providing the initial impetuous to the field. TOGAF could now be seen as leading the way, due to the weight of the number and size of the organisations providing support. SAP's EAF is significant firstly through the connection to TOGAF and secondly simply because of the numerous ES installations on SAP's customer sites. LEADing Practice must incur recognition due to the academic support from numerous institutions and practitioners which has brought a fresh input of new ideas and meta-models.

A complete comparison and detailed study of these EA frameworks would be too great for the scope of this thesis. Looking into the literature authors such as Kotusev (2016) have identified scope for improvement with regards current solutions, such that organisations have not been always able to fully translate EA solutions and frameworks to meet organizational needs despite the vast selection of existing EA frameworks. EA can be seen as the process of aligning the business part of a company with information technology where there is an integration of processes between the organizations and people in each organisation, although similar to the management of IT architectures, the EA structure alone is not enough to reach architectural goals in the long term (Dumitriu and Popescu, 2020).

TOGAF provides the definition of an EA as being "The structure of components, their inter-relationships, and the principles and guidelines governing their design and evolution over time", however current EA frameworks and software suites that are available on the market today appear to fall short of fulfilling these demanding requirements

(Mayall and Carter, 2015).

Although each of the EA framework vendors state that they have defined THE model, simply the recognition that there are so many models and EA frameworks available would indicate that some further work is required (Mayall and Carter, 2015). Of course competition leads to advancement and innovation, meaning that EA frameworks will inherently benefit from the direct competition and each framework will of course be validated against other frameworks by both practitioners and academics. One point to note is that whilst each of the EAF frameworks propose a solution to EA. None of them in-fact use an ideology or methodology which would allow the EA design to go from identification of business requirements through the complete design from gap analysis, through to technological implementation and then once complete also allow for iterative round trip engineering, where for example problems seen in the technology architecture can be easily reflected back into the business architecture.

Problems associated with using EA design tools, both observed and experienced during the completion of real world ES development projects are detailed below in Table 2.1. These problems were not encountered with any specific EA framework, more a set of general observations and insights gained through using multiple tools over many years. The table also provides and indication of importance (1-high, 5-low) of each problem, whereby the key problem for EA design tools is to allow the same design to be readable by both humans and machines allowing the design process to be automated where possible.

| Problem | Description | Importance |
|---|---|---|
| 1 | models are completed at the beginning of a project and design tools are not iterative, thus designs are often made and thrown away | 2 |
| 2 | designs do not always allow for multiple layers of abstraction | 3 |
| 3 | parts of the design are often human or machine readable, but often not both | 1 |
| 4 | design process is not automated, or iterative | 2 |
| 5 | database design is not integrated with the business modelling process, leading to separate designs causing interdependencies | 3 |
| 6 | data analysis model verification such as FCA is not usually included automatically | 4 |
| 7 | human effort to maintain models which are not bi-directional is great and often underestimated | 3 |

Table 2.1: Problems associated with ES development

Which leads to the question; Is there a possibility to define/develop a tool which allows an EA to be defined across the three levels of Architecture; B:Business, C:Information Systems, D:Technology shown in TOGAF's Architecture Development Cycle shown in Figure 2.2 and which would address some of the problems identified above in Table 2.1.

# Chapter 3

# Basis of the Transaction Concept (TC)

**DSRM Step 2 - Define the objectives for a solution.** Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible. The objectives can be quantitative, e.g., terms in which a desirable solution would be better than current ones, or qualitative, e.g., a description of how a new artifact is expected to support solutions to problems not hitherto addressed.

## 3.1 Introduction

This chapter first defines why a solution is required and then presents the key concepts required to form the basis of a KMS tool which will provide a solution and capture TOA data flows for an EA using the TC and the REA Ontology.

As previously discussed the goal of ES is to assist an organisation in representing the real-world relationship between the organisation and its operating environment. When correctly implemented, ES can provide an organisation with an advantage over market competitors, conversely when poorly implemented, ES can lead to poor operating results. Thus much effort and resources are currently invested in the development and improvement of enterprise ES solutions. Current understanding of ES is still not fully complete and constantly evolving, as are the requirements of old and new business processes, this can be seen in the continual updating of even the standard off-the-shelf enterprise systems software such as SAP.

The management of data is one of the key fundamental requirements in ES and the process of designing and developing enterprise applications is both a complex and error prone. Even once the user requirements have been defined clearly, they are often incomplete, even contradictory and are known to change over time (Hruby, 2006).

Ontologies can assist the design of new applications through the process of capturing domain knowledge or through the sharing and re-use of existing ontologies. Additionally requirements capture is important since the goals of stakeholders can then be defined, captured and stored which will then provide a faithful high-level representation of the organisations goals. These requirements can be defined manually by the EA practitioner, however the aim would be to automate as many steps as possible which will save both time and also aid the development of a rigorous model (Hill, 2006).

The problem of manually using different tools is noted by Andrews and Polovina (2018), who state that CGs as with other forms of diagraphs are still often drawn by hand. There are tools available such as CoGui which can be used with other tools to manually provide FCA validation, but this can lead to problems when potentially erroneous CGs are manually entered. This provides further justification for the requirement of a KMS tool which would provide exploring, reasoning and validation ( FCA ) functions on CGs all within the same tool.

Detailed below in Table 3.1 are some of the challenges associated with developing and modelling EA for ES which have been observed or experienced through the previous 30 years of industry experience. This table is not intended to be an exhaustive list but simply provides details of some the challenges which the EA practitioner experiences or must overcome.

| No. | Challenge |
|---|---|
| 1 | **Store** interactions between an organisation and its trading partners |
| 2 | **Track** increases and decreases of the value of resources |
| 3 | **Define** requirements of business users, which can seem to be clearly definable but often become only apparent in later stages |
| 4 | **Produce** designs which are consistent with business domain rules |
| 5 | **Include** business semantics |
| 6 | **Track** requirements changes over time |
| 7 | **Capture** both past and present events |
| 8 | **Provide** for multiple perspectives of the same data |

Table 3.1: Challenges of developing ES

Hill (2006) looked closely at the process of a modelling environment in ES and proposed the requirements detailed below in Table 3.2. Note the requirement id (REQ ID) has been added so that these requirements can be referenced throughout this research work.

| REQ ID | Requirement |
|---|---|
| REQ H1 | **Utilise** a notation which is rich, expressive and can tolerate both quantitative and qualitative high-level domain concepts |
| REQ H2 | **Provide** a mechanism whereby models can be queried, reasoned against and verified |
| REQ H3 | **Support** the implicit capture and explicit expression of ontological data |
| REQ H4 | **Impose** a rigour upon the modelling process |

Table 3.2: Requirements for Modelling Environment (Hill, 2006)

## 3.2 REA

The work of McCarthy(1982) built upon the work of Chen(1976) to propose a generalised model for accounting systems. Through analysing numerous accounting transactions and identifying similar features in the transaction flows, he noticed a common pattern in the flow of data. Within the data he identified the three principle constructs of the REA core pattern; Resources Events and Agents, from which the acronym REA is derived as shown below in Figure 3.1.

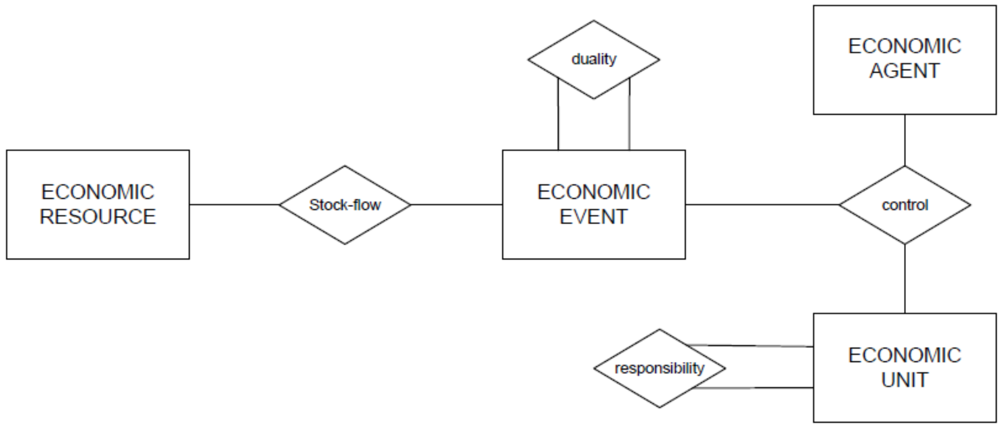


Figure 3.1: The REA Accounting Model (McCarthy, 1982)

The core REA pattern allows the practitioner to detail an organisation's activities over the course of operational business by recording the history of economic exchanges or economic conversions with other parties inside or outside of the organisation. These activities or exchanges can all be shown to follow a specific object pattern, that of a transaction.

Each transaction can be defined as an economic Event, where an internal Agent provides something of value, an economic Resource to an outside entity, an economic Agent. Whereby each decrement event is always paired with a corresponding increment event where the internal Agent receives a corresponding type of a different economic Resource which has more value to the organisation, e.g. goods are sold for cash (Geerts and McCarthy, 2002).

Double entry bookkeeping has dominated financial information and transaction recording since its introduction in the 15th century (Vandenbossche, 2007). However when using double book entry system to store data within Information Systems (IS) this can lead to drawbacks and data inconsistencies, including data gaps as was shown in earlier work (Fallon, 2012; Fallon and Polovina, 2013).

REA was envisaged as the solution to this problem of inconsistent data and data spread, McCarthy (1982) detailed how through using REA, and by defining various different views using the same transaction data this would allow for different flexible access to separate cross sections of the central database containing the financial transaction data (McCarthy, 1982).

### 3.2.1 Resources

Resources are items with economic value, either with or without physical substance which are consumed by or provided by an organisation. Examples of economic resources are products, services, raw materials, money, tools and services used by the organisation (Hruby, 2006).

### 3.2.2 Events

Events are activities within an organisation which are planned, controlled executed and evaluated. Some economic events can occur immediately such as sales of goods, whereas as others occur over a period of time such as rentals, labour acquisition and use and provision of services.

### 3.2.3 Agents

Agents are identified as individuals, divisions, departments or organisations which participate in, control or execute events. Examples of economic Agents are vendors, customers, employees and organisations.

### 3.2.4 REA Enterprise Ontology

Further authors have advanced the earlier work of McCarthy (1982) to define an REA Enterprise Ontology (Geerts and McCarthy, 2002; Dunn et al., 2005). The REA ontology views enterprises with four levels of detail which are shown below.

**Level 1 - Value system level:** focuses on the Resources which are exchanged between enterprises and their external business partners, which includes Agents such as customers, creditors, investors, suppliers and employees.

**Level 2 - Value chain level**: details Resources flows through depicting Events showing business processes that fulfil Resource exchanges. The term business process meaning an entire transaction cycle within the enterprise.

**Level 3 - Business process level:** which concentrates one or more transaction cycles in an enterprise's value chain by expanding further the interaction between the Resources, Events and Agents which are present.

**Level 4 - Task level:** expands further on the individual steps involved in accomplishing the Events within the enterprise.

### 3.2.5 REA extensions

Further advancements and technological developments, such as Radio Frequency IDentification (RFID) and the concept of the "Internet of Things", have necessitated some REA extensions, which have been proposed such as the ability to capture the position or location of a resource or the event. More specifically in the "Supply Chain of Things" where a critical component or requirement is an ontology to facilitate the visibility and interoperability of things along the supply chain which can change position, as shown below in Figure 3.2 (Geerts and O'Leary, 2014).

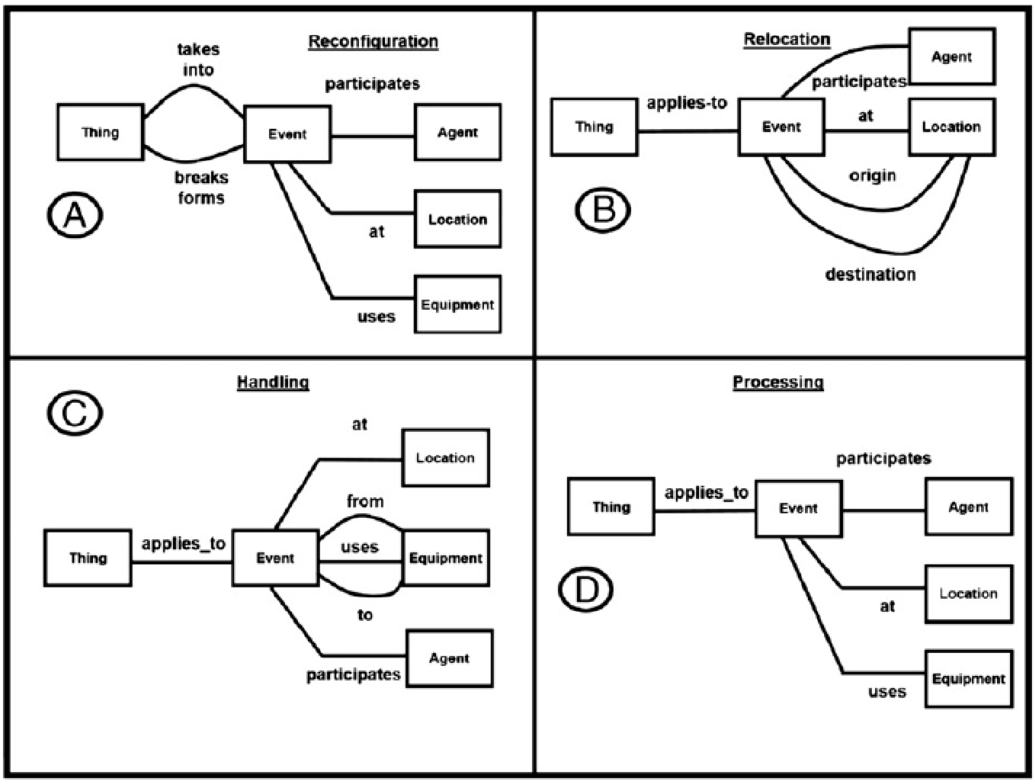


Figure 3.2: Supply Chain Requirement for Location entity (Geerts and O'Leary, 2014)

Laurier et al. (2018) have suggested that REA[2] provides a new viewpoint in real-time transactions, through providing the perspective of both trading partners (in the transaction) at the same time. Thus allowing for both view points, customer and supplier, the dependent and independent to be defined within the same model. To enable this perspective, the suggestion is that the economic-agent should be modelled as "rolemixins", meaning that the same or different person can play multiple inside and outside roles. For example, when a purchase is made on behalf of myself as inside and outside agent, I can be involved in both transfer events, payment and delivery as both an inside and outside agent.

## 3.3 The Generic Transaction Model (TM)

The concept of a TOA within EA, builds upon earlier work from several authors such as Hill (2006) who provided as a solution to modelling and defining transactions a generic Transaction Model (TM), which was originally envisaged for the analysis and design of Multi-Agent System (MAS). Using the idea that through using a CG design, the TM would provide a means of applying working transaction knowledge across domains (Launders, 2011). For more information regarding CGs refer to Section 5.3.

The TM CG shown below in Figure 3.3 (generated via the AREA KMS ) shows that all transactions comprise of two economic events, denoted by {a} and {b}. The transaction is complete when both economic Events balance, which indicates that { × a} always opposes {b}, representing debits and credits. Also depicted are the two related economic Resources, {c} and {d}, which each have a independent source and destination Agent. The Inside Agent and Outside Agent refer to the parties involved in the transaction. The Inside and Outside prefix denotes the relative perspective of the transaction for each party. The braces {*} denote plurality, indicating that each concept can represent a number of aggregated Resources, Events or Agents (Launders, 2011).

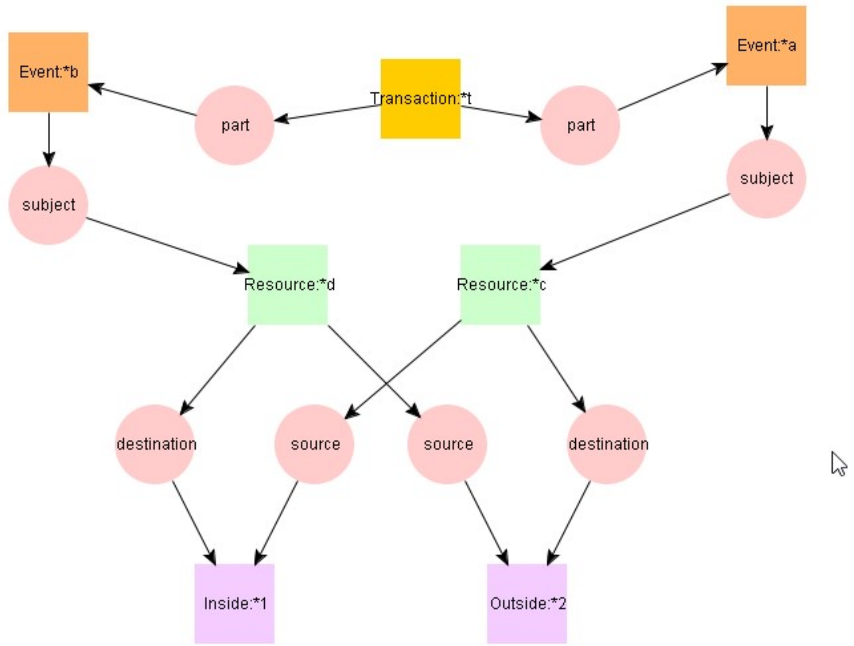


Figure 3.3: The Transaction Model Graph (Hill, 2006)[1]

## 3.4 The Transaction Pyramid (TP)

The term "transaction" appears regularly in the definition and design specifications of ES, but should actually be viewed from two different perspectives (Polovina, 2013). Firstly as a high-level declarative statement that identifies the enterprise itself and the "Transactions" (capital T) which occur with external and to some extent internal Agents. Secondly as the term "transaction" (lowercase t) which makes up a number of lower-level transactions which support the enterprises business processes.

The concept of two separate perspectives or levels of transactions in EA, which can be called a TOA is predicated on the TC (Polovina, 2013). Advancing this theory further, a third tier of transactions is added to the concept of a TOA that of the database transactions, which are responsible, among other things, that parallel transactions from

[1] This diagram was produced using the AREA KMS with the CGIF shown in A.2.1

multiple database sessions are processed correctly and the database moves from one consistent state to another, with the possibility of handling error conditions (triggering a database roll-back) as detailed below in Figure 3.4 (*MaxDB Transactions*, 2021).

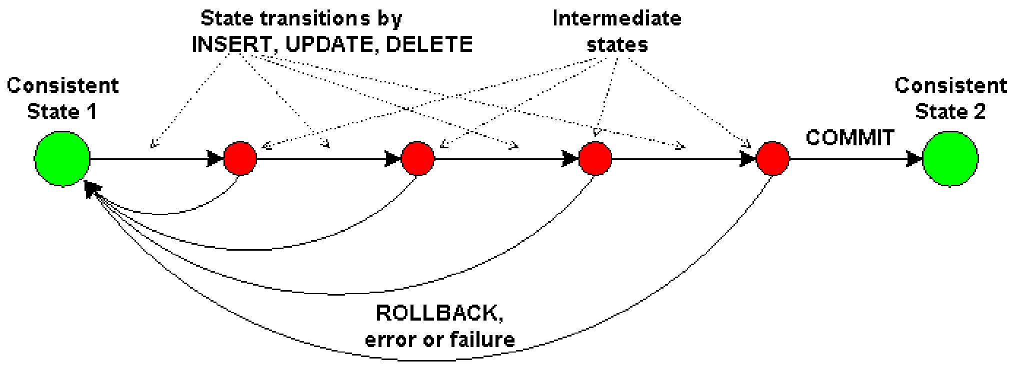


Figure 3.4: Transition of the Database from one Consistent State to Another (*MaxDB Transactions*, 2021)

The high-level enterprise Transactions and low-level business transactions are enabled by database transactions and to aid the understanding of this structure the mind-model of the The Transaction Pyramid (TP) is offered as a solution and detailed below in Figure 3.5. The TP details the three tiers of transactions which comprise a TOA, showing how the complexity of the transactions goes from top to bottom and conversely the abstraction level is highest at the top.

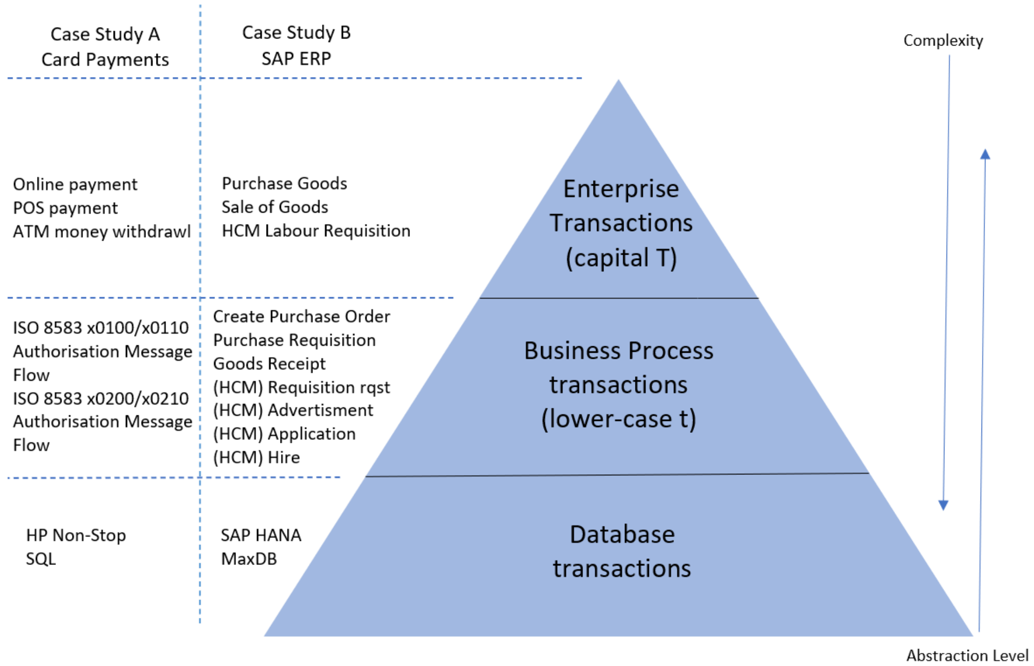


Figure 3.5: The Transaction Pyramid (TP)

Further justification and evidence can be added to support the concept of three levels of transactions, when looking at the requirements for two separate use-cases, detailed below, which are referenced throughout this research.

The first use-case: Case Study A, Card Payments, that of an enterprise who's mission statement is to process monetary, card transactions within a financial context. In the ES high-level Transactions constitute the enterprise transactions, such as a customer (Agent) using either a credit or debit card to pay (Event) for services/products (Resource) or withdrawing money (Resource). The higher-level Transactions that of making a payment with a Card, are made up of several low-level business process transactions, which are implemented using request/response ISO message interchanges (refer to Section 8.5). Each ISO 8583 request/response message exchange uses at least one if not multiple database transactions to ensure the validity of the transaction data in the enterprise database. Typically a fault tolerant database is used to store payment transaction data, such as Hewlett-Packard Non-Stop SQL (*HP NonStop SQL*, 2021), which is responsible for the database transactions. In Section 8.5, a demonstration is provided to show how a card payment EA can be implemented using a TOA design.

The second use-case: Case Study B, SAP ERP, an ES which is an enterprise-wide, integrated IS, the main of goal of which, is to coordinate high-level enterprise transactions and low-level business transactions (both internal and external) which fulfil the business goals. ERP systems must also manage and coordinate all the resources, information, and functions of a business from shared data stores (Appelbaum et al., 2017). ERP systems must integrate these high-level enterprise transactions and enterprise information into one central database which is then accessed by multiple organizational divisions. When looking at a specific implementation of an ERP solution that of SAP, the high-level Transactions constitute the enterprise transactions of the ES solutions; ERP, CRM etc., enabling enterprise functionality such as the sale or purchase of goods, which satisfies the enterprise's mission statement such as producing (Event) and selling (Event) a product (Resource) to another organisation (Agent). These high-level Transactions, consist of multiple low-level business process transactions which together provide the functional basis, such as Purchase Requisition or Goods Receipt. Each of the low-level business process transactions use one or more database transactions to maintain consistency of the data within the enterprise database. SAP ERP stores the transaction data typically within a SAP (enterprise) database (SAP HANA, MaxDB), which is also responsible for processing the database transactions (*MaxDB Transactions*, 2021). In Section 8.6, a demonstration is provided of how an ERP EA can be implemented using a TOA design.

A further requirement for a TOA is that of predictive analytics, since tools are required to continuously provide predictive analytics on the transaction data from both an internal and external process perspective. This data mining can assist in the optimization of enterprise transactions, which can also then be used by management accountants to understand and improve the flow of transactions (Appelbaum et al., 2017).

Naturally enterprises do not always seek to maximise their profit in purely monetary ways, even many outwardly profit-oriented enterprises present their mission statements in qualitative ways (e.g. quality of service, duty stakeholders, society, and reputation to name a few) (Polovina, 2013).

The importance of both high-level enterprise Transactions, low-level business transactions and database transactions is clearly crucial to fulfilling the business goals of enterprises and their ES, providing both a clear requirement for accurate modelling of the transaction flows and further confirmation of the importance of this research.

## 3.5 Using the Pyramid Principles

In this Section he Pyramid Principles (Minto, 1987; Rumsey, 2021) are used, to structure the analysis and look at the research objective of "Conceptual Structures using the REA ontology adds value when defining a Transaction Oriented Architecture (TOA) within Enterprise Systems(ES)". The Section below looks at each one of the three basic section of the pyramidal structure shown previously in Figure 1.1 - "What is the current situation?", "Why is the problem important, what is the impact if it is not addressed" and "How - can the problem be solved".

### 3.5.1 What - Current Situation/Solutions

In this Section the research question is addressed "Conceptual Structures using the REA ontology adds value when defining a transaction oriented architecture within enterprise systems" by first looking at what is currently available.

Sowa (1984) identified the requirements for a (generic) knowledge based system shown below in 3.6, the conclusion was that the same knowledge base that drives the expert system should also generate the requirements specifications for conventional programs and databases that interact with it. Integration is key, since database systems, knowledge based systems and conventional programs must all co-exist and to do this must use the same knowledge base. This specification although missing some details is as actual today as it was in 1984.

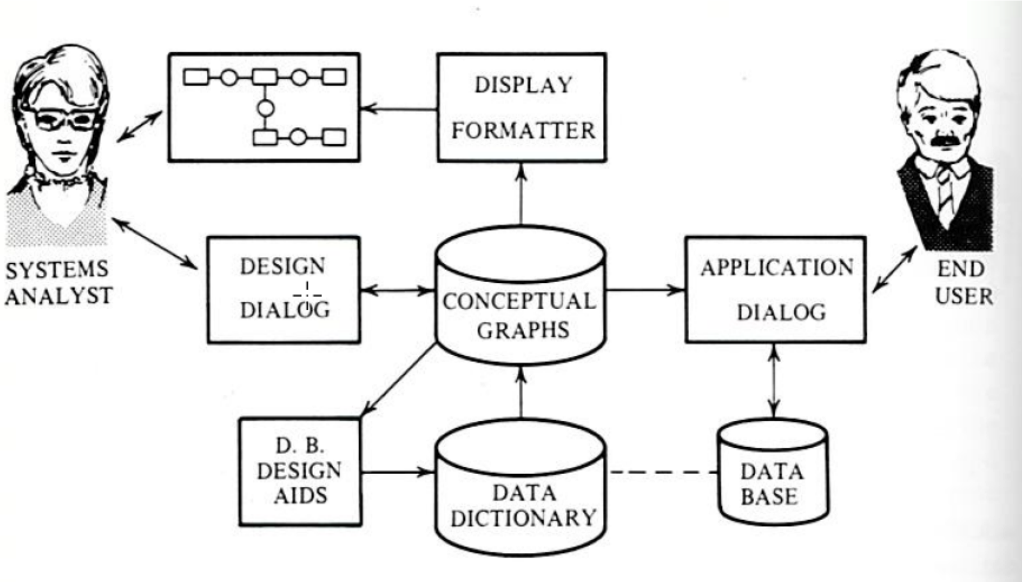


Figure 3.6: Designing and Using a Knowledge Based System (Sowa, 1984)

Looking at how Sowa's specification fits in with contemporary ideas, a smaller sub-set of TOGAFs "Requirements Management" are examined, as shown below in Figure 3.7. Key for the integration and implementation of an ES system are the three Architecture components: B: Business, C: Information and D: Technology. Of course the other architecture components shown in Figure 2.2 are also important and should also use the same knowledge repository. However to keep the scope of this thesis to a workable minimum, it concentrates only on these three components for the implementation of an EA design KMS tool using a central KR.

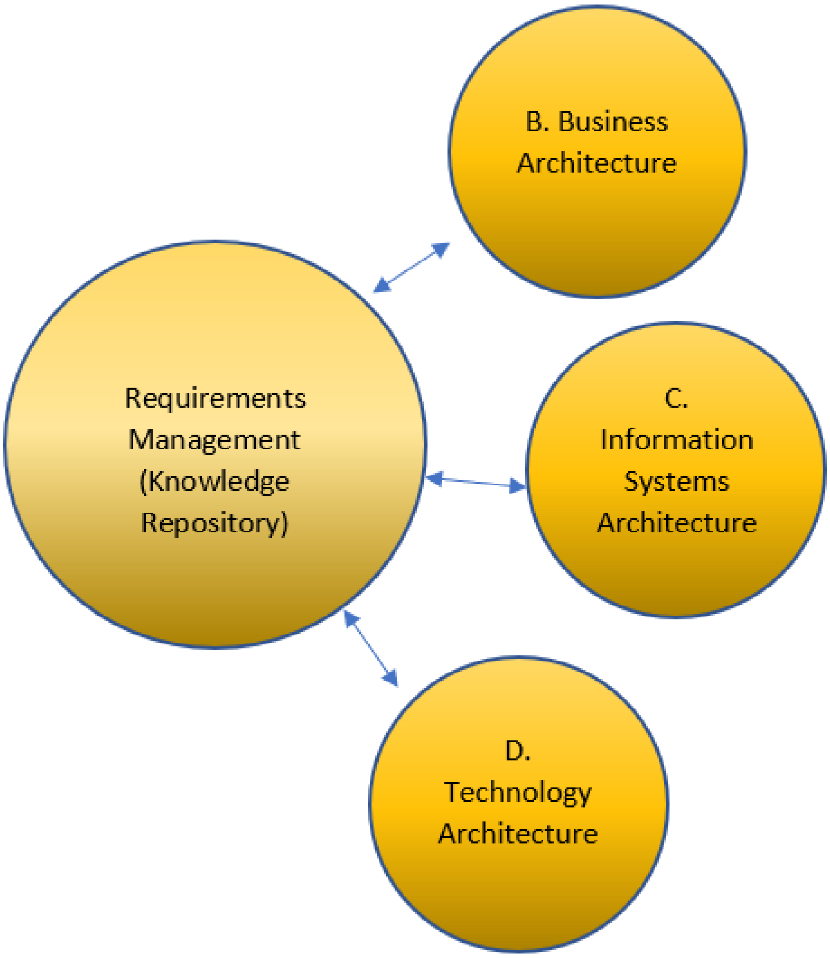


Figure 3.7: TOGAF Requirements Management (Cycles:B,C,D)

A more detailed view is provided by Hay (2010) who describes the data column of the architecture framework which is concerned with what is significant to an organization from six points of view. Together with our additions to his diagram in RED, we show how a TOA KMS consisting of CGs could provide a definition of a TOA ontology using REA.

To show clearly how the TOA architecture fits also within this framework we have added the REA perspective or lens by adding the REA entities in BLUE, note the "extra" REA entity location, described previously in Section 3.2.5 REA Extensions.

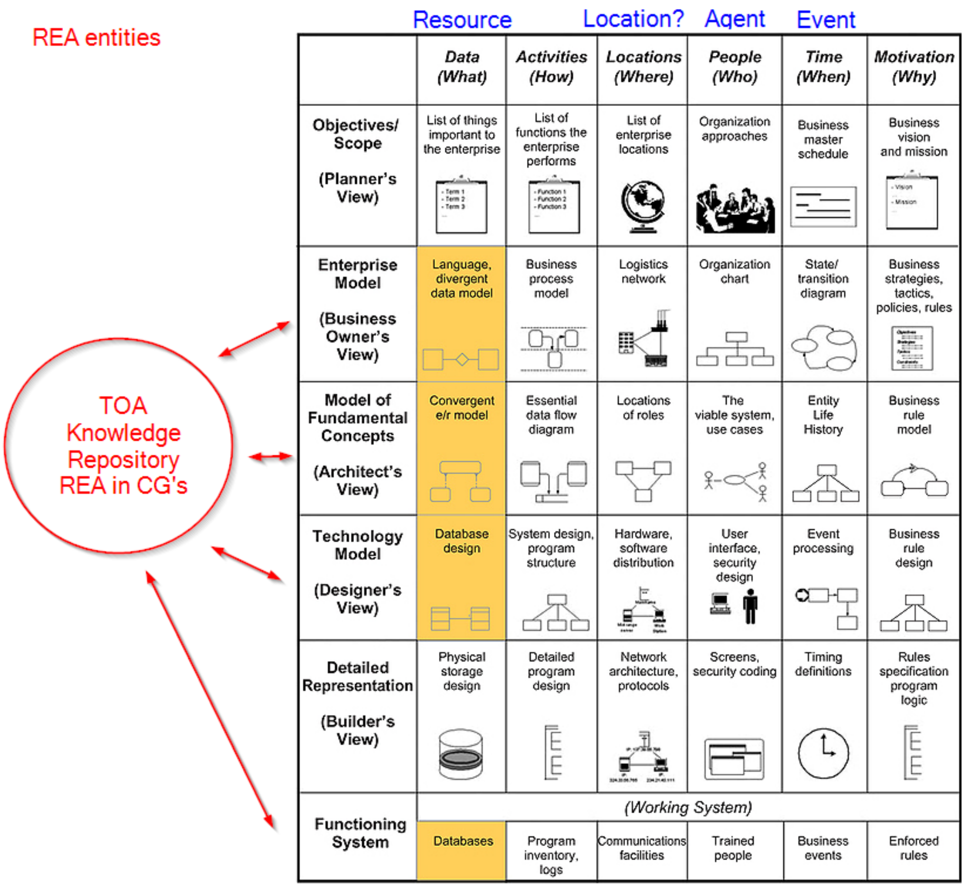


Figure 3.8: Architecture Framework (modified) (Hay, 2010)

There are currently manual tools available, which could partly enable a centralised KR which uses Conceptual Structures to store entries and other tools which would offer model validation etc., these tools are briefly detailed below:

| Tool | Description |
|---|---|
| **CharGer** | CharGer is a conceptual graph editor primarily an editor to create visual display of graphs (Delugach, 2021) |
| **CoGui** | conceptual graph knowledge base with a semantic query mechanism as well as inference and verification services (*CoGUI*, 2020) |
| **CG-FCA** | CG-FCA is a program that converts Conceptual Graph files in the .cgif format and 3 column csv files to Formal Context files in the .cxt(Andrews, 2017*a*) |
| **In-Close** | a fast Formal Concept Miner and Tree Builder for FCA files (Andrews, 2017*b*) |
| **FCA Concept Explorer** | allows the users to view/explore the FCA concepts stored in a CXT file |

Table 3.3: Current Tools using Conceptual Structures

### 3.5.2 Why - Impact if not addressed

There are numerous reasons why a new TOA KMS would be useful, several authors (Hill, 2006; Dunn et al., 2016) and domain experts (refer to email B.2) have identified a clear requirement for a TOA KMS which would "would complement every existing design methodology by providing not only a means of generating an ontology, but also by making the ontology of use to an agent be describing the rules".

REA has been shown to be a semantically rich business domain ontology which can be used for many enterprise applications. To exploit this potential, what is required is a generally accepted, explicit and formal specification of the TOA based on an REA ontology, which is reusable across different types of business applications.

Gailly et al. (2008) goes further and provides a clear identification of the degree of formalization required depending on the type of application: For an educational context a formal representation of the REA ontology is less desirable than in ontology driven information system (engineering) contexts. In an educational context, formats are required which provide a succinct representation which easily suit the understanding of the human mind where context-specific reasoning or association is required. However

IS machines require a format which is based on formal logic. A further requirement for a formal and explicit specification of the REA ontology, would be the ability to provide a high degree of formality is the possibility to enable a graphical and easy-to-understand representation. A TOA KMS would promote a general agreement about a formal and explicit specification based on the REA ontology and allow the realization of currently only theoretical applications. This would also further promote the REA ontology and make the implementation more useful for application areas that currently are not explored by the REA ontology community.

Currently the tools listed above in Table 3.5.1 have the following deficiencies or problems:

- The current tools are not Integrated with other tools, for example some offer CG design capabilities and others offer FCA (refer to Section 5.6). But they are not integrated together. The knowledge practitioner must use each tool individually and then guide the results from one tool into the next, which is both error-prone and time consuming.
- Currently none of the available tools have the ability (without further configuration) to capture transactions using the REA ontology and provide **TOA perspective** of Transactions.
- None of the available tools provide a clear path to Automation of models, which would promote a more data-driven methodology.

Hill (2006) references the tools in Table 3.5.1 but also makes a clear call for further work, "Tool support is already available for some elements of the Transaction Agent Modelling (TrAM) process (Charger, (Delugach, 2021), Protégé, (*Protege-Frames User's Guide*, 2008)), but there needs to be better interoperability of tools for the process to be mechanised."

Until these problems above are resolved and a useable TOA KMS is provided the move to understanding and usage of a TOA architecture using Conceptual Structures and the REA ontology for EA, will be only slowly moved forward.

### 3.5.3 How - Requirements for a KMS based on a TOA EA

The Requirements Management process of the Architecture Development Method (ADM) shown in Figure 2.2 defines a continuous process consisting of multiple phases A-H. All future changes to the requirements, should also be reflected in all other phases, so that an enterprise records all current and new requirements, including those which are in scope of the current Statement of Architecture Work through a single Requirements Repository, or KR. The phases of the ADM cycles (B, C, D), identified in Figure 3.7 are further divided into steps, detailed below (*TOGAF, Ver. 9.2*, 2020):

- Select reference models, viewpoints, and tools
- Develop Baseline Architecture Description
- Develop Target Architecture Description
- Perform gap analysis
- Define candidate roadmap components
- Resolve impacts across the Architecture Landscape
- Conduct formal stakeholder review(s)
- Finalize the Architecture
- Create the Architecture Definition Document

The process of Requirements Management of an EA, should be focused on the data stored within the KR, through the usage of a KMS. This will allow the user to have maximal understanding and control of each step of the reasoning process. The KMS should allow for knowledge, both ontological and factual to be easily entered into the system (KR) and also provide easy access and validation of the knowledge stored in the repository (Chein and Mugnier, 2008).

Peffers et al. (2007) describes the use of what could be called a mental model for defining the characteristics of the research outputs, whereby the mental model is a “small-scale [model]” of reality which can be analogous to an architect’s models or to physicist’s diagrams. The Requirements Management Wheel (RMW) (defined in Figure 3.9) is offered as a mental model which provides a structure defining a KMS based on Conceptual Structures, using CGs which would provide the framework for EA based on TOA using the REA ontology. The RMW is based on CGs, which shows how the EA requirements can be defined and accessed (Input, Output, Query and Validate) by each of the different phases A-H using CGs (defined using the ISO CL CGIF standard refer to Section 5.4.2) as the interface layer. Key to the **RMW** is the KR, in the centre which is based on a CWA, for further details of the merits of a CWA KR, refer to Section 4.3.2.

As a solution to the requirement for a tool providing a KMS, we have proposed a TOA KMS, called: “Automated REA” (AREA) Knowledge Management System (KMS), because of it’s foundation within the REA ontology and the ability to provide a data-driven design which will enable automation of the design process (Fallon and Polovina, 2016). The arrows in RMW in Figure 3.9 indicate: how the Query,Input,Validate,Output wheel can rotate, so that for example, the B: Business Architecture Requirements can be *input* to the KR and subsequently, the C: Informations Systems Architecture can be *output* from the KR.

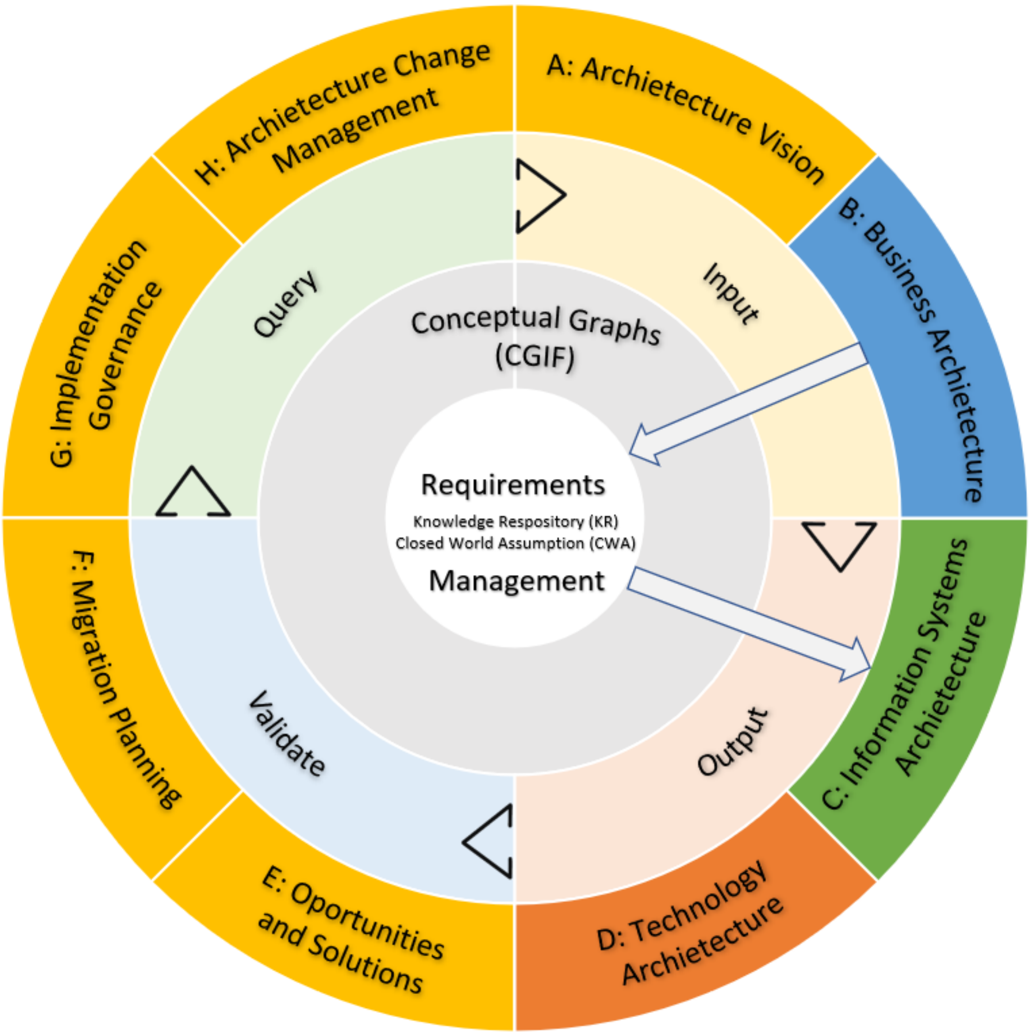


Figure 3.9: Requirements Management Wheel (RMW) (based on CGs)

When looking at the key requirements for the AREA KMS, the following four key functions shown below in Figure 3.10 have been identified and are shown in the **RMW**.

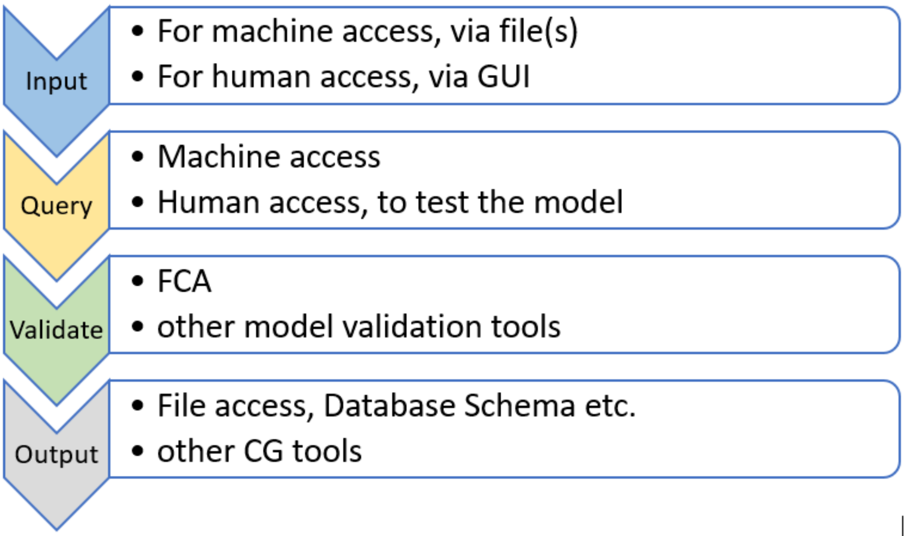


Figure 3.10: The Four Key Functions of the AREA KMS

Looking at the key requirements and expanding this functionality further, extra detail is added together with the concepts from TOGAF, the result is detailed in Figure 3.11 below, the detailed requirements for the AREA KMS.

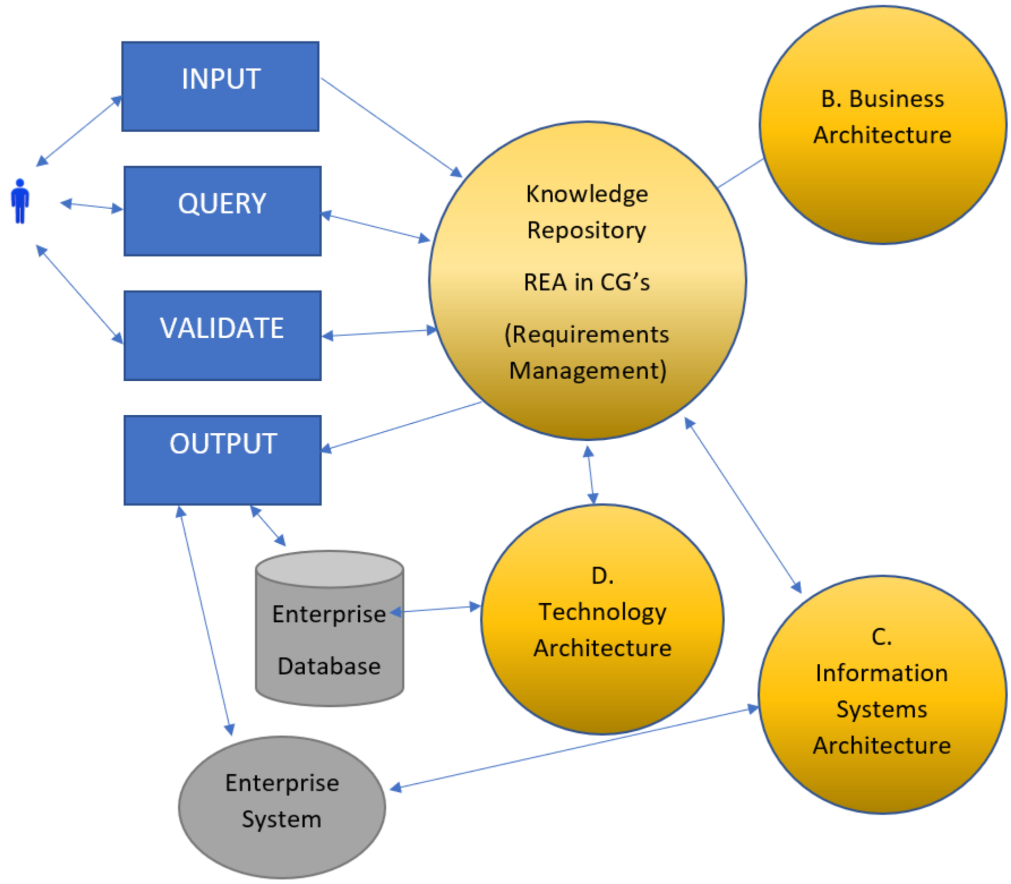


Figure 3.11: Detailed Requirements for the AREA KMS

The Key Requirements of AREA KMS are highlighted below in table 3.4, note the requirement id (REQ ID) has been added so that the requirements can be referenced throughout this research work.

| **REQ ID** | **Description** |
|---|---|
| REQ K1 | **Input** of CGs into KR |
| REQ K2 | **Query** of CGs in KR |
| REQ K3 | **Validate** CGs in KR |
| REQ K4 | **Output** of CGs from KR |

Table 3.4: AREA KMS - Key Requirements

The General Requirements for the AREA KMS are identified below in Table 3.5.

| **REQ ID** | **Requirement** |
|---|---|
| REQ G1 | Process and interpret CGs |
| REQ G2 | Process and interpret REA attributes |
| REQ G3 | Allow for machine readable data capture, analogous to the requirements of the Semantic Web see Section 4.2 |
| REQ G4 | Allow for human readable data capture |
| REQ G5 | Enable reverse engineering and design recovery applications |
| REQ G6 | Allow data analysis for discovering the Hidden Knowledge in Transaction Data |
| REQ G7 | Promote automated development |
| REQ G8 | Promote iterative development |
| REQ G9 | Enable full development life cycle |

Table 3.5: AREA KMS - General Requirements

Further more Architectural Requirements for the AREA KMS are detailed below in Table 3.6.

| **REQ ID** | **Description** |
|---|---|
| REQ A1 | **GUI interface** - provide a GUI interface |
| REQ A2 | **Use common standards** - use common non-proprietary industry standards |
| REQ A3 | **Open source-software** - based on open-source software |
| REQ A4 | **Interoperable** - must be interoperable with other tools |
| REQ A5 | **Capture layers** - be able to capture the layers identified within EA (Scheruhn et al., 2015). |

Table 3.6: AREA KMS - Architectural Requirements

## 3.6 Conclusions in Chapter 3

This chapter has looked briefly at the challenges of designing and implementing ES solutions, which will adequately manage the enterprise data of organisations when completing transactions. It has also been shown that relying on the old double book entry systems can lead to problems storing data. The REA ontology has then been shown to provide a solution to some of these problems by providing a framework, the core REA pattern which can be used to model transactional information.

Economic events, transactions which are occurring in the world today are already collected and stored within numerous databases (Amazon, Banking systems etc.). REA provides a new method to look at these economic events (transactions) together with all their relevant interdependencies and interconnections. This would allow for new methods of reasoning and access from intelligent systems to make intelligent decisions. REA also provides enterprises with a tool which allows for the control and understanding of not only their internal operations but their external relationships with markets and partners, allowing enterprises to become outward-facing rather than inward-facing.

Evidence and information has been presented detailing why these Transactions are important, both the low-level business transactions and the high-level enterprise Transactions which together with the Database transactions, provide a useful theoretical basis for modelling ES using the concept of Transaction Pyramid (TP).

Hill (2006) provided a further justification for TOA Knowledge Management System (KMS), which would be required to impose a rigour upon the requirements elicitation process for agent-based systems.

The pyramid principles have been used to detail, first "what" the problem is and which solutions are currently available, followed by "why" a solution is required and finally "how" the problem could be solved.

Two core concepts of this thesis are firstly the idea of the Requirements Management Wheel (RMW), to store the details of requirements using CGs as an interface layer detailed in Figure 3.9. Secondly the proposal to develop a Knowledge Management System (KMS) called AREA which will provide a TOA design tool for EA based on the REA ontology.

The four key functions (Input, Query, Validate and Output, refer to Figure 3.10) of the AREA KMS were identified, which will fulfil the potential of (RMW). Further more detailed requirements were also identified and detailed in Table 3.6.

Subsequent Chapters in this thesis expand further on these ideas using DSRM to provide a POC.

# Chapter 4

# Semantics and Ontology in Enterprise Architecture

## 4.1 Introduction

Through a literature review, this chapter explores and reviews the use of Semantics and Ontology in Enterprise Architecture modelling, looking also at some of the currently available solutions.

### 4.1.1 Semantics

Semantics is defined as the study of the relationship between words and how meaning can be drawn from those words. Looking at ES the primary requirement of semantics is to provide a definition of the syntax (i.e. abstract and or concrete syntax) and to develop the grammar which can be subsequently used to design and define the meaning of the language of the problem domain. There are four steps to this process: (i) defining concepts, (ii) designing and developing systematic domain-specific rule language, with (iii) definitions for the functions and its parameters, priorities or precedence of operators and its values and finally by (iv) providing a naming convention system, both external and internal (Mani et al., 2018).

Ontologies which represent process or service vocabularies require tools which enable ontology analysis, visualization, and interface generation. Other useful features for such tools is the possibility to carry out reverse engineering and complete design recovery on completed applications. Ontologies should be used throughout the enterprise system development life cycle process and must also enhance the target system as well as support validation and maintenance. Knowledge engineering requirements may include some ontology development for traditional domain, process, or service ontologies (*Ontology Definition Metamodel*, 2014).

Domain-Specific Language (DSLs) can be used for defining incomplete models by capturing the domain knowledge in a domain-specific environment which can then be used to resolve semantic mismatches and defects, which subsequently once resolved can provide the domain expert or analyst with a problem domain at a higher level of abstraction (Mani et al., 2018).

### 4.1.2 Ontology

Defining the semantics of a problem domain will result in an ontology which consists of a set of concepts and categories together with a set of properties and the relations between them. Through the development and exploitation of ontologies within the problem domain the implicit design artefacts are defined explicitly and through this iterative process the problem design becomes easier to understand.

An enterprise ontology can provide significant benefits to a business but must have the ambition to cover all aspects of the business domain (as opposed to specific silo ontologies). The business Ontology must be organized in a top-level foundational Ontology, with relating core reference, domain, task and application ontologies (von Rosing et al., 2017).

### 4.1.3 Meta-models

For a business ontology to be used in a computing application, it must be represented in such a form which provides machine-readable data structures. OMG defines Ontology as an example of a data model, whereby the syntactic rules for representing the business data structure are called a meta-model (Colomb et al., 2006).

The meta-model consists of the concrete syntax (abstract and static) of the DSL together with the abstract syntax to define the modelling elements, such as: classes, nodes, association, aggregation and generalization, and relationships between the modelling elements. The abstract syntax may be considered as more structurally defined by the grammar and meta-model, representing the structure of the domain (Mani et al., 2018) .

Like other software artefacts meta-models also evolve over time. This evolution can occur during (i) design time, when alternative meta-model versions are developed and well-known solutions are customised for new applications, and (ii) during implementation when meta-models are changed to a fixed meta-model which is supported by a tool, and (iii) during maintenance when errors are discovered and the meta-model is corrected and (iv) when parts of the meta-model are redesigned due to advancements in the knowledge domain or to encourage reuse (Wachsmuth, 2007).

### 4.1.4 Model Driven Architecture (MDA)

Using MDA meta-models can provide a fundamental building block such that models which result from the MDA design process comply with constraints and are expressed at the meta-level, and model transformations are based on source and target meta-models (*OMG MDA Guide rev. 2.0*, 2014).

## 4.2 Semantic Web

As defined by Berners-Lee et al. (2001), The Semantic Web is not a separate Web but in fact an extension of the initial web, where pages were linked together using hypertext links. Due to its universality, The World Wide Web (WWW) allows the owner of any page to generate a hypertext link to any other page, meaning that "anything can link to anything". The Semantic web goes further with the aim of providing more contextual information to provide more well-defined meaning to the linked pages, better enabling computers and people to work in cooperation. One essential property of the Web technology is that it must discriminate between the "scribbled draft and the polished performance, between commercial and academic information, or among cultures, languages, media". A further key distinction is the difference between information which is produced primarily for human consumption and that which is produced mainly for machines. To enable the Semantic web to function, computers must also have access to structured collections of information and sets of inference rules, which enable systems to carry out automated reasoning.

The Semantic Web uses languages which expresses both data and rules for determining reasoning against the data. These rules can also be exported from existing knowledge-representation systems onto the Web, adding logic to the Web. These rules allow the user to make inferences, choose courses of action and answer questions. The logic must be powerful enough to describe complex properties of objects but not so powerful that agents can be tricked by being asked to consider a paradox. Fortunately, a large majority of the information is required for definitions such as, "a hex-head bolt is a type of machine bolt", currently this information can be written in existing languages with a extra vocabulary.

The advance of technologies and specifications which enable the Semantic Web are part of an on-going process which was first started with the Xtensible Markup Language (XML) and the Resource Description Framework (RDF), XML allows anyone to create their own tags or hidden labels. Scripts or programs can use these tags in sophisticated ways using the defined rules. One of the problems associated with RDF is that the script writer must know what the page writer uses each tag for, meaning that XML allows users to add arbitrary structure to their documents but says nothing about what the structures actually mean (Berners-Lee et al., 2001).

Founded in 1994, the World Wide Web Consortium W3C, is made up of member organisations and is the main international organization for defining the World Wide Web standards. In addition to the classic "Web of documents", W3C provides also standards for the Semantic Web, to build a technology stack to support a "Web of data, similar to the sort of data you find in databases". The goal of the Web-of-data is to enable computers to complete more useful work and allow systems which can support trusted interactions over the WWW. To enable the Semantic Web, technology standards for storing data, building vocabularies and writing rules for handling data, have been defined by W3C and include the following technologies RDF, SPARQL, Web Ontology Language (OWL), and SKOS. Figure 4.1 below details how these technologies fit together (*OWL 2 Web Ontology Language*, 2009).

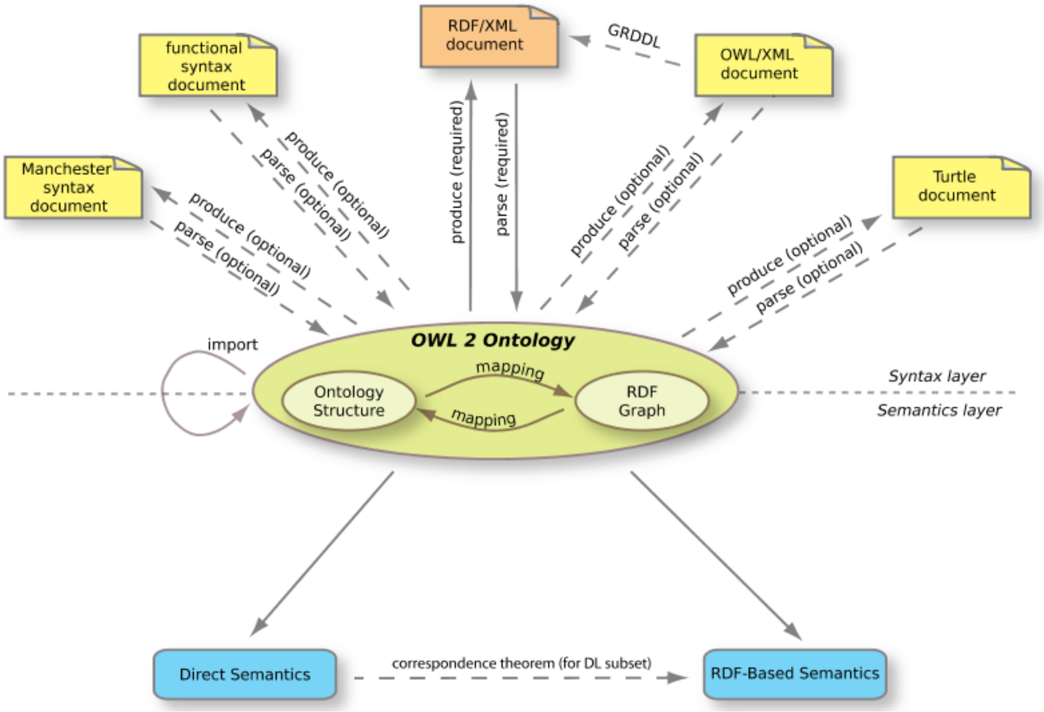


Figure 4.1: The Structure of OWL 2 (*OWL 2 Web Ontology Language*, 2009)

### 4.2.1 RDF

The primary exchange syntax for OWL2 is RDF/XML which is the only syntax which must be supported by all OWL 2 tools.

Analogous to CGs (refer to Section 5.3), the RDF format uses RDF Triples, thus the underlying structure of any expression in an RDF document becomes a collection of triples. As in CG's, each RDF triple consists of a subject, a predicate and an object and a set of such triples is called an RDF graph. This can be illustrated by a node and directed-arc diagram, in which each triple is represented as a node-arc-node link (hence the term "graph"). The structure of an RDF triple is detailed below in Figure 4.2.

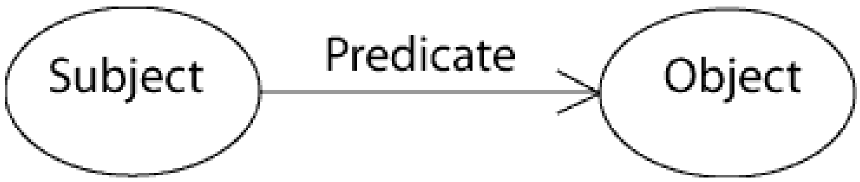


Figure 4.2: RDF Triple (*OWL 2 Web Ontology Language*, 2009)

Each RDF triple represents a statement of the relationship between the things denoted by the nodes that it links, each triple has three parts, the direction of the arc is significant since it always points toward the object. The nodes of an RDF graph are its subjects and objects:

1. **subject**
2. **object**
3. **predicate** also called a property, that which denotes the relationship

The assertion of an RDF triple states that some relationship, indicated by the predicate, holds between the things denoted by subject and object of the triple. The assertion of an RDF graph amounts to asserting all the triples in it, so that the meaning of an RDF graph is the conjunction (logical AND) of the statements corresponding to all the triples it contains (*OWL 2 Web Ontology Language*, 2009).

Based on XML, RDF triples although easy for machines/computers to read are not easy for human operators to understand. When looking at the "Transaction Model Ontology" defined by Hill (2006) shown in Section A.2.2 and comparing this with "The Transaction Model (TM) Graph - REA" shown in Figure A.2.1, which essentially define the same set of triples, the former as a CG in ISO CL CGIF standard and the latter as a set of triples in RDF format, this assertion can be verified.

### 4.2.2 SPARQL

Relational databases which store data use a syntax called SQL to allow the user to access data, conversely for RDF graphs a query language is also defined to access the Web of Data stored in RDF format. This query language is called SPARQL and uses its own, RDF-specific query facilities. RDF queries and received results are sent using protocols such as HTTP or SOAP.

### 4.2.3 OWL

The current version of OWL: Version 2 (informally known as OWL2), is the W3C Web Ontology Language which enables formally defined meaning to the Semantic Web. OWL2 ontologies provide classes, properties, individuals, and data values which can be stored in Semantic Web documents. OWL2 Ontologies are used along side information documents written in RDF which are also primarily exchanged as RDF documents (*OWL 2 Web Ontology Language*, 2009).

The Semantic Web, through the implementation of OWL supports what could be called an OWA. OWA is a reasonable assumption to make in the World Wide Web context (and thus for Semantic Web applications) (Sengupta et al., 2011) refer to Section 4.3.2 below for details of OWA versus CWA. An OWA allows for flexibility since everything in the Knowledge Base (KB), the Semantic Web, is "permitted until it is prohibited". However this causes problems as discussed by Zhang (2017) and Sengupta et al. (2011), through semantically linking large, real-world ontologies which must be populated with entities from heterogeneous sources.

Several authors have proposed solutions to this problem: Zhang (2017) proposes discovering ontology alignments in enterprise-scale applications through using a tool which enables the user to query for related entities in a scalable manner, and Sengupta et al. (2011) discuss efforts which have been made to combine OWA and CWA modelling for the Semantic Web using knowledge representation languages which have both OWA and CWA modelling features which are said to adhere to the Local Closed World Assumption (LCWA).

## 4.3 Semantic Enterprise Architecture and Modelling (EAM) Tools

There are currently several Semantic Enterprise Architecture Modelling (EAM) Tools available, this Section provides brief details of there capabilities.

### 4.3.1 EnterprisePLUS

The LEADing Practice provides not only an Enterprise Architecture Framework as detailed in Section 2.2.4, but additionally provides a tool EnterprisePLUS (E+), which is offered as a Software as a Service (SaaS) solution. E+ consists of two separate application components, (i) Modelling Software component where the user can create and work with many different types of modelling and architecture components and (ii) a KMS where models, views and standards can be shared with other practitioners in the enterprise. E+ was one of the first tools to incorporate standards from ISO, OMG, LEADing Practice and IEEE to support standards such as Business Process Modelling Notations (BPMN) and Robotic Automation Modelling Notations (RAMN) (*EnterprisePLUS*, 2021).

### 4.3.2 Protégé

Stanford University started the Protégé project in the 1980s and it is still going strong, Protégé is one of the most widely used software tools for building, developing and maintaining ontologies for knowledge based systems. The Protégé project was envisaged to support the basic research into intelligent systems and to develop better methods for constructing new knowledge bases. Due to the fact that the project has been running over decades, this longevity, indicates clearly its success and also the importance of Protégé. Protégé is available under an open-source license, but of course it is not the only solution and it does have some limitations.

Protégé exists in a number of different versions and frameworks, a desktop system (Protégé 5) supports many advanced features to enable the construction and management of OWL ontologies and a Web-based system (WebProtégé) offers a distributed access over the Internet using any Web browser to a central KR.

Early perception of Protégé has changed since its inception, and it is no longer viewed mainly as a tool for building knowledge-based systems but instead a tool for building ontologies. The Protégé project has moved from an idea which was based on requirement for domain-specific knowledge-acquisition, to a tool with a code base modified by thousands of people, whereby the project has benefited tremendously from the expanding user base (Musen, 2015). The Protégé project committed early on to support the full implementation of World Wide Web Consortium W3C recommendations for ontologies supporting OWL. Other commercial ontology editors also (now) offer support for OWL but there has been no decline in enthusiasm for Protégé and its plug-ins (Musen, 2015).

A clear differentiation and understanding must be made between the two most widely-used ontology modelling paradigms, the OWL paradigm and the Frame paradigm. Protégé supports both paradigms within a single overall framework and two separate tools: Protégé OWL and Protégé Frames Wang et al. (2006).

The two paradigms have many similar modelling constructs, both are built around the notion of classes, representing concepts in the domain of discourse and use the same names for different properties. However there are significant differences in the semantics of how these constructs are used to infer new facts in the ontology, thus the way that the modelling constructs are used is also different Wang et al. (2006). How the differences of each of the two separate paradigms effect the semantics and the implications that result are detailed below.

**Unique Name Assumption (UNA)** In Frames, if two objects have different names, they are assumed to be different, unless explicitly stated otherwise conversely in OWL, no such assumption is made, meaning that in OWL, different names can also refer to the same object, which is detailed below in Figure 4.3.

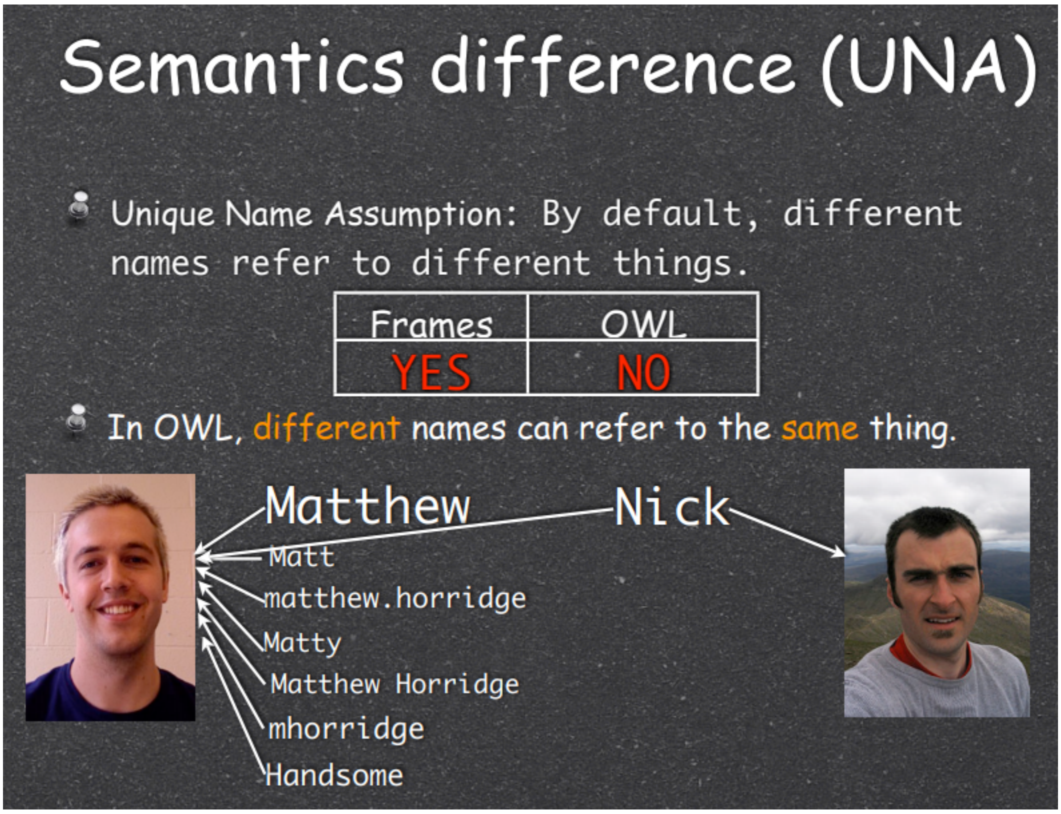


Figure 4.3: Semantics Difference (UNA) (*Frames and OWL side by side*, 2021)

**Closed World Assumption (CWA) vs Open World Assumption(OWA)** Frames prohibits everything until it is permitted, in OWL everything is permitted until it is prohibited. Meaning that in Frames nothing can be entered into the KB until there is a place for it in the corresponding template. Conversely OWL allows anything to be entered into the KB unless it violates one of the constraints.

This means in Frames if a fact is absent from the knowledge base then it is assumed to be false conversely in OWL something is false only IF it contradicts other information. The Semantic differences between Close World versus Open World Reasoning, are detailed below in Figure 4.4.

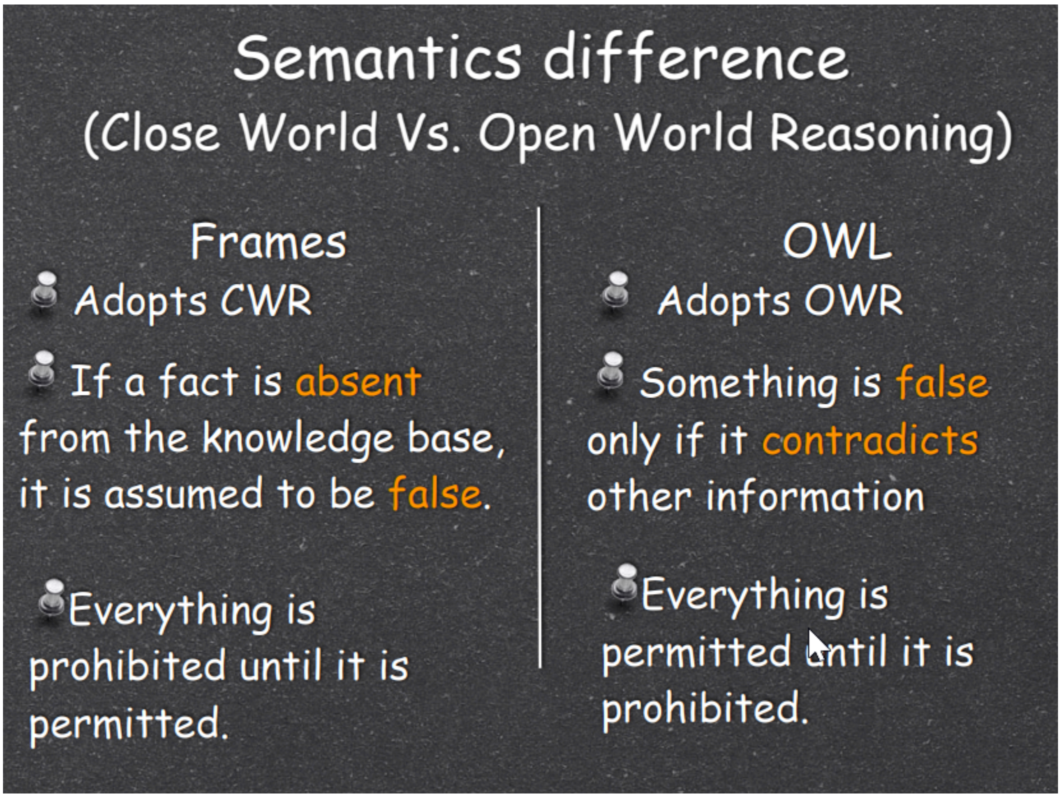


Figure 4.4: Semantics Difference (CWA versus OWA) (*Frames and OWL side by side*, 2021)

**Single vs Multiple models** A Frames ontology has one model which satisfies each of the assertions of the Frames ontology, meaning that a Frames ontology can only contain instances which are explicitly specified. Conversely an OWL ontology will have many models consisting of all possible interpretations that satisfy each of the assertions in the OWL ontology.

This means that unless the Frames model is defined to support the semantics of the KB, the (incomplete) data can not be captured. Conversely because OWL allows multiple models incomplete (data) information can be captured. The Semantic difference between Single Model versus Multi Model is detailed below in Figure 4.5.

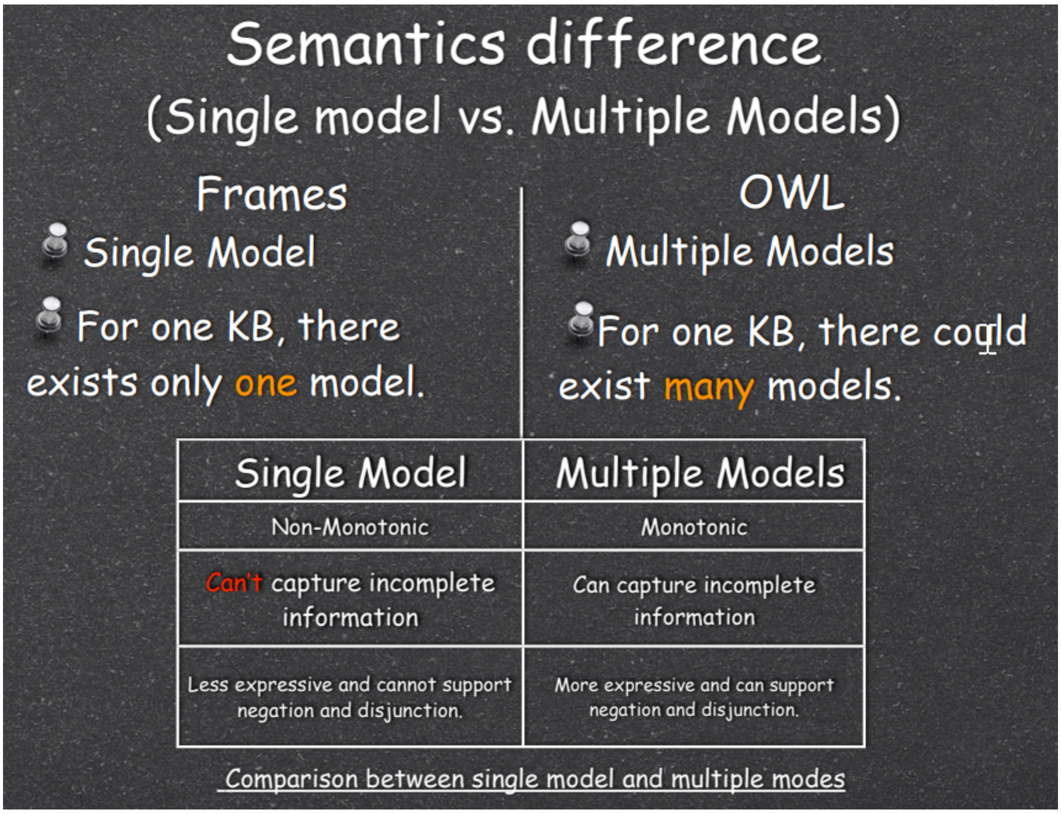


Figure 4.5: Semantics Difference (Single Model versus Multi Models) (*Frames and OWL side by side*, 2021)

**Implications for modelling** In Frames all subclass relations must be asserted explicitly conversely for OWL subclass relations can be inferred on the class definition. For example in Frames an "Oak tree" can be defined as a sub-class of Tree conversely in an OWL KB if an "Oak tree" has a sufficient definition then its subclass relation can be referred. This also has significant implications for how the different KBs are checked for consistency in the two different paradigms.

**Class** Is defined as a thing but can also be an instance. A class can have a set of entities.

**Instances** Are defined objects of a specific class.

**Slot** Describes the properties of classes and instances. There are two ways in which slots can be attached to a frame/class: Template slot and Own slot.

**Facet** Specify the constraints on slot values.

The two different paradigms: Frames and OWL allow the user to decide which one to use depending on the requirements of the Knowledge Base or ontology:

**Frames** should be chosen when the problem domain has a closed world assumption which focuses on the data acquisition of instances and meta-modelling is important.

**OWL** should be chosen where an open world assumption is required together with a complex class hierarchy which will be later published on the semantic web.

### 4.3.3 Essential Enterprise Architecture

The Essential Enterprise Architecture (EA) is a product of the Essential Project, initially envisaged as a purely open source EA tool, the framework of Essential tools has grown to provide a solution for organisations of all sizes. Essential EA tools have an interactive tool for visualising, traversing and searching the EA meta model and views. Similar to the LEADing practice tools the Essential EA tools provide an EA framework which can be used for organisations wanting to use TOGAF, DODAF, FEAF, or other frameworks.

The Essential EA tools are built using the Meta Model of the Protégé frames KB, the reasoning behind this decision can be found in the emails detailed in Section B.2.4. Importance is given to the ability during the "data acquisition" phase, so that the constraints of the meta model are defined clearly to ensure consistent semantics can then be applied to the data during input. This allows the results of the KB or ontology to be defined reliably. The OWL solution is not suitable since it allows the user during the data input phase of the (EA) ontology to capture terms which are later not valid or useable. EA tools require the benefits of defining a meta-model based on a CWA as opposed to a OWA. Enterprise EA tools use a data driven approach to developing models, meaning the EA practitioner does not have to draw or maintain pictures since the Essential EA tools create the visualisations. This is confirmed by other domain experts (refer to email:B.26), who stated that "RDF(S) allow for meta-modelling, whereas the OWL KB do not".

### 4.3.4 CoGui

CoGui is a visual tool for building a CG KB, allowing practitioners to create and edit the KB. CoGui supports imports and exports from the KB using the Resource Description Framework Schema (RDFS) and OWL formats. Further CoGui tools allow for the analysis and checking of facts and constraints. The tool also allows for queries on the KB, while taking into account inferences enabled by the ontology. The KB is composed of an ontology and a set of CGs representing assertions, called facts (*CoGUI*, 2020).

Previously CoGui used Cogitant (refer to Section4.3.5 below) as the reasoning and processing engine for CGs, refer to emails: B.6 and B.7.

### 4.3.5 Cogitant

Cogitant is a library of a set of C++ classes enabling the user to easily handle CGs as well as the other objects of a KB (*Cogitant*, 2021). Cogitant was recognised as one of the fastest CG engines, refer to email B.17.

### 4.3.6 Comparison of Semantic EAM Tools

The table 4.1 below provides a direct comparison between the functionality of the Semantic Enterprise Architecture and Modelling (EAM) Tools described in the above sections.

Several of the EAM tools are based on open-source software which allows the user to make modifications as required. Only two of the tools are commercially available products supported by the vendor.

Both of the commercially available tools: EnterprisePlus and Essential Enterprise Architecture can also be set aside from the other tools in that they provide the solution: (i) through providing Software as a Service (SaaS) solution (ii) a base EA reference content which aides the user in providing content which has already been analysed through research into a standard Enterprise Architecture.

| **Tool** | **Active code base** | **Provide EA Content** | **Open-Source** | **Commercial Product** |
|---|---|---|---|---|
| **EnterprisePlus** | ✓ | ✓ | | ✓ |
| **Protégé** | ✓[1] | | ✓ | |
| **Essential Enterprise Architecture** | ✓ | ✓ | ✓ | ✓ |
| **CoGui** | ✓ | | ✓ | |
| **Cogitant** | | | ✓ | |

Table 4.1: Comparison of Semantic EAM Tools

## 4.4 Conclusions in Chapter 4

This Chapter has explored the usage of Semantics and Ontologies within Enterprise Architecture (EA).

Why is this important? Previously the accounting system was the core module of any EA, however this module is now only one of many within ES which share data (internal and external) within the Enterprise database. EA now encompasses multiple modules (Customer, Sales, Production etc.) which must all share the same enterprise data. Rather than looking at accounting systems alone, the internet or Semantic Web provides a closer example of an external network or system which more closely matches this complex architecture within an enterprise.

However when looking at the Semantic Web as an example (for a definition of how to provide an EA), it has been shown that through the implementation of OWL, using a

[1]The Protégé OWL version has an active code base however the Protégé Frames code base is no longer been actively developed

OWA, which offers flexibility, "everything is permitted until it is prohibited". However this architecture also causes problems requiring tools to provide alignment and query capabilities to Semantic Web Ontologies.

An overview has been provided of some of the currently available Semantic EAM tools, detailing the extent to which it is possible to capture Semantics and Ontology in EA.

This leads to the question: would an EA benefit from an OWA as used by the Semantic Web, or quite clearly would a CWA provide a much clearer and less problematic framework for an EA?

# Chapter 5

# Conceptual Structures in Enterprise Architecture

## 5.1 Introduction

Through a literature search this chapter explores the use of Conceptual Structures in Enterprise Architecture modelling. Showing how Conceptual Graphs (CGs) can assist the representation of ontological concepts. CGs and Peirce (pronounced "Purse") logic are discussed as a means of building Enterprise Architecture (EA) conceptual models thus also assisting the creation of ontologies, which can then be subsequently verified using FCA. In particular, CG type hierarchies are used to illustrate how CGs can implicitly provide the concepts and relationships required for an REA ontology. Thus this Chapter will show how previous work provides a basis for the use of Conceptual Structures in Enterprise Architecture modelling and also demonstrate how CG's can be used to fulfil EA modelling as CG's also provide the capability to produce inference rules. Moreover this chapter uses one of the contributions of this research, the AREA KMS (refer to 7.9) to produce two of the CG diagrams in this chapter 5.1, 5.2. Chapter 7.5 uses this theoretical basis to define the use of the ISO CL CGIF standard to support type hierarchies in a TOA EA.

## 5.2 Logic

### 5.2.1 Introduction

In the 19th century, even before the invention of logical machines: computers, early definitions of logic tried to interpret the term literally and thus align logic with the study of thinking. It was determined that the object of logic lies in process of thought, thus logic was first aligned in the domain of psychology. However this is not exactly correct since the actual object of logic is not the act of thinking, that "psychic process or mental activity" but instead the something which lies within it. The systematic move of logic away from the science of thoughts, the domain of phycology, took several different paths. The key definition began by presenting logic using the difference between theoretical and practical sciences. Logic was aligned with the practical sciences, conversely the act of thinking was determined to be a theoretical science. This of course brought about a new problem since logic could not be defined truly as practical science, rendering logic to be of no real use. However, logic is distinguished from the other branches of knowledge as a science of truths, moreover a more realistic definition would be to ascertain that logic is in fact the science of deduction (Pfaender, 2013).

Looking more closely at the processes which work together when determining logic, the process of thought can be defined as a real psychic event which occurs in all awakened adult human beings. This process can be defined by a series of unique interrelationships of five factors; i) there belongs to every act of thinking a subject, by whom is the thinking performed ii) the act of thinking itself, a real psychic event at a particular point in time iii) a the thought-content of that event of thinking iv). this thought-content, expressed or clothed in certain linguistic forms v) the thinking subject, or some object in the most general sense of the term (Pfaender, 2013).

Logic can be defined using concepts, judgments, and inferences, with concepts defined as distinct elements of thought. Judgments are necessarily related to certain objects about which they make certain assertions or inference. More complex concepts of logic can also include other more particular kinds of interconnections of thoughts, those in which one or more judgments of another judgment are inferred. To develop a particular concept of logic the thought process must go through specific controlled acts of comparison and distinction. This process can also include further analysis including the determination of similarities and differences which can then include either the addition and subtraction of other elements or concepts (Pfaender, 2013).

When communicating the act of thinking the event must be formed in complete linguistic sentences, whether orally or in writing, by expressing the conceived thought content exhaustively in sentences whereby its unexpressed components must first be divined by the listener or reader into the correct components (Pfaender, 2013).

Hacking (1979) defines a further key approach to the understanding of logic, since he determines that the representation of logic is concerned with the characteristic of defining sentences of truth, rather than that of the transitions from sentences to sentences. Thus logic can be defined as not the theory of the act of thinking but as the science of thoughts more precisely, that of asserting those thoughts. Meaning that using logic we can define the "essence of thoughts, their ultimate elements, their construction, varieties, and the interconnections and relationships that exist between them" (Pfaender, 2013).

With the introduction of logical machines: computers the determination of logic acquired a whole new perspective and importance.

### 5.2.2 First Order Logic

The foundations of first-order logic were developed independently by both Gottlob Frege and Charles Sanders Peirce, around 1900 before the invention of modern day computers to provide a language to define a collection of formal systems (Hammer, 1998). Peirce developed the first linear notation for first-order logic, further variations were developed by Schröder, Peano, and Russell which then evolved into the modern system of predicate calculus (Sowa, 1992).

First-order logic uses quantified variables which allows the use of sentences which contain variables, so that instead of a proposition such as "David is a man", one can instead use the expression using a variable (instead of David) so that it would read "there exists x such that x is David and x is a man", where "there exists" is a quantifier, while x is a variable. First-order logic collects together what could be called a theory over a specified domain of discourse, over which the quantified variables range. Thus a set of sentences in first-order logic, define finitely many functions from that domain to itself, together with a set of predicates defined on the domain (Hammer, 1998).

Using the logic of Charles Sanders Peirce as a basis, Conceptual Graphs (CGs) as an existential notation were developed by Sowa to allow for the direct mapping between graphs and first order predicate logic (Hill, 2006).

## 5.3 Conceptual Graphs (CGs)

### 5.3.1 Introduction

As we have seen in the previous Section first-order logic allows the practitioner to convert sentences into logical rules with variables. The philosopher and logician C.S. Peirce in 1883 was one of the first to use the basis of first order logic to define CGs. John Sowa then introduced the box and circle notation for CGs with the aim of representing the semantics of natural language, such that meaning could be described in a "logically precise, humanly readable and computationally tractable way" (Sowa, 2000). Both natural languages and symbolic logic are universal knowledge representations which provide a set of standards enabling the user (human or machine), to represent everything which could be said or written (human language) or in the case of symbolic logic to define a computer program, which will allow some task to be completed, which could run on a digital machine: a computer. The design goal for CG's was to bridge the gap between two distinctly separate worlds or environments, that of the rather un-precise non-digital human language and that of the computer program which uses a precise symbolic logic digital machine interface (Sowa, 1992).

The existential graphs created by Charles Peirce which he called "the logic of the future", form the basis of CGs, which were later defined by (Sowa, 1984) as "a finite, connected, bipartite graph" and offer the following advantages:

1. full power of first-order logic
2. can represent modal and higher-order logic
3. provide rules of inference which are simple and elegant
4. notation is easily adapted to CGs
5. easily translated directly to/from natural language

CG's can be aligned along side the triples defined for RDF, described in Section 4.2.1. Where the RDF Subject and Object are Concept Nodes (in CGs) and the RDF Predicate is a Relation node (in CGs). The Sections below present the different elements which allow for the definition of CGs.

### 5.3.2 Concept Nodes

Within CGs, concept nodes represent entities attributes, states and events. Relating CG's directly to the REA ontology, concept nodes would define the Resources, Events and Agents. Concepts are used to define a type and IF there exists one of this type a *referent* is used, as shown below.

**[Type:referent]**

**[Bird:Osprey]** meaning that there exists a Type which is called Bird, and there exists one of this type which is an Osprey (the referent).

### 5.3.3 Relation Nodes

Relation nodes define how the concepts (nodes) are interconnected.

### 5.3.4 Concept Types

Concept types provide the key ability of CGs to be used to define an ontology which is built using type hierarchies and using the relationship subtype or super-type, an example of REA ontology can be seen in the TM Graph detailed in Section A.2.1.

### 5.3.5 Graph Formation

It is usual to show multiple concepts and relations within a graph, the existence of a singular concept by itself, without any connecting arcs, is however acceptable and is defined as a “singleton” and it is still considered to be a “well-formed” graph, for example:

**[House]** meaning that there is a graph which defines an object or concept, such that ’There exists a House’.

**(part)** this syntax is considered to be incorrect, since a Relation node can not be defined alone, since there are no arc’s defined

**[Window] ->(part)->[Glass]** this syntax is now considered correct since the arc’s have been added.

### 5.3.6 Notation

An important feature of CGs is the ability to define CG's both graphically but also using a standard written notation, for example;

**[House]->(Part)->[Window]** this graph when denoted in Linear Form (LF), states that a "Part of a House is a Window". The connecting part between Concepts and Relations is the Arc. CGs are thus read as follows, for example the CG below, states that "the *Relation* of Concept1 is *Concept2*" (Hill, 2006).

[Concept1]->(Relation)->[Concept2]

A further benefit of CGs is that they can not only be expressed in written Linear Form notation, but can also be displayed in a graphical/visual form as detailed below in 5.1.

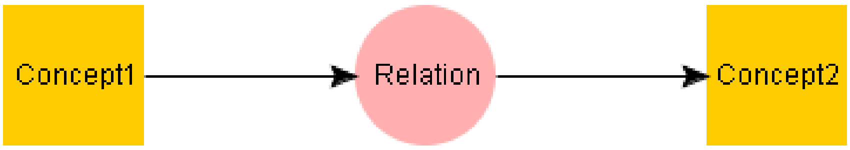


Figure 5.1: Simple CG in Graphical form[1]

All conceptual relations have one or more arcs which must be connected to some concept, a CG can be formed using a single concept however each conceptual relation must be connected to some concepts. Every concept in the graph is typically represented by its type label, thus if two concepts have the same type label they are of course of the same type. A differentiation is made between concepts and type labels. Each and every concept is an instance of a type and type labels are used as a unique identifier or label to indicate that all of the instances belong to a specific type. There is an "is-a" relation that is called a conceptual relation between concepts and types

[1]This diagram was produced using the AREA KMS from the CGIF detailed in A.1.1

which identify the type of a concept, as defined by Sowa, a Type hierarchy is "a partial ordering over the set of type labels". Thus one could state "*Horse is-a Mammal*" and also however that "*Mammal is-a Animal*". Thus the use of type hierarchy classifies the concepts into subtypes and super-types, looking at the example above Mammal is a super-type of Horse and Horse is a subtype of Animal, which is shown in Graphical form below in Figure 5.2.

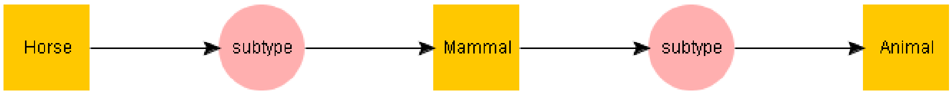


Figure 5.2: Type Hierarchy in CGs[2]

### 5.3.7 Interpretation Problems

Some early problems can occur for the practitioner using CGs, since CGs require interpretation from the inside out (starting with the relation), and then often from right to left, which means that the user requires time to read graphs naturally. For technical people, who are proficient at reading computer programs this does not cause any great problems, however for other people such as domain experts, time must be taken to understand the standard language which exists to assist graph comprehension. Using this standard language, CGs can be read either in the direction of the arrows, or against them.

Other problems of Graph interpretation can arise such as when a Graph looks too complex, it is often not the complexity which causes the problem but rather that the incorrect naming for a Relation/Concept node has been chosen thus making the Graph seem implausible, or unsuitable. As a solution the Graph should be reviewed and the names changed appropriately making the Graph more readable (Hill, 2006).

[2]This diagram was produced using the AREA KMS using the CGIF shown in A.1.3

**[House]->(Part)->[Window]** reading left to right would be a "House has a part which is Window". Reading right to left - "Window is a part of a House"

## 5.4 Common Logic (CL)

CL was defined by ISO with the main motivation of providing a solution for the interchange of information using a language for the Semantic Web. From a historic perspective the CL project arose from an effort to update and rationalize the design of the Knowledge Interchange Format (KIF) standard which was first proposed over a decade ago.

To support web applications the design goals of CL were to produce a common interface language to exchange data over a number of different KR notations. Designed to be both syntactically as unconstrained as possible but at the same time semantically correct but simple as possible.

KIF in a simplified form became the de facto standard notation in many applications of logic for knowledge interchange, CL uses several features from KIF such as sequence markers, though the design philosophy of CL differs from that of KIF in three ways:

1. Initial goals of CL and KIF were different, KIF was intended to be a common notation into which a variety of other languages could be translated without loss of meaning. CL is intended to be used for information interchange over a network, without the need for any translation.

2. KIF contained what could be called a "full" language, representing syntax for a wide variety of expressions into which a wide different other languages could be directly mapped, including, for example, quantifier sorting, various definition formats, which included a fully expressive meta-language. Conversely CL was deliberately kept "small" making it easier to define precise Semantics including encodings of axiomatic theories expressed in CL.

3. KIF was based on LISP and LISP-based ideas were incorporated into the semantics of KIF. Conversely the CL CLIF syntax retains only a superficial LISP-like appearance, CL is not LISP-based and makes no basic assumptions of any LISP structures but is instead based on XML which was not available when KIF was created.

CL is a framework intended for information exchange and transmission which enables a variety of different syntactic forms, called dialects. Each dialect is translatable via a semantics-preserving transformation to a common XML-based syntax. CL provides a syntax which permits "higher-order" constructions, such as quantification over classes or relations while preserving a first-order model theory. The standard contains also a provision for Semantics which allow theories to describe intentional entities such as classes or properties and allow for the definition and use of data-types. One of the key aims been the naming, importing and transmitting of content across the World Wide Web using XML (*ISO/IEC24707 CL Framework*, 2018).

### 5.4.1 Common Logic Interchange Format (CLIF)

The Common Logic Interchange Format (CLIF) standard is a CL dialect text-based first-order formalism using a LISP-like list notation and is based loosely on KIF. The new name was chosen primarily to identify it as a new version and to distinguish it from various other dialects of KIF that may or may not be exactly compatible. KIF and CLIF are similar in several ways. Both languages contain as sub-dialects a syntax for classical first-order (FO) logic. Both languages have notation for sequence variables (called sequence markers). Both languages use exclusively a prefix notational convention and expression style syntax conventions. Both use parentheses as lexical delimiters. Both indicate quantifier restrictions similarly.

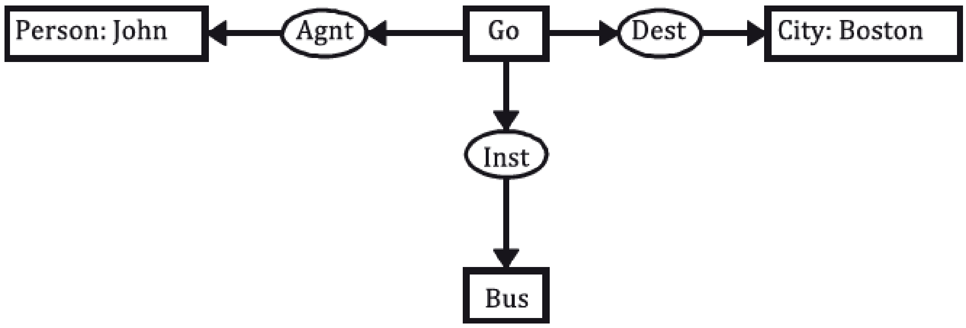


Figure 5.3: CG display form for "John is going to Boston by bus" (*ISO/IEC24707 CL Framework*, 2018)

The following CG detailed above in Figure 5.3 can be stored using CLIF using the following syntax.

```
(exists ((x Go) (y Bus))
(and (Person John) (city Boston)
(Agnt x John) (Dest x Boston) (Inst x y)))
```

### 5.4.2 Conceptual Graph Interchange Format (CGIF)

The CGIF is a fully conformant dialect of CL which can be used to represent and serialise CGs. The CG abstract syntax is a notation-independent specification of the expressions and components of the CG core, which is the minimal CG subset capable of expressing the full CL semantics.

When using CGIF, the concepts are represented using square brackets and the conceptual relations are represented by parentheses. When a character string prefixed with an asterisk, e.g. *x, then x is the defining label. This defining label can then be referenced by the bound label ?x, which is prefixed with a question mark. These strings are called co-reference labels in CGIF and correspond to variables in CLIF.

The specification of CGIF brought together academic research to provide a specification for defining CGs which is readable by both humans and software machines.

The CL CGIF standard has not yet gained wide spread usage since there were (at the beginning of this research), no implementations or tools using the CL CGIF standard, although some work has been completed on the draft standard (Sastry, 2001).

The following CG shown in Figure 5.3 can be stored using CGIF using the following syntax.

```
[Go: *x] [Person: John] [City: Boston] [Bus: *y]
(Agnt ?x John) (Dest ?x Boston) (Inst ?x ?y)
```

## 5.5 AI and Knowledge Learning

In early the 2000's, most people in Artificial Inteligence (AI) felt a bit pretentious using the word Ontology in everyday conversation, since then the world of IS has changed considerably and Ontologies are now recognised as an essential element of much of AI technology (Musen, 2015). Nowadays, many organisations are investing resources into developing their Ontology, organisations including the BBC (*BBC Ontology*, 2021).

The goal of many enterprises is to "own" the information, knowledge and skills of the enterprise employees, which can to some extent be separated from the simple time-worked constructs which were previously the sole factor when analysing the performance of employees. To enable this knowledge storage process enterprises are generating KR and AI based decision support systems (Dunn et al., 2005). A TOA architecture based on CGs would provide a solution to such a requirement.

## 5.6 Formal Concept Analysis (FCA)

FCA is a field of applied mathematics which is based on the the mathematical understanding and representation of concept and conceptual hierarchy, with the aim of activating mathematical thinking for conceptual data analysis and knowledge processing. The adjective "formal" is meant to emphasise mathematical notions (Ganter and Wille, 1999).

FCA is based on mathematical order and lattice theory, FCA provides a method for data analysis, knowledge representation and information management. The basic steps of FCA involve representing data in a formal context, alternatively known as a cross table which can also be represented as a structure or concept lattice (Watmough, 2013).

Using the data analysis ability of FCA based on lattice theory, FCA has been shown to be beneficial in supporting ontology building. To form a formal context, FCA consists of three elements: (i) a set of formal objects, (ii) a set of formal attributes and (iii) the binary relations between them. The formal context is generally formed using a cross table which is then graphically visualized using a lattice diagram (Jiang, 2016).

FCA can be used to validate CGs, through extracting the triples from a CG using the form: Source Concept - relation - Target Concept. Each triple is then represented with a corresponding binary relation i.e. Source Concept-relation, Target Concept, thus the Target Concept then becomes a Source Concept for a following relation. This produces a set of captured binary relations, where the original Source Concept relation is paired with subsequent Target Concepts. This can be more easily understood when looking at a simple CG with the CG Concepts, [Cat], [Mat] and [Colour: Grey]. [Cat] and [Mat] are linked by the CG relation (sits-on) and [Mat], [Colour: Grey] are linked by (has-attribute). In simple English, the CG describes a cat which sits on a grey mat (Andrews and Polovina, 2018). The graphical version of this CG, together with the FCA binary relations are detailed below in Figure 5.4.

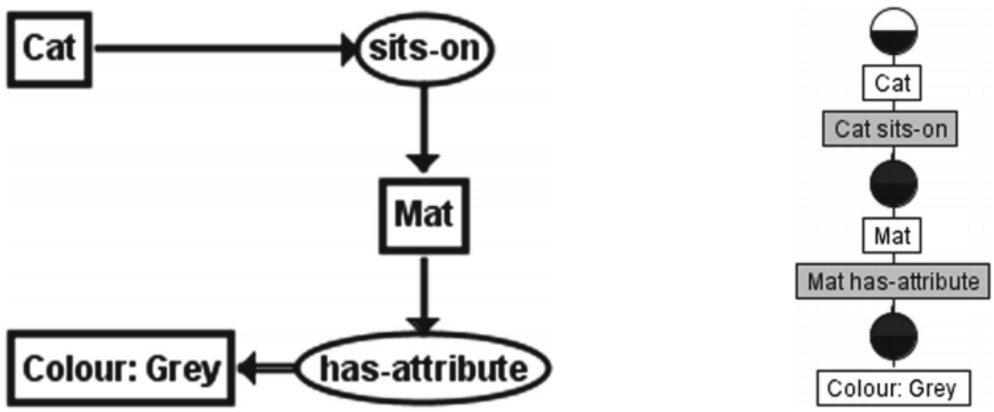


Figure 5.4: Simple CG and FCL for simple CG (Andrews and Polovina, 2018)

The set of captured binary relations for this Formal Concept Lattice (FCL) are shown below in Figure 5.5. The rows represent CG Concepts and columns CG Source Concept-relations, the cross table is then known as a Formal Context in FCA, so by converting CGs into these binary relations, FCA can then be applied (Andrews and Polovina, 2018).

| Simple CG | Cat sits-on | Mat has-attribute |
|---|---|---|
| *Cat* | | |
| *Mat* | × | |
| *Colour : Grey* | × | × |

Figure 5.5: The Simple CG as a cross table (Andrews and Polovina, 2018)

CGs are an expressive form of digraphs which allow the user to model and express meaning in a form which is logically precise but at the same time easy for humans to read. Andrews and Polovina (2018) have shown that through using FCA a model comprised of CGs can by validated. Thus FCA provides a solution for discovering failed ontologies in an OWA KR scenario (refer to Section 4.3.2), since FCA finds CGs which are incorrectly linked together.

## 5.7 Conclusions in Chapter 5

Through a literature search this Chapter has introduced the concepts of CGs and CL, showing how Conceptual Structures can provide a solution for EA modelling in IS.

EA modelling can be a challenging task since in practice Enterprise Systems (ES) are only a small subset of information systems which form a small part of a much larger information processing environment. Well designed ES can provide numerous advantages to an organisation, such as faster information transactions and better financial management to name but two (Davenport et al., 2000).

Key to both EA and the Internet or more precisely the Semantic Web is the concept of a triple. When using RDFs (refer to Section 4.2.1) the triple consists of a subject, a predicate and an object and when using a CG the triple is formed using Concept Nodes and Relation nodes.

RDFs are stored using an XML syntax which although easy for machines to interpret is difficult for humans to read. Whereas as CGs can be defined using the CL protocol CGIF, although the standard has not yet gained wide spread usage, some work has been completed on the draft version (Sastry, 2001), the standard still offers possibilities for defining CGs in a format which is both human readable and can be interpreted easily by machines.

Further benefits to using CGs (stored in CGIFs) as opposed to using RDFs (stored in XML), can be seen when the KR chosen to store the data uses a CWA (refer to Section 4.3.2), since the semantics of the KR will be more closely defined.

Thus this Chapter has presented a clear path to using Conceptual Structures, for a KMS which would enable an EA using a TOA.

# Chapter 6

# Research Methodology

## 6.1 Introduction

Critical to the development of a research project is the choice and usage of the correct research methodology. This chapter looks first at the two main forms of data collection; quantitative and qualitative. Then examines briefly the details of three separate research methodologies commonly used for Information Systems Research; Action Research, Case Study research and Design Science research. These three methodologies are compared and then in conclusion details are provided of the research methodology chosen and the reasons for its choice.

Qualitative research in information systems has been steadily increasing and depending on the philosophical assumptions of the researcher there is a discussion between positivism vs. interpretivism in IS qualitative research. A third option is to follow the paradigm of pragmatism when using qualitative research which is associated with action intervention and constructive knowledge.

Pragmatist thinking has been seen to positively influence IS research although the paradigmatic foundations are not always fully acknowledged. The pragmatism paradigm is concerned with action and change to enable the connection between determining knowledge and intervening in the real-world and not merely observing. Meaning that the intervention or organisational change or building of artefacts using design research allow the practitioner of pragmatic research paradigm to observe the interplay between knowledge and action Goldkuhl (2012, 2011).

## 6.2 Data Collection

In the academic arena there is a continuing discussion of the merits of two different forms of data collection; quantitative and qualitative. Quantitative research data collection in the form of numbers or figures commonly taken from mathematical modelling, statistical analysis and laboratory experiments. Qualitative research data collection is conducted in natural settings and uses data in the form of words rather than numbers. Qualitative data is gathered primarily from observations, interviews, and documents which are then analysed using a variety of systematic techniques (Kaplan and Maxwell, 2005).

Previously quantitative research data was considered to be superior to qualitative research data, however it is now widely accepted that qualitative analysis methods can be as productive when used in the correct context.

Quantitative methods are excellent when studying the evaluation of complex questions. For example research questions which analyse the features of information technology solutions. Where the organization, the user and the information need to be treated as independent, objective, and discrete entities. These entities are usually considered to be constant over the course of the research study. Qualitative methods are primarily inductive where hypotheses are developed during the study so as to take into account what is being learned about the setting and the people within it (Kaplan and Maxwell, 2005).

When deciding which method of data collection to use, the researcher must look to see which approach is more appropriate, this will of course depend on the research topic and the research questions which are being addressed. The power of qualitative methods for IS research can be attributed to their ability to describe what is actually occurring within an organisation or business process.

Qualitative data collection is often used when the research practitioner must look at and understand the ill-structured and fuzzy world of complex organizations, people and the complexity of business processes which are what make organizations so complex and different (Olesen and Myers, 1999).

Since the aim of this thesis question is to learn about the impact of conceptual structures on transaction data and Enterprise Architecture practices which can be considered to be a complex question. The intention of this research was to develop the Hypotheses during the study using data recorded, during AR in the form of words rather than numbers taking into account what is being learned about the subject matter. Thus qualitative data collection was chosen as the most appropriate form of data collection for this research.

## 6.3 Action Research (AR)

AR uses qualitative research data to combine theory and practice through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework (Nielsen et al., 1999).

Researchers and practitioners using Action Research work together in an iterative process involving a specific cycle of activities, which commonly include (i) problem diagnosis, (ii) action intervention, and (iii) reflective learning. The emphasis of Action Research is to collaborate with multiple practitioners on the same information system, business process or problem domain, thus allowing for the investigation of complex real-life situations.

Researchers using Action Research must adhere to following the cycles of Action Research as shown in Figure 6.1 from Susman and Evered (1978), taking great care to document each step of the iterative process.

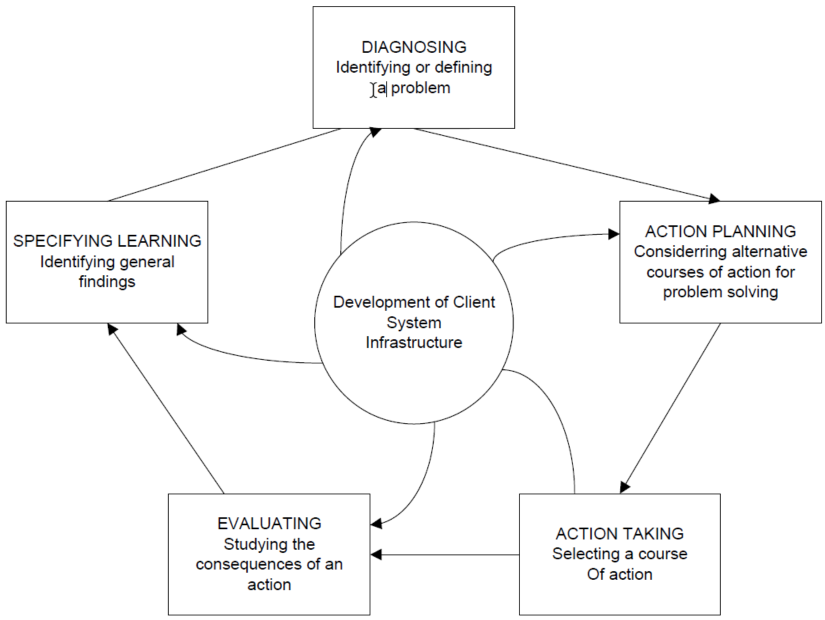


Figure 6.1: The cyclical process of Action Research (AR) (Susman and Evered, 1978)

The approach taken must be clearly set out at the beginning of the research process, defining the aim the of theory and the methods intended to be used. These methods must then be applied and adhered to throughout the whole process. Naturally the researcher may experiment on improving the documentation, diaries and concept maps during the research process.

As with other research methodologies explicit criteria should be defined before performing the research in order to be able to evaluate the outcome later. This information can then be fed into further iterations and cycles to refine the process of problem diagnosis and action intervention, which leads subsequently to reflective learning. Unless these steps are followed, the process could be described as action (but not research) or research (but not Action Research).

One of the key factors to successful Action Research is that practitioners must explain their approach and its application, via proper documentation since it is the process and not only the data which will be evaluated. Action Research also encourages researchers to experiment through integration and to reflect on the effects of their intervention and the implication on their theories (Olesen and Myers, 1999).

Practitioners using Action Research, must be careful to explicitly follow the tenets of AR otherwise their research into real-life problems could be deemed to be more akin to consulting work. Whilst using Action Research, if practitioners only interview and observe people in real-life situation, without the prospect of a proposed intervention, then this can not be deemed to be Action Research. Since then this process would be instead described as case study research. Since case-study research frequently reports what practitioners say they do, whilst in Action Research, the goal is more on what practitioners actually do (Nielsen et al., 1999).

Researchers and practitioners working together using Action Research, must work under a mutually acceptable ethical framework which becomes part of the definition of the research cycle. Unless this ethical framework is clearly defined there is the possibility of conflicts between the actors which can only lead to problems and conflicts within the research framework (Nielsen et al., 1999).

## 6.4 Case Study

The case study research methodology is defined as a research methodology which is based on interviews which can be used in a postgraduate thesis involving a body of knowledge. The methodology is usually used to investigate a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident. Using the case study approach allows the practitioner to investigate the phenomenon in a natural setting using multiple sources of evidence, through multiple 'cases'. The definition of the unit of the 'case' is dependent on the initial research questions which were defined Yin (1994).

Due to the requirement of realism for case study research, generally the research problems chosen, are topics which are usually more descriptive than prescriptive. Thus no positivist experiments or cause-and-effect paths are required to solve the research problem. For case study research, the problem is usually a "how do?" problem rather than a “how should?” problem, since case study research is more usually concerned with describing real world phenomena rather than developing normative decision models. Since provisional theory building rather than theory testing is the aim of the final thesis the final conclusions usually present the “how do” research problem based on a model of boxes and connecting lines. In case study research the prior theory informs the interview protocol used for data collection, meaning that the prior theory informs the main data collection equally. Thus case study research is suited to studying theories where it only takes one case that is inconsistent with a theory to invalidate it (Perry, 1998). The key characteristics of the case study approach identified by Benbasat et al. (1987) are detailed below in Table 6.1.

| **No.** | **Characteristic** |
|---|---|
| 1 | Phenomenon is examined in a natural setting |
| 2 | Data are collected by multiple means |
| 3 | One or few entities (person, group, or organization) are examined |
| 4 | The complexity of the unit is studied intensively |
| 5 | Case studies are more suitable for the exploration, classification and hypothesis development stages of the knowledge building process; the investigator should have a receptive attitude towards exploration |
| 6 | No experimental controls or manipulation are involved |
| 7 | The investigator may not specify the set of independent and dependent variables in advance |
| 8 | The results derived depend heavily on the integrative powers of the investigator |
| 9 | Changes in site selection and data collection methods could take place as the investigator develops new hypotheses. |
| 10 | Case research is useful in the study of ”why” and ”how” questions because these deal with operational links to be traced over time rather than with frequency or incidence |
| 11 | The focus is on contemporary events |

Table 6.1: Key Characteristics of Case Studies (Benbasat et al., 1987)

The context of IS is commonly characterized by constant technological change and innovation. Therefore IS researchers often find themselves trailing behind practitioners in proposing changes or in evaluating methods for developing new systems. Resulting in the fact that researchers usually learn by studying the innovations put in place by practitioners, rather than by providing the input of innovative ideas. There are three reasons why case study research can be seen as a suitable IS research strategy. (i) The practitioner can study information systems in a natural setting, learn about the state of the art, and generate theories from practice. (ii) The researcher can answer "how" and "why" questions which allow for the understanding the nature and complexity of the processes taking place. (iii) Case approach is an appropriate way to research an area in which few previous studies have been carried out (Benbasat et al., 1987).

## 6.5 Design Science Research Methodology (DSRM)

Previously the dominant research methods used for research into IS were generally those of traditional descriptive research methods which were borrowed from the social and natural sciences, such as case study described in the previous Section.

DSRM consists of the necessary principles, practices and procedures which are required to carry out IS research, since DSRM fulfils three important objectives: (i) consistent with prior literature, (ii) provides a nominal process model for doing DSRM (iii) provides a mental model for presenting and evaluating Design Science (DS) research in IS (Peffers et al., 2007).

For IS research DSRM provides a commonly accepted framework for successfully carrying out DS research and a mental model which allows for the presentation of the research.

The difference between DS and other paradigms, is that DS provides a framework for theory building, providing a solution and testing and evaluating the results against the theory. The key difference between research in an IS domain and research in natural sciences and social sciences, is that in the latter the practitioners are trying to develop an understanding of reality whereas in the former the practitioner is attempting to provide a framework which allows the user to develop a new reality.

DS provides a framework for creating and evaluating IT artefacts which are intended to solve an identified organizational problem. To make research contributions the DS process involves a set of defined steps which show how the design artefacts are then used to solve observed problems. The artefacts produced may include constructs, models, methods, and instantiations. Building upon existing theories and the current knowledge base the artefacts must be relevant to the solution of an unsolved and important business problem. During the evaluation the artefacts must be studied for their usefulness, quality, and efficacy. The design is then evaluated and the results communicated to the appropriate audiences (Peffers et al., 2007).

An important outcome of DSRM is that it provides a mental model for the characteristics of the research outputs. A mental model is a "small-scale [model]" of reality which can be analogous to an architect's models or to physicist's diagrams. So that the mental model provides structure of the situation which is been defined as opposed to the structure of logical forms which are used in formal rule theories. Commonly DSRM is defined as consisting of six key steps identified below in Table 6.2 (Järvinen, 2007; Peffers et al., 2007).

| Step | Description |
|---|---|
| 1 | **Problem identification and motivation.** Define the specific research problem and justify the value of a solution. Since the problem definition will be used to develop an artefact that can effectively provide a solution, it may be useful to atomize the problem conceptually so that the solution can capture its complexity. |
| 2 | **Define the objectives for a solution.** Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible. The objectives can be quantitative, e.g., terms in which a desirable solution would be better than current ones, or qualitative, e.g., a description of how a new artefact is expected to support solutions to problems not hitherto addressed. |
| 3 | **Design and development.** Create the artefact. Such artefacts are potentially constructs, models, methods, or instantiations. A design research artefact can be any designed object in which a research contribution is embedded in the design. |
| 4 | **Demonstration.** Demonstrate the use of the artefact to solve one or more instances of the problem. This could involve its use in experimentation, simulation, case study, proof, or other appropriate activity. Resources required for the demonstration include effective knowledge of how to use the artefact to solve the problem. |
| 5 | **Evaluation.** Observe and measure how well the artefact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artefact in the demonstration. It requires knowledge of relevant metrics and analysis techniques. |
| 6 | **Communication.** Communicate the problem and its importance, the artefact, its utility and novelty, the rigour of its design, and its effectiveness to researchers and other relevant audiences |

Table 6.2: Design Science Activities (Peffers et al., 2007)

Important in the application of the DSRM are the methods used for evaluation. Frameworks exist for the both the ex post perspective in which evaluation occurs after the construction of an IS artefact is complete and ex ante (prior to artefact construction) evaluation (Pries-Heje et al., 2008). In Chapter 9 a more detailed discussion of the different types of DSRM evaluation methods is presented and subsequently each of the artefacts are evaluated.

## 6.6 Conclusions in Chapter 6

DSRM has already a tradition in REA research since through the design cycles it offers relevance and rigour, providing the practitioner the ability to contextualize the design artefact(s) by referring to a practical problem in the real world (Geerts, 2011). This thesis uses the DSRM framework as the primary research method, since DSRM provides a structured approach to the development of theories and artefacts for an IS problem domain.

Action Research is used as secondary research method to provide a more granular basis for DSRM Step 3 : "Design and development", which required multiple minor iterations of the cyclical process of Action Research to produce the required artefacts, which would fulfil the goals set out in the primary research method DSRM step 2, "Define the objectives for a solution". For these multiple iterations of Action Research, the author worked together with the Director of Studies: Dr. Simon Polovina in what can be described as a single supervisor model, using this model the supervisor is not only an advisor and facilitator but is also considered to be a co-worker on the Action Research project (Zuber-Skerritt and Perry, 2002).

The case study approach is used also as a secondary research method for empirical inquiry and investigation required for DSRM step 4: "Demonstration".

When looking at the role of the researcher both DSRM and Action Research determine a similar role in that the researcher has a dual role as both researcher and implementer of the defined solution.

This thesis has been structured to include the 6 steps of the primary research method, DSRM as detailed below in Table 6.3:

| DSRM Step | Description |
|---|---|
| 1 | **Problem identification and motivation** - Chapter 1 |
| 2 | **Define the objectives for a solution** - Chapter 3 |
| 3 | **Design and development** - Chapter 7 |
| 4 | **Demonstration** - Chapter 8 |
| 5 | **Evaluation** - Chapter 9 |
| 6 | **Communication** - Chapter 10 |

Table 6.3: Design Science Activities within this thesis

# Chapter 7

# Implementation

**DSRM Step 3 - Design and development.** Create the artefact. Such artefacts are potentially constructs, models, methods, or instantiations. A design research artefact can be any designed object in which a research contribution is embedded in the design.

## 7.1 Introduction

This Chapter details the "Research Implementation", DSRM step 3, or what could be also called design and development. Design Science has had a dominant tradition in REA research since it provides relevance and rigour to the design cycle (Geerts, 2011). In Chapter 3 the objectives of the solution were identified, by presenting first "What" is currently available for CG tools, "Why" a solution is required and a description of "How" the problem can be solved.

Through a literature search this chapter identifies the state of the art through scientific and professional literature of currently available artefacts. Then as defined in Chapter 6, DSRM is used as a the primary research framework together with the secondary research method Action Research. Using the rigour of multiple Action Research cycles, an inspection is made of the foundation and innovative aspects of the design of the currently available artefacts.

Working together with domain experts, using the secondary research method of

Action Research in an iterative process involving multiple cycles of activities, which include (i) problem diagnosis, (ii) action intervention, and (iii) reflective learning. Through the presentation of the Action Research cycles, the design of the artefacts is defined, subsequently the artefacts are developed through an iterative process of radical innovation and continuous improvement (Laurier et al., 2018).

This Section forms the basis of "How" the solution can be solved, providing more details of the solution, using Action Research the question of "How" the problem can be solved is determined through multiple iterations of Action Research cycles.

In Figure 3.11 details of the four key requirements which were identified for a TOA KMS, these items are detailed for clarity again below.

- **Input** - conceptual structures CGs into the KR
- **Query** - the data/design in the KR
- **Validate** - the data/design in the KR
- **Output** - the data/design form the KR to other tools (e.g. Database Design schematic, or CharGer)

Through the AR cycles, the design artefacts are contextualized by referring to practical problems which are identified in the real world and detailed in the methodological approach. Using Action Research, the following key questions are addressed and evaluated ex ante in individual steps, using the DSRM principles of evaluation (described in Section 9.1), given the defined evaluation criteria and summarised in Table 7.1. The process of evaluation is detailed in Section 7.2.

| Step (EVAL) | Methodological approach | Eval. criteria | Eval. timing |
|---|---|---|---|
| 2.1 | How can REA/TOA ontology design be improved? | Technical and operational feasibility | Ex Ante |
| 2.2 | What is the best-practice for storing CGs in a KR? | Technical and operational feasibility | Ex Ante |
| 2.3 | Which Knowledge Repository (KR) structure: Closed World Assumption (CWA) or Open World Assumption (OWA) would provide best-practice for supporting a TOA EA? | Technical and operational feasibility | Ex Ante |
| 2.4 | How can the ISO CL standard, CG format CGIF be used to support type hierarchies when providing a framework for a TOA EA? | Technical and operational feasibility | Ex Ante |
| 2.5 | Which tools would be suitable for an REA ontology? | Technical and operational feasibility | Ex Ante |
| 2.6 | Evaluate CharGer | Technical and operational feasibility | Ex Ante |
| 2.7 | Evaluate Protégé 3.5 Frames | Technical and operational feasibility | Ex Ante |

Table 7.1: DSRM Evaluation Steps for Pre-existing Artefacts

Following the ex ante evaluation and the determination of a general solution Section 7.9, details the artefacts of the AREA KMS and the Protégé artefacts which were developed in an iterative process using development methods loosely coupled on Scrum (Baijens et al., 2020).

## 7.2 EVAL 2.1: How can REA/TOA ontology design be improved?

### 7.2.1 DIAGNOSING

This Section details the first AR cycle, which defines one of the important parts of this document, crucial to the research project that of determining what is required for further formalisation of the REA ontology, which would provide a framework for a TOA EA. REA provides a semantically rich business domain ontology however to allow for the ontology to be further exploited and thus fulfil the potential of providing a business domain ontology a clearly defined and explicit formal specification is required, supported by freely available software tools Gailly et al. (2008).

The requirement (referring to email B.2) is to enable the ability to transfer the "TM into rules for an agent's knowledge base, first by identifying the agents (from roles/stakeholders/actors/responsibility groupings) and then creating the appropriate TMs and then create a knowledge base". Therefore providing an automation which would allow the TM rules to be defined. Meaning that a TOA would "complement every existing design methodology by providing not only a means of generating an ontology, but also by making the ontology of use to an agent be describing the rules in agent-speak", with the secondary "benefit is that it side-steps our current difficulty in trying to identify all of the agents from the TM", thus allowing for "automation, in an area that is likely to produce more repeatable results".

Which leads to the question, how can a software KMS be used to allow the use of Conceptual Structures using the REA ontology to provide automation of design for capturing TOA scenarios ?

### 7.2.2 ACTION PLANNING

- Complete a literature research.

- Contact domain experts.

### 7.2.3 ACTION TAKING

- Through discussions with Dr Simon Polovina (SP), clear requirement identified, to capture TM referring to email: B.3.

- "We could take CharGer files and get them mapped into Jadex/JESS (rule engines for agents)" referring to email: B.3

- "rudimentary tools such as CoGui and CharGer are available" referring to email: B.3

- "BPMN as encountered in SAP NWCE" could be a solution, referring to email: B.3

### 7.2.4 EVALUATING

- There are currently tools which are available: CharGer, CoGui and Protégé, referring to email: B.2 and B.9

### 7.2.5 SPECIFYING LEARNING

- Clear requirement for TOA/REA tools.

- Further understanding of conceptual structures and the problem domain required.

- For example what is current best-practice for storing CGs?

## 7.3 EVAL 2.2: What is the best-practice for storing CGs in a KR?

Key to the capture of REA and a TOA is the requirement to define and process CGs, for this to be completed the CG's must be stored within a Knowledge Repository (KR), the question is what would be the most suitable format to store CG's within a KR.

### 7.3.1 DIAGNOSING

- What storage formats are currently available for defining and storing CGs?
- What are the advantages and disadvantages associated with each format?

### 7.3.2 ACTION PLANNING

- Complete literature search.
- Contact the Conceptual Structures Research Group mailing list cg@lists.iccs-conference.org and request information from domain experts regarding the formats which are available together with current usage of available formats.

### 7.3.3 ACTION TAKING

- Contacted CL work group - Conceptual Structures Research Group mailing list refer to email:B.27
- Two main contenders: OWL, refer to Section 4.2.3 and CGIF, refer to Section 5.4.2

### 7.3.4 EVALUATING

- OWL only allows for an OWA refer to Section 4.3.2.

- OWL is based on XML and thus difficult for human's to interpret, refer to Section A.2
- CGIF is not predicated on either OWA or CWA implementation.
- CGIF is intended to be both machine and human readable
- CGIF was defined for the capture of CG's
- CGIF has not yet been implemented within a tool, currently only a specification
- "we need a way to represent type and relation hierarchies in CGIF. However I do not agree that it should be in XML.", refer to email B.38

### 7.3.5 SPECIFYING LEARNING

- CGIF format preferred to RDF and XML due to easier human readability
- Although CGIF has not yet implemented, this specification from CL provides all that is required for defining CG's within a knowledge base.
- Opened up the question of whether a CWA or OWA KR is required (refer to Section 4.3.2) ?

## 7.4 EVAL 2.3: Which KR structure: CWA or OWA would provide best-practice for supporting a TOA EA?

### 7.4.1 DIAGNOSING

When looking at the question: Which Knowledge Repository (KR) structure: Closed World Assumption (CWA) or Open World Assumption (OWA) would provide best-practice for supporting a TOA EA? (refer to Section 4.3.2)? Using the Protégé KB this is the difference between the Frames (Protégé 3.x) and the OWL (Protégé 5.x) implementations refer to Section 4.3.2 for further details. Following the decision to use a CG storage format defined in the previous AR cycle as CGIF, a decision must now be made as to the most appropriate type of KR.

### 7.4.2 ACTION PLANNING

- Complete literature search
- Contact domain experts (Essential Project and other experts) and request information, clarification.

### 7.4.3 ACTION TAKING

- Contacted Essential Project, refer to email:B.20, why does Essential Project use Protégé Version 3.5 and the Frames KR?
- Contacted CS expert and CG practitioner refer to email:B.24.

### 7.4.4 EVALUATING

- Sengupta et al. (2011) states that "OWA is a reasonable assumption to make in the World Wide Web context (and thus for Semantic Web applications). However, situations naturally arise where it would be preferable to use the CWA, that is, statements which are not logical consequences of a given knowledge base are considered false. Such situations include, for example, when data is being retrieved from a database, or when data can be considered complete with respect to the application at hand". Given that an enterprise database is a requirement, a clear preference for a CWA Knowledge Repository (KR) is established.
- Essential Project team stated that Protégé Version 3.5 and the Frames KB are used because:

- OWL is not the correct approach, referring to emails:B.21 and B.22, Essential Project stated that they require a solution which focuses on data acquisition, OWL is too flexible, constraints on the meta-model are too loose, which means during data capture inconsistencies in the semantics can occur.
- Frames solution is more object-orientated, OWL does not provide support for multiple relationships, Whereas Frames allows more than 2 individuals to relate to a list, refer to email:B.23

• Other CG experts confirmed this opinion (from Essential Project), that OWL does not allow for easy meta-modelling, refer to email:B.25

• "There are other meta-logical issues – e.g., single vs. multiple super-types, etc." , refer to email:B.36

• "This is a problem with logics such as OWL, which allows classes to be specified by definition *and* by subclass statements. That is why many OWL developers use FCA to check OWL for contradictions.", refer to email:B.41

### 7.4.5 SPECIFYING LEARNING

• Clear preference for CWA has been established, refer to email B.39

• Protégé Version 3.5 and the Frames KB and a CWA provide a clear advantage (when defining an ontology for an Enterprise Architecture where data will be stored in an Enterprise Database) over the OWL solution and an OWA.

• However, how can the ISO CL CGIF standard be used to support type hierarchies when providing a framework for a TOA EA, which would be required for defining an REA Ontology?

## 7.5 EVAL 2.4: How can the ISO CL CGIF standard be used to support type hierarchies?

### 7.5.1 DIAGNOSING

To provide for a basis for defining a domain ontology (REA/TOA), the ability to define a type hierarchy is required, which would allow the practitioner to capture the REA ontology. Given that: (i) in the previous AR cycle, the decision was made to use the ISO CL CGIF standard for defining and storing CGs and (ii) there are no current software tools using CGIF to reference, the question now, is how can this (CGIF) standard also support type hierarchies when providing a framework for a TOA EA?

### 7.5.2 ACTION PLANNING

- Contact the Conceptual Structures Research Group mailing list cg@lists.iccs-conference.org and request information.
- Complete literature search.
- Contact domain experts.

### 7.5.3 ACTION TAKING

- "please could you thus support this in the CGIF export for the Type Hierarchy in CharGer", refer to emails:B.42 and B.43

### 7.5.4 EVALUATING

- The solution, "would be [Type: Employee] [Type: Manager] (subtype Employee Manager) and wouldn't need to be hard-coded, but interpreted accordingly by the tools." , refer to email:B.37

- Implementation of type hierarchies in CGIF is still under discussion - "Since type hierarchies aren't part of CL", refer to email: B.35.
- "John Heaton even went as far as making the type labels variables, thus providing a way around in CG", refer to email:B.40
- There are however concerns with the proposed solutions, "does this mean that all users of CGIF who want to use type hierarchies will use exactly this form to represent hierarchies. All CG systems that read CGIF would have to interpret it this way and all CG systems that write CGIF would have to export in this form. My discomfort is that the four of us have just standardized one way (out of several) to represent this", refer to email:B.44
- "This capability is needed if Richard and I are do anything with CGIF", refer to email:B.45

### 7.5.5 SPECIFYING LEARNING

- A solution could be through implementing in Protégé refer to email:B.41?
- "From my understanding we can use the 2007 version of CGIF to specify the hierarchy in this way." refer to email:B.42
- However before implementing new tools, are there any currently available tools which could also be used?

## 7.6 EVAL 2.5: Which tools would be suitable for an REA ontology?

### 7.6.1 DIAGNOSING

A clear decisions has now been made: use a CWA KR together with CGIF to store in CGs, which will support a type hierarchy. The question is now which which tools would provide this functionality and be suitable for an REA/TOA ontology?

### 7.6.2 ACTION PLANNING

- Contact the CharGer team and review the source code.
- Contact the CoGui team and review the source code.
- Contact the Cogitant team and review the source code.
- Contact the EssentialProject team.

### 7.6.3 ACTION TAKING

- Downloaded Cogitant code and produced working version, refer to email: B.32
- Review the Protégé manuals/technical documentation.
- Updated CoGui team with findings, refer to email: B.33

### 7.6.4 EVALUATING

- Cogitant not suitable and no longer maintained, refer to emails: B.17, B.18, B.19
- CoGui does not support CGIF, there is an implementation available, but this is poorly written and does not adhere to OO conventions/standards, refer to email: B.10

- “CoGui uses Coitant library which is no longer maintained”, refer to email: B.10

- The tool CharGer is worth further investigation in a further AR cycle below.

### 7.6.5 SPECIFYING LEARNING

- EssentialProject is already a commercial product, which does allow for easy research changes and modifications.

- EssentialProject use Protégé 3.5 using Frames and a CWA KB.

- Two possibilities remain: CharGer (refer to Section 7.7) and Protégé Frames 3.5 (refer to Section 7.8), both of which will be further investigated in AR cycles below.

## 7.7 EVAL 2.6: Evaluate CharGer

### 7.7.1 DIAGNOSING

CharGer is a candidate for a usable TOA Knowledge Management System (KMS) and thus merits further investigation.

### 7.7.2 ACTION PLANNING

- Contact CharGer team, detail requirements and request permission to access AND modify source code.

- Once permission granted for modification, use CharGer to produce REA ontology design.

### 7.7.3 ACTION TAKING

- CharGer team granted permission and provided source code (dropbox), but have (themselves) reservations about the quality of current code-base, refer to email: B.29
- Understood the intricacies of the CharGer implementation

### 7.7.4 EVALUATING

- CharGer's CGIF conversion poorly written, refer to email B.29
- CharGer needs completely re-writing, refer to email B.29

### 7.7.5 SPECIFYING LEARNING

- Too much effort required to modify CharGer code base for CGIF
- Updated CharGer with findings, refer to email B.34

## 7.8 EVAL 2.7: Evaluate Protégé 3.5 Frames

### 7.8.1 DIAGNOSING

Protégé is one of the most widely used software tools for building, developing and maintaining ontologies for knowledge based systems and Protégé is available under an open-source license (Musen, 2015). Clearly Protégé needs investigating further to see whether it can be used as-is or modified to enable an TOA/REA ontology tool.

### 7.8.2 ACTION PLANNING

- Review further the Protégé documentation
- Discuss Protégé with the EssentialProject team.

### 7.8.3 ACTION TAKING

- Documentation investigated
- Source code downloaded

### 7.8.4 EVALUATING

- Protégé Frames 3.5 supports CWA, KB
- Protégé is open source, modifications allowed
- Protégé has defined interface specifications for Input, Output, Validate and Query
- Protégé supports JESS for KB validation, refer to email B.2
- Protégé has the possibility to enable FCA for KB validation
- Protégé has its own tool to make Queries on the KB

### 7.8.5 SPECIFYING LEARNING

Protégé provides the necessary framework for a KMS, begin the implementation.

## 7.9 Protégé: Artefacts of the AREA KMS

The Protégé artefacts were developed in an iterative process using development principles loosely coupled on Scrum methods to provide for early results. In comparison with other agile methods, Scrum focuses on constant iteration which delivers quick incremental results (Baijens et al., 2020).

Scrum works in a similar way to traditional software development through defining a user story which describes a feature of/or a software product which is required. The user stories are further refined to deliver fully realized work items through each iteration process. Each user story or work item, should be independent, valuable, estimable, testable, and realizable. When Scrum is used in organisations with multiple team members Scrum has five events defined which include sprints, daily stand-up, retrospective, review and refinement. As previously defined in Section 6.6, the author was working together with the Director of Studies Dr. Simon Polovina in what can be defined as a single supervisor model, in which the advisor becomes a facilitator and co-worker on the project. Due to the relatively small size of the project team, in terms of team members (2), the Scrum process was only loosely coupled on these events (Baijens et al., 2020).

Each work item was given to a specific sprint process with each sprint cycle, been roughly a fixed period (1-4 weeks). The goal of each sprint was the completion of a work item, the activities been those required to design, develop and implement a software work item.

Sprint reviews were completed together in the form of ad-hoc meetings and formal PhD supervision meetings where the results of each of the sprints were presented and discussed RF/SP) (excerpts detailed in Section B.1). These meetings also included a form of sprint retrospective where the team reflected on the work and collaboration of the past sprint. During these meetings process improvements requiring implementation in future sprints were then defined. Finally these meetings also detailed refinements where decisions were made of how the work items could be refined. Given the small size of the team, the traditional Scrum roles of Scrum Master, Product Owner, and Development Team were incorporated using the two team members. To keep this thesis concise the complete Scrum process will not be detailed within this document only the brief details necessary for documentation of the design and implementation of each work item.

Looking at the requirements for the AREA KMS detailed in Figure 7.1, each artefact is identified (ARTE) and given an ID, then in terms of Scrum, the "work items" or in terms of DSRM, the "artefacts" are defined in the following Table 7.2 together with the ARTEfact ID.

| Artefact (ARTE) ID | Name | Description |
|---|---|---|
| ARTE 1 | CG template for Protégé | Provides the framework to add CGs |
| ARTE 2 | REA template for Protégé | Provides the framework to add REA entities |
| ARTE 3 | CGimport - Protégé import tool | Enable the Input (import) of CGIF files. Fulfilment of key requirement:REQ K1 (refer to Table 3.4) |
| ARTE 4 | CGexport - Protégé export tool | Enable the Output (export) of CGIF files. Fulfilment of key Requirement:REQ K4 (refer to Table 3.4) |
| ARTE 5 | FCAView integration | Enable FCA Validation of CG/REA models. Fulfilment of key Requirement:REQ K3 (refer to Table 3.4) |
| ARTE 6 | JESS integration | Enable JESS Validation. Fulfilment of key Requirement:REQ K3 (refer to 3.4) |
| ARTE 7 | READBexport - Protégé export tool | Enable Database schema Output (export). Fulfilment of key Requirement:REQ K4 (refer to Table 3.4) |

Table 7.2: Artefacts Required for the AREA KMS

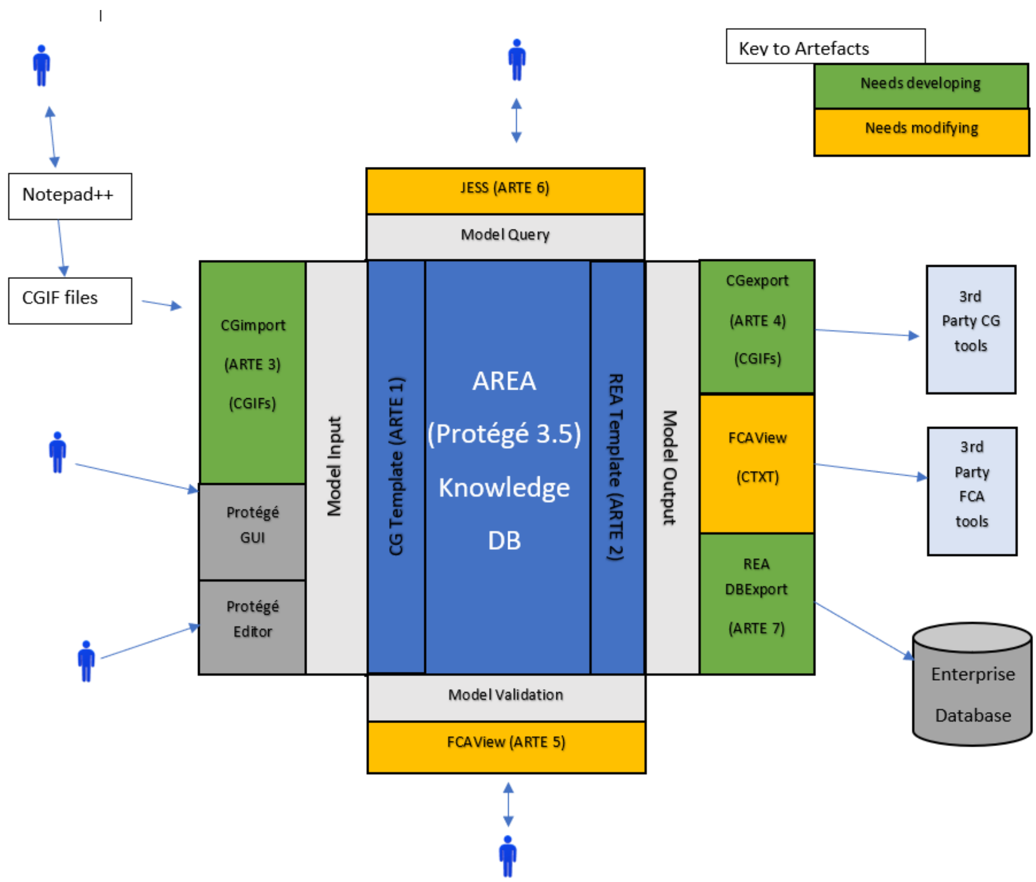


Figure 7.1: Artefacts Required for the AREA KMS

The development process was undertaken using the principles of a composite mash-up to provide a solution as quickly and efficiently as possible. Composite applications are constructed by connecting disparate software components together to generate a combination of new functionality, with little requirement to write any new code. Often the components which are used to build a composite application are built together using a connection via a Service Oriented Architecture (SOA) (Ngu et al., 2010).

Only applications were deemed to be suitable for the mash-up were those which have an open source software license and can therefore be modified when required. Using these two principles of integrating applications together where possible and modifying only when necessary, the Protégé-Frames framework was chosen, as detailed in the Action Research cycle refer to Section 7.8.

The heart of a successful Protégé-Frames project is the design of the class and slot structure of the ontology. Specifically the model used to build the ontology must balance the needs of the domain expert when defining and building the KB during the acquisition of domain knowledge, together with the requirements for problem solving methods and the application at run-time. Thus the model must be defined with a specific problem and problem-solving requirement in mind. The ontology must also be defined so that it can be used to generate and customize the appropriate Knowledge Analysis tools when required (*Protege-Frames User's Guide*, 2008).

Given these model requirements for a TOA, a Protégé model for the AREA KMS was defined using specific templates (refer to Sections 7.9.1 and 7.9.2) which would support and CG and REA ontology for an EA design.

The Protégé-Frames model for the AREA KMS does not imply a specific enterprise architecture implementation, thus the AREA KMS can complement other design methodologies which lack a requirements gathering stage.

The artefacts or work items produced using a mash-up of currently available tools and software to produce the AREA KMS are detailed below.

### 7.9.1 ARTE 1: CG template for Protégé

The first requirement or work item, was to develop a CG template for Protégé. This Protégé template shown below in Figure 7.2, provides the framework to which CGs can be added to Protégé using one of the three input methods: CGimport (refer to Section 7.9.3), Protégé GUI or Protégé editor.

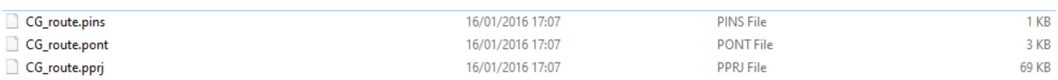


Figure 7.2: CG template for Protégé

Once the template has been loaded into Protégé manually or via CGimport, the template provides the basis for adding the CG design as detailed below in Figure 7.3.

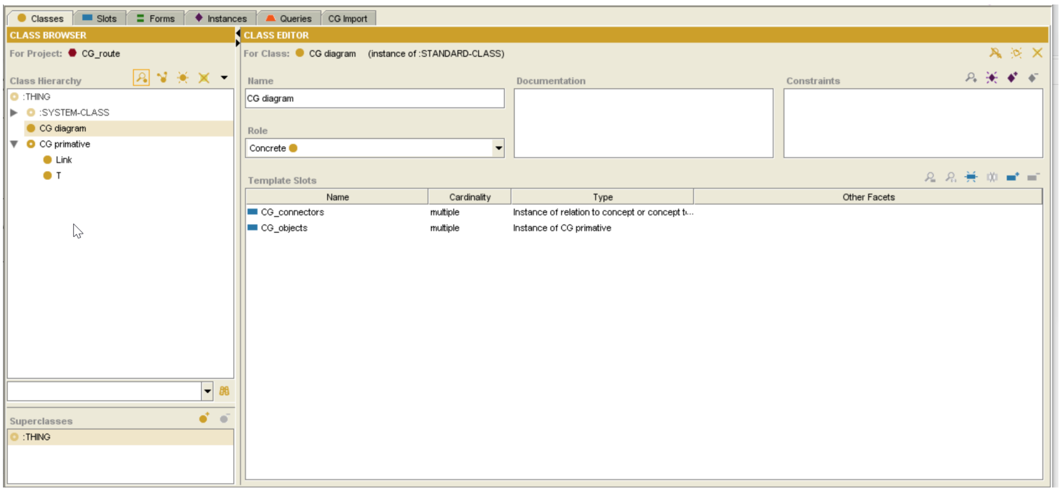


Figure 7.3: CG template loaded into Protégé

### 7.9.2 ARTE 2: REA template for Protégé

Additionally to the CG template above, a further requirement or work item, was the development of an REA template for Protégé based upon the CG template defined above in Section 7.9.1. This template shown below in Figure 7.4, provides the framework to which REA designs can be added to Protégé using one of the three input methods: CGimport (refer to Section 7.9.3), Protégé GUI or Protégé editor.

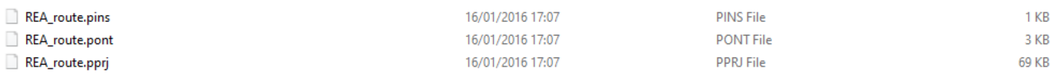


Figure 7.4: REA template for Protégé

Once the template has been loaded into Protégé manually or via CGimport, it provides the basis for adding REA entities to the model by defining each of REA entities as types as shown below in Figure 7.5.

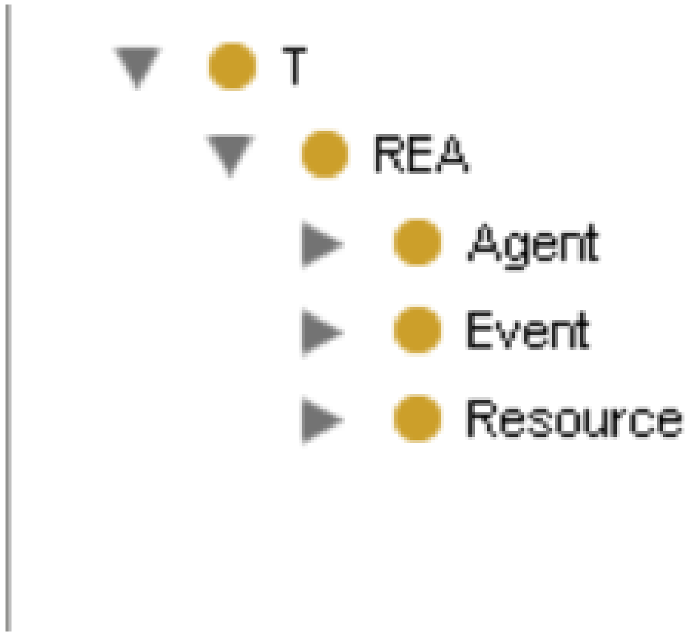


Figure 7.5: REA template loaded into Protégé

### 7.9.3 ARTE 3: CGimport - Protégé import tool

This artefact of the AREA KMS, allows the user to import CGs into Protégé, which have been defined in a standard text editor such as Notepad++ (refer to Section 8.4.2).

The work item is a Java program which is programmed to adhere to the Protégé plug-in specification so that it can be added to the Protégé runtime environment. The plug-in referenced and reused several design ideas and code from DataGenie which is an import tab plug-in that allows Protégé to read from arbitrary databases (*DataGenie Tab*, 2005).

The source code for the CGimport plug-in has an open source license and can be referenced here: Fallon (2015*c*).

### 7.9.4 ARTE 4: CGexport - Protégé export tool

This artefact, CGexport of the AREA KMS, allows the user to export the KB from Protégé in ISO CL CGIF standard. This allows CG and REA designs to be then shared with other tools, e.g. CharGer. Thus fulfils the design goal of interoperability, since it allows the user to share designs with other tools via CGIF.

The work item is a Java program which is programmed to adhere to the Protégé plug-in specification so that it can be added to the Protégé runtime environment. The plug-in referenced and reused several design ideas and code from Docgen which is a plug-in which provides the ability to export from Protégé all the content of an ontology (classes, instances and documentation) in various formats (*ProtegeDocgen*, 2008).

The source code for the CGexport plug-in has an open source license and can be referenced here Fallon (2015*b*).

### 7.9.5 ARTE 5: FCA integration

The Protégé template defined above in Section 7.9.1, was designed and configured to support the integration of the Protégé plug-in FCAView, developed by Jiang (2016). The FCAView Tab plug-in provides Protégé users the possibility to analyse and visualize Protégé ontologies stored in the KB using the principles of FCA. Briefly, FCA uses a mathematical approach to data analysis based on lattice theory and has been shown to aid ontology building in several studies (Polovina et al., 2016), for a more detailed discussion of the benefits of FCA refer to Section 5.6.

The support and integration of FCA for REA/TOA designs full-fills one of the goals defined for the AREA KMS, that of model validation as discussed in emails: B.53 and B.54.

The integration of FCAView also full-fills a further goal of the AREA KMS that of automation of the REA/TOA design process, since the designs can be validated from within Protégé. Previously FCA analysis has been only available by manual integration of separate tools.

### 7.9.6 ARTE 6: JESS integration

Java Expert System Shell (JESS) is a rule based expert system which can be tightly coupled to code written in JAVA. The JESS rules represent the heuristic knowledge of a human expert in some domain, and are executed against a knowledge base, which is typically an evolving ontology. The JESS rules constitute what could be considered an expert system which can provide reasoning to intelligent agents.

JESS can run independently without Protégé, but a JessTab has been implemented to provide the advantage of the JESS API to map information directly within the Protégé KB (Eriksson, 2003).

JESS development environment provides the user with a framework to create programs that perform operations on ontologies or modify a KB. Thus validation checks and rules can be defined with JESS, which can trigger actions after matching KB patterns. Other functions include recording the results of problem-solving methods in the KB (Eriksson, 2003).

The Protégé template defined above in Section 7.9.1, was designed and configured to support the integration of the Protégé plug-in JessTab.

The integration of JESS with the AREA KMS, full-fills one of the design goals, expressed in one of the early emails: B.2 that of providing a model query interface and also the possibility of adding automated validation checks (via JESS rules) on the REA/TOA ontology.

### 7.9.7 ARTE 7: READBexport - Protégé export tool

The goal of the REA DB Export artefact or work item, is to define a further Protégé plug-in READBExport, which will use the information stored within the KB, defining the REA/TOA ontology and produce a Database table creation schematic. Fulfilling the requirement of the RMW (shown in Figure 3.9), of exporting the "D: Technology Architecture". For example looking at the demonstration of a Credit card request in

Section 8.5.2, the attributes defined with the CGIF and stored with the Protégé KB, are mapped directly to the columns of the database table as shown below in Figure 7.6.

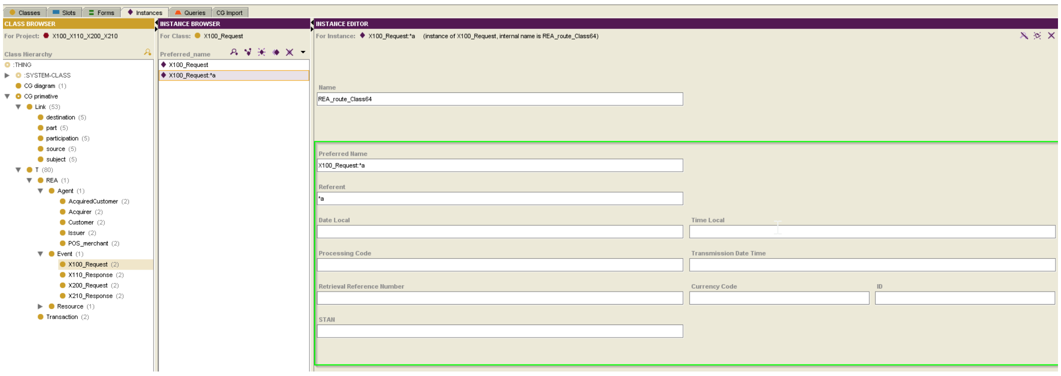

Figure 7.6: READB Export from Protégé

The Protégé export tool READBexport can support multiple different Database vendors. For example when using Microsoft SQL database the following output would be produced by READBexport (given the example shown above):

```
CREATE TABLE X100_Request (
    ID int,
    STAN varchar(255),
    Time_local_transaction time,
    Date_local_transaction date,
    Retrieval_reference_number varchar(255),
    Currency_code int,
);
```

The plug-in READexport full-fills a further design goal of the AREA KMS, that of interoperability, since it allows the user to export the KB from Protégé directly as a database schematic. Thus allowing the ontology modifications to be quickly reflected in the database design.

However as with all projects, time lines are finite and unfortunately the READexport work item was not completed.

## 7.10 Other artefacts

As part of the Scrum cycles other artefacts or work items were also produced or partly completed, which are not part of the AREA KMS. These Scrum cycles aided the understanding and implementation of other artefacts in the knowledge domain, but since they are not part of the AREA KMS they are only briefly detailed here.

### 7.10.1 3to2

Using the code from Andrews (2017a), further enhancements were made which allows the user to complete a conversion from CG into a FCA lattice, make amendments in the FCA lattice and then convert back into a CG using CGIF as the storage method. Although it turned out to have limited scope for usage, the 3to2 development process aided the understanding (learning process) of both FCA and conceptual structures (Fallon, 2015*a*).

### 7.10.2 EnterprisePlus and FCA

As detailed in the emails B.56, B.57, B.58 and B.59, there is a requirement to carry out FCA analysis within the EnterprisePlus tools. The initial development was started and made successful steps forward, however due to the requirement to complete this thesis the completion of the work has been put on hold.

## 7.11 Limitations of the approach

Although using Protégé frames version 3.5 to benefit from the CWA (refer to Section 4.3.2) provides the basis of an ontology KB framework which meets the initial requirements specification. There are some drawbacks to using a code base which is not as actively updated as the Protégé OWL 5.x codebase, such as no major new developments. There is however still an active support group providing feedback via:

https://mailman.stanford.edu/mailman/listinfo/protege-dev.

EssentialProject have also recognised this problem since their commercial product also relies on the Protégé frames version 3.5 codebase. Their solution to this problem, when necessary is to take over the open-source codebase and develop further as and when required, refer to email: B.21, "this has over time lead to something of a divergence with the Protégé development path, we are still convinced that we have taken the right approach. This may mean at some point that we have to take responsibility for the 'data management' side of the Essential toolset, e.g. by continuing to make Protégé 3.x available and running or build something based on it."

Protégé frames version 3.5 also has some technical drawbacks: (i) written using JAVA, the graphics seem now outdated, (ii) the auto-route feature needs also updating, (iii) it can be difficult to visualise large designs.

## 7.12 Conclusions in Chapter 7

In Chapter 3, the requirements were defined for a tool, the AREA KMS, required to capture TOA data flows; TC: REA, REA Enterprise Ontology, REA extensions and the Transaction Model. This chapter has taken these requirements and using multiple Action Research cycles evaluated the currently available artefacts using ex ante evaluation. From this evaluation, a specification was produced for a structured framework as a solution to the requirements. Working on the principles of using available open-source solutions where possible and only making modifications to the initial codebase where completely necessary.

This chapter also documents the process of development, once the basis for a framework was identified based upon Protégé frames version 3.5. The development process as detailed in Section 7.9 was loosely coupled on the principles of the agile development process Scrum.

This chapter has also detailed how the development process and specification of the solution has been guided also by the domain experts and the developers of the currently available tools (CharGer, EssentialProject, CoGui).

Such a development process is never completed without going down paths which, later prove to be unsuccessful (referring to other artefacts in Section 7.10.1), however this was of course part of the learning process. Naturally, there are nearly always parts of the solution which still require further work, but this leaves a path open to further researchers to advance this work further, since future developments can be undertaken, refer to Section 7.9.7.

In the following chapter 8, the completed AREA KMS is demonstrated showing how the requirements have been fulfilled and finally in chapter 9, a structured evaluation of the AREA KMS is presented.

# Chapter 8

# Demonstration

**DSRM Step 4 - Demonstration.** Demonstrate the use of the artifact to solve one or more instances of the problem. This could involve its use in experimentation, simulation, case study, proof, or other appropriate activity. Resources required for the demonstration include effective knowledge of how to use the artifact to solve the problem.

## 8.1 Introduction

This Chapter details the "Research Demonstration", DSRM step 4, where examples are presented that demonstrate the usefulness of the AREA KMS for supporting the design principles of a TOA. Also demonstrated is the viability of the individual artefacts of the AREA KMS, which form part of the justification that this research effort supports its goal and that the solution delivers the intended results that TOA enhances Semantics and Ontology in Enterprise Systems.

Using the AREA KMS and a TOA design approach, enables the early definition of domain knowledge, leading to the subsequent outputs for an ontology. The framework of the AREA KMS artefacts, incorporate a robust transaction model which allow for the representation of business transactions, which can be assembled at a much faster rate than working with manual individual design tools. A further positive effect is the confidence in the design produced since it relies on the basis of a solid TOA framework.

The demonstration takes two different paths: The first path provides a demonstration of each of the individual artefacts of the AREA KMS detailed in Section 8.3. Then because the research focuses on how data semantics and knowledge may be applied in industry rather than in an educational research in its own right, the second path demonstrates the solution: using the AREA KMS as a whole together with two industrial case-studies. The two case-studies (refer to Sections 8.5 and 8.6) demonstrate the finished artefacts in a native environment showing that they have utility, quality, and efficacy.

## 8.2 Protégé

This Section provides a brief demonstration of Protégé Frames 3.5, refer to Section 4.3.2 for more details on Protégé. The demonstration details the GUI interface, the structure of Classes, Instances and Slots etc. and how a (REA) type hierarchy has been added to the Protégé KB.

### 8.2.1 GUI Interface

Whilst CGImport is a powerful tool which allows the user to create and import the AREA KMS designs very quickly, AREA KMS designs can also be created using a blank Protégé project template. Or once CGImport is complete new entities can also be added as required. For example Figure 8.1 below shows how a "New Agent" has been added to a design which was first imported via CGImport.

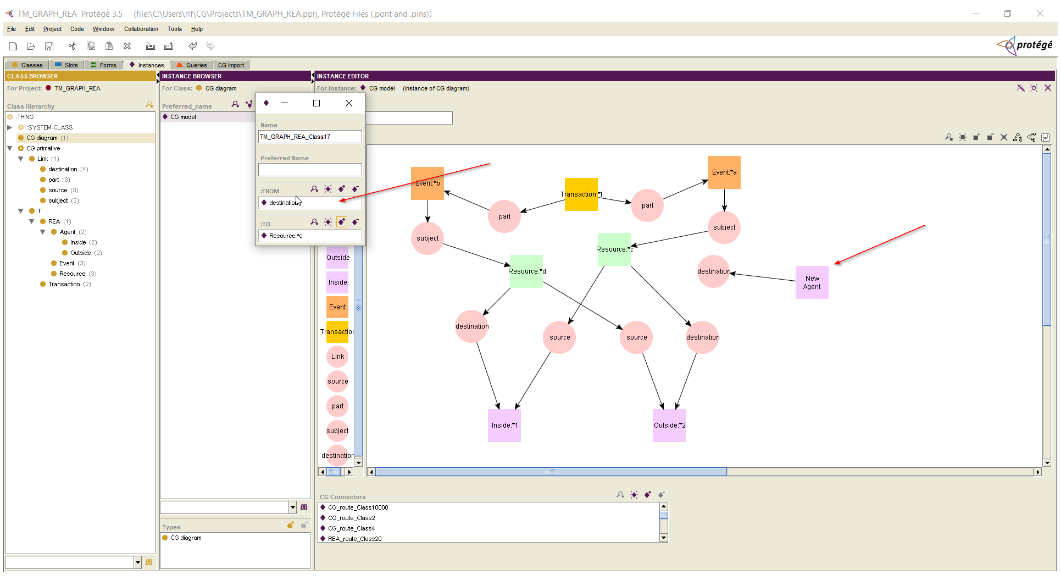

Figure 8.1: Protégé GUI Design

### 8.2.2 Classes

Protégé uses the concept of a "Class" for the definition of types, so that there is a type which is an object or concept (an Agent) which is called "Customer", which is defined in the KR as a class. The same concept is defined using CG as a concept node in CGIF format as "[Customer]", which is then defined as a class in the Protégé KB as shown in Figure 8.2.

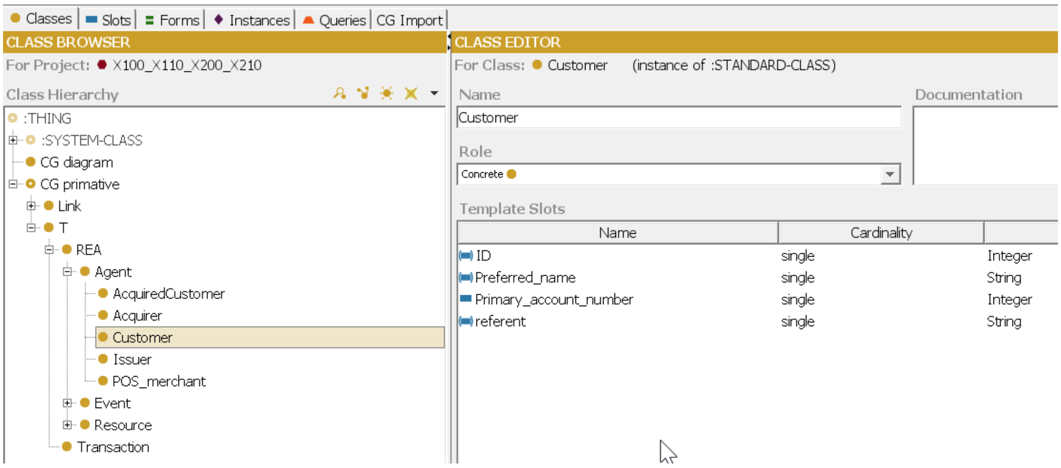


Figure 8.2: Protégé Classes

### 8.2.3 Instances

Protégé uses the concept of "Instance" for objects of a specific class or type, for example there is a type or class which is called an "Acquirer" of which there is a referent or instance of this type, which is called "*acq". Defined as a CG with as a referent of concept node in CGIF format as, "[Acquirer: *acq]". Which is subsequently defined as an instance of a class in the Protégé KB and is shown in Figure 8.3.

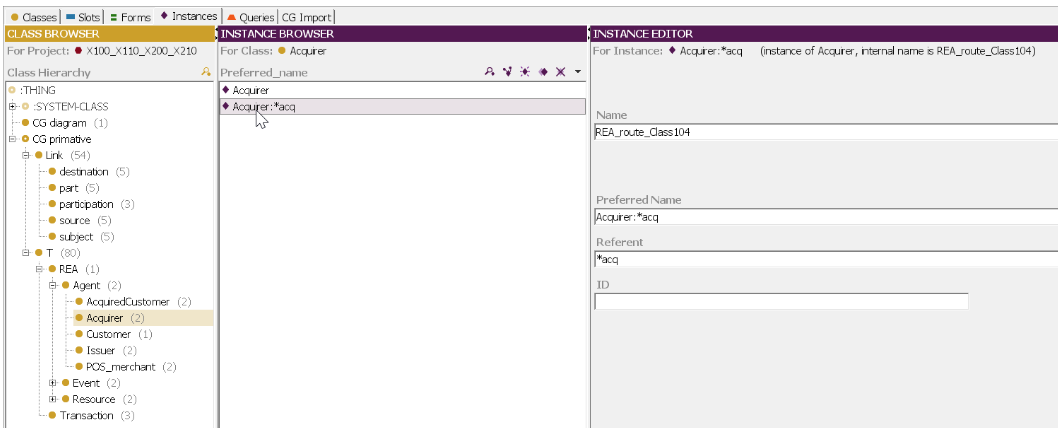


Figure 8.3: Protégé Instances

### 8.2.4 Slots

Protégé uses the concept of "Slots" for attributes of types or classes, so that for example, there is a type which is an object or concept which has an attribute e.g. STAN. Defined as a CG as an attribute in CGIF format for example "(attribute X200_Request STAN)". Which Is defined as an instance of a class in the Protégé KB and is shown in Figure 8.4.

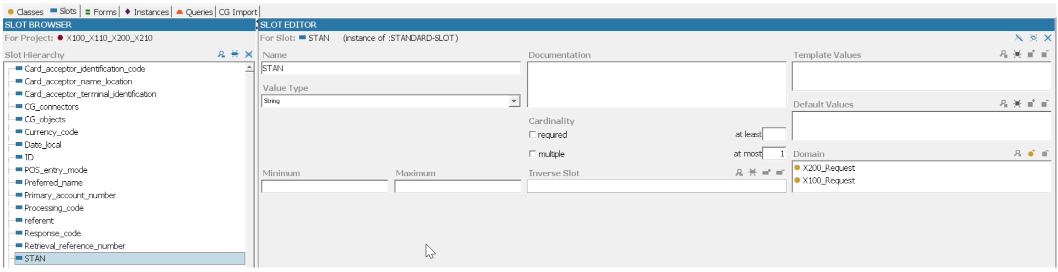


Figure 8.4: Protégé Slots, attributes of types

### 8.2.5 Sub-type relations

In Protégé, sub-type relations allow type hierarchies to be formed, a subtype is defined in CG in CGIF format for example as "(subtype Customer Agent)". Thus a subtype of a class can be shown in the Protégé KB as in Figure 8.5.

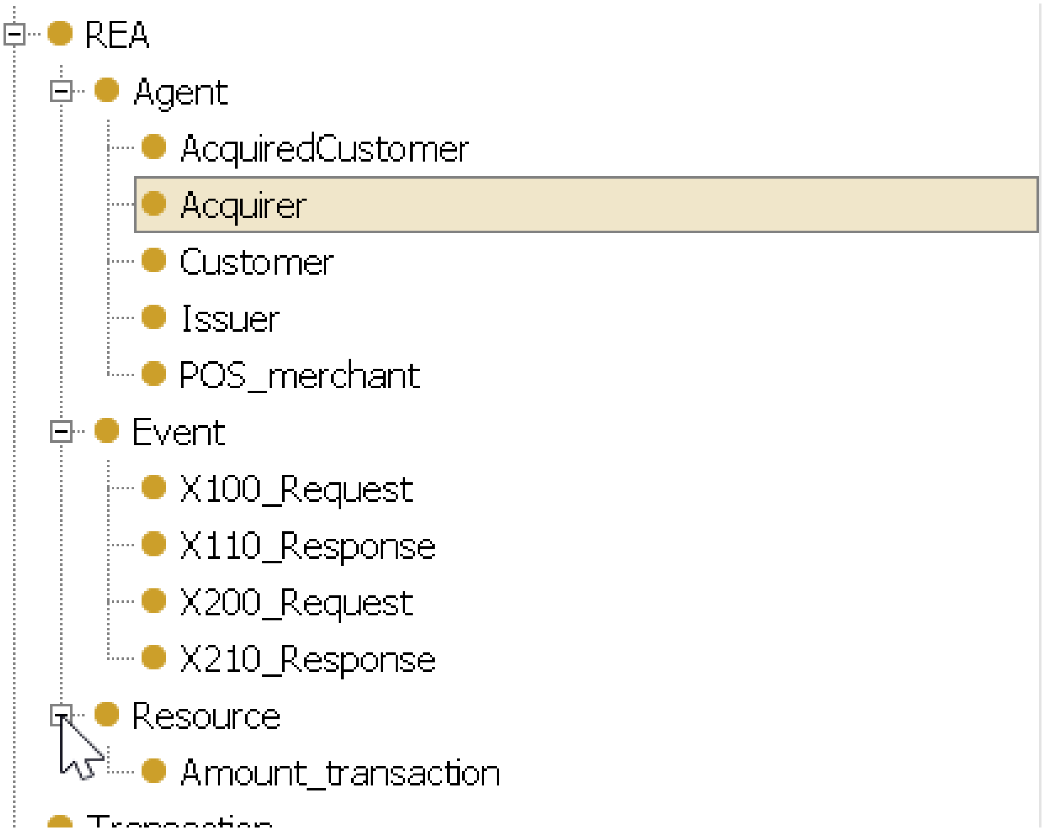


Figure 8.5: Protégé Sub-type relations

### 8.2.6 Instance-of relations

To allow the graphical display of type hierarchies there is an option to also add "extra" instance-of relations to the Protégé KB.

### 8.2.7 Shapes

To aid human readability, AREA KMS makes a differentiation between the shapes used for basic CG's and the shapes used for REA entities when drawn using the Protégé GUI. The **CG**s shapes of the different CG entities are defined as follows:

- **Concept** nodes are drawn as rectangles.
- **Relation** nodes are drawn as circles.
- **Arcs** are drawn as arrows.

The **REA** ontology uses the same shapes as for CGs, with the addition that (refer to Figure 8.6 below):

- **Resource** nodes are drawn as rectangles.
- **Event** nodes are drawn as rectangles.
- **Agent** nodes are drawn as rectangles.

### 8.2.8 Colours

To aid human readability the AREA KMS assigns the different CG/REA shapes with different colour as defined below. Here a differentiation is made between the colours used for basic CG shapes and the colours used for REA ontology shapes (refer to Figure 8.6 below), **CG** colours are defined as:

- **Concept** nodes are drawn in Yellow
- **Relation** nodes are drawn in Pink
- **Arcs** are drawn in black

The **REA** ontology uses the same shapes and colours as for CGs, with the addition that for REA:

- **Resources** are drawn in Green
- **Events** are drawn in Orange
- **Agents** are drawn in Lilac


Figure 8.6: CGs and REA Shapes and Colours

## 8.3 Protégé: Artefacts of the AREA KMS

This Section demonstrates the utility of each of the individual artefacts which are part of the framework of the AREA KMS.

### 8.3.1 ARTE 1: CG template for Protégé

To enable the import of CGs into Protégé, a CG template was defined within a Protégé project file, called CG_route.pprj. Using the selection shown below in Figure 8.7, this allows the user to import CGs in CGIF format using the artefact CGimport (refer to Section 8.3.3 below).

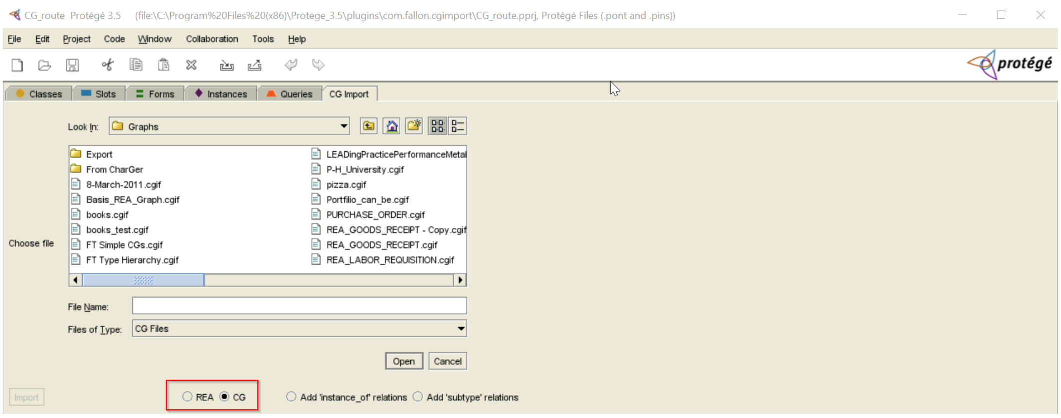


Figure 8.7: CG Import - Option CG

### 8.3.2 ARTE 2: REA template for Protégé

To enable the import of REA entities, using CGs into Protégé a CG template was defined within a Protégé project file, called REA_route.pprj. Using the selection shown above in Figure 8.7, this allows the user to import CGs in CGIF format using the artefact CGimport (refer to Section 8.3.3 below).

### 8.3.3 ARTE 3: CGImport - Protégé Import Tool

CGImport allows the user to import CG's which define either a CG or an REA design, defined using the ISO CL CGIF standard. Once the Protégé plug-in CGImport (Fallon, 2015*c*) is installed, the user should select as follows referring to the screen-shot below in Figure 8.8.

1. CG Import TAB.
2. Select to either import CG or REA defined file.
3. Add instance of relations if required.
4. Add subtype relations to display a more detailed class map.
5. Import the design.

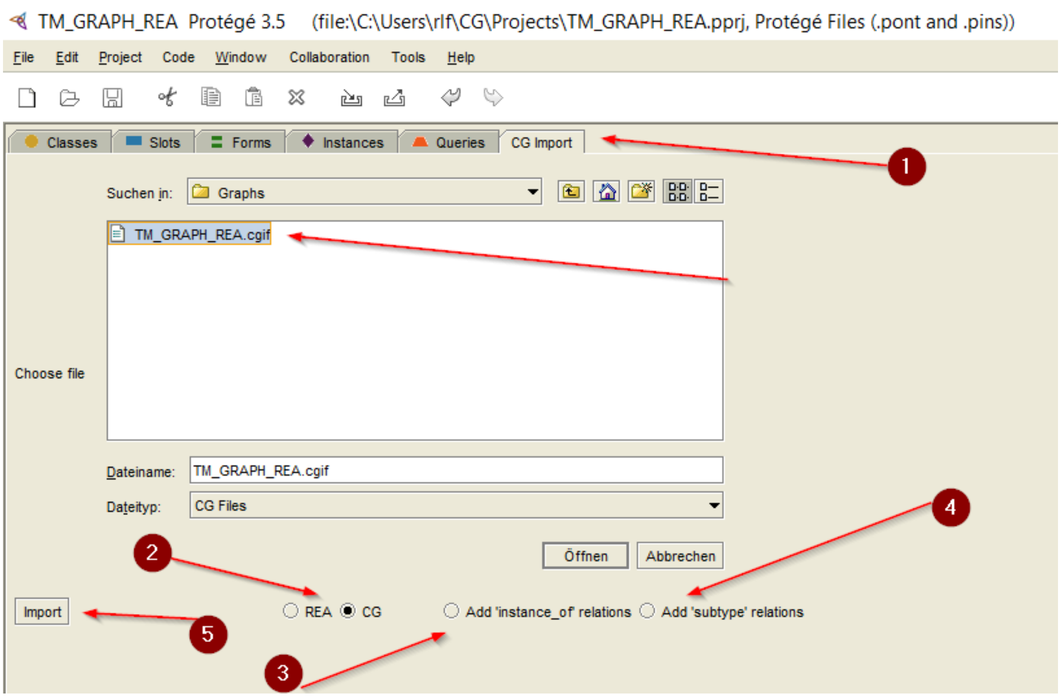


Figure 8.8: CG Import - step 1

Once CGImport is complete the user receives a list of the imported entities, refer to Figure 8.9 below.

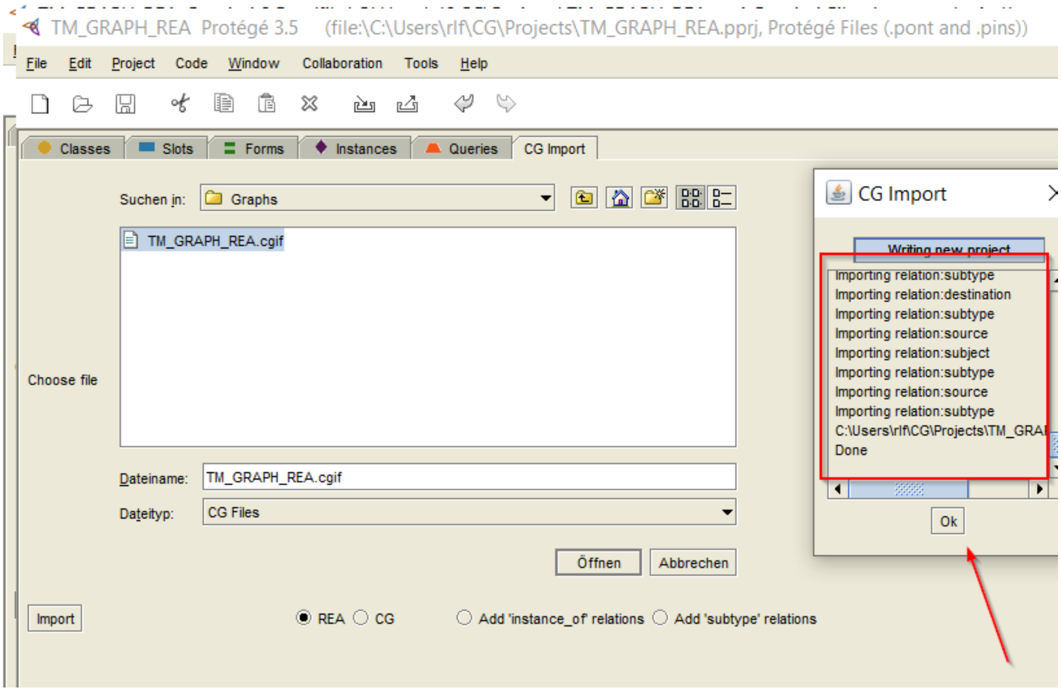


Figure 8.9: CG Import - step 2

The new design is now located in a new Protégé project file which should now be Opened, as shown in Figure 8.10 below.

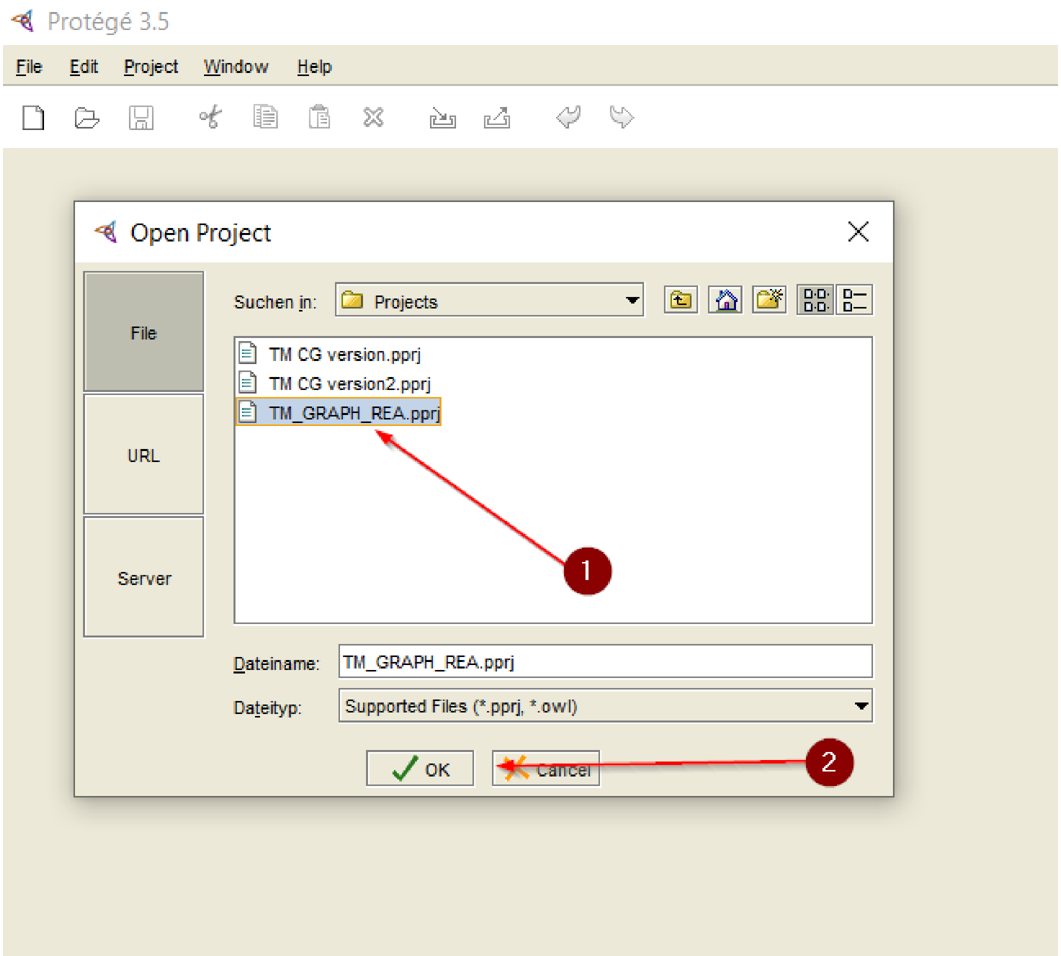


Figure 8.10: CG Import - step 3

Once the new Protégé project file is Opened, the new Class entities are detailed, refer to Figure 8.11 below.

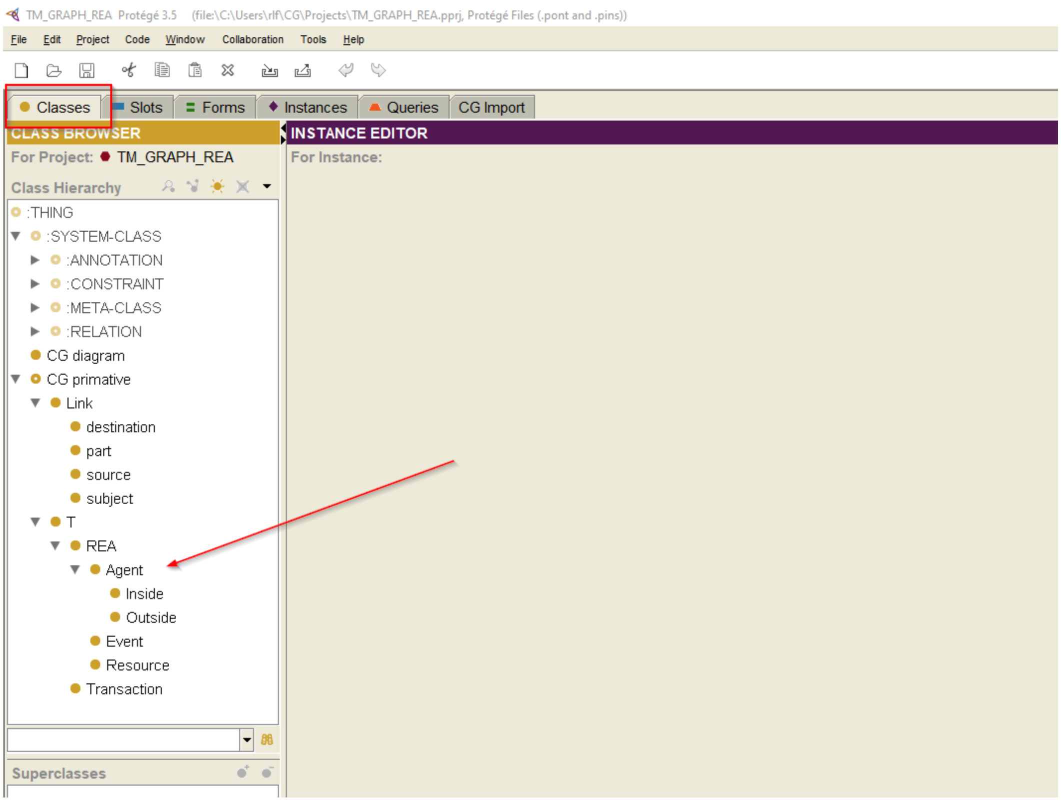


Figure 8.11: CG Import - step 4

When the user selects the Protégé *Instance tab*, the new Objects of the Class entities are detailed, refer to Figure 8.12 below.

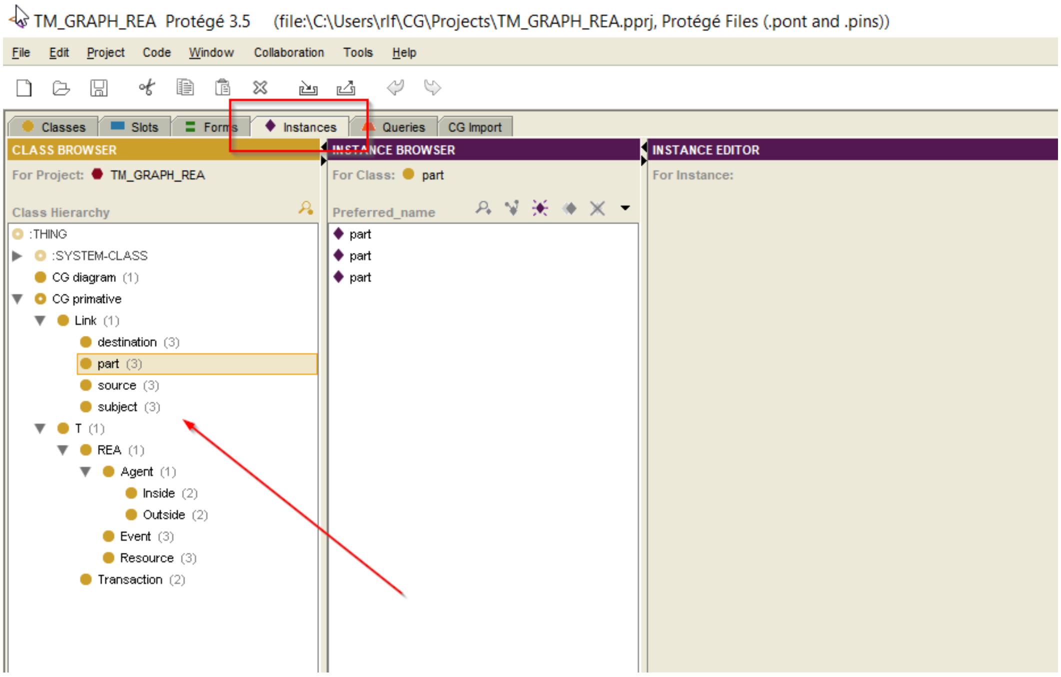


Figure 8.12: CG Import - step 5

CGImport has also created a CG Diagram, which when selected shows the REA entities, refer to Figure 8.13 below.

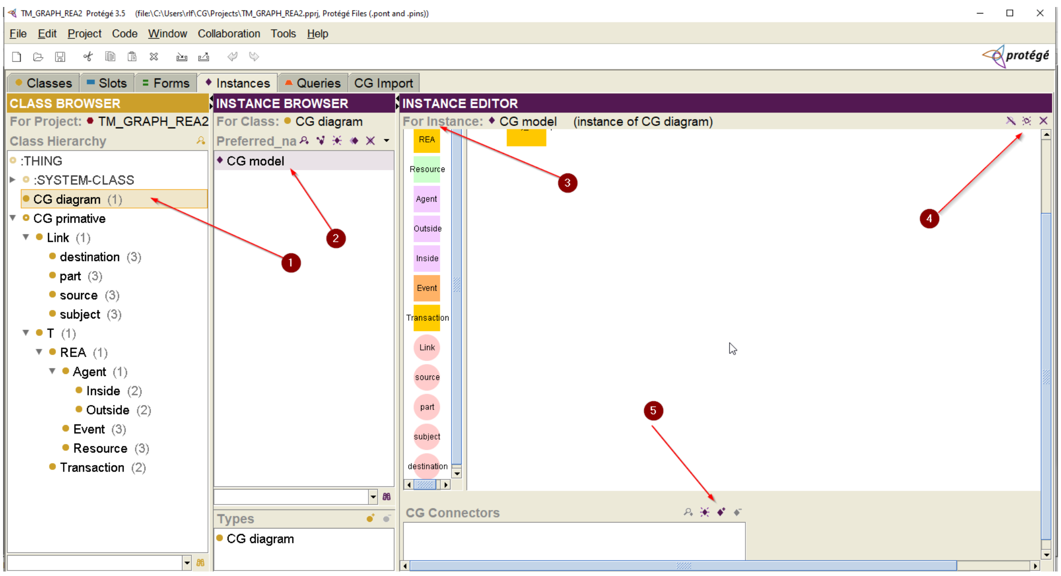


Figure 8.13: CG Import - step 6

The REA entities must now be added to the diagram, refer to Figure 8.14 below.

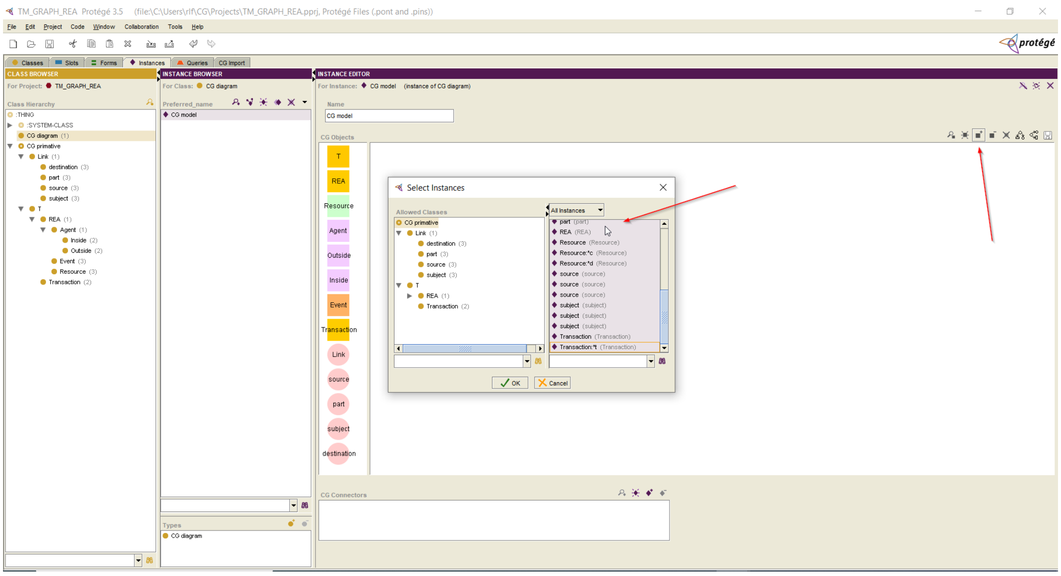

Figure 8.14: CG Import - step 7

The connections (concept to relation/relation to concepts) must also now be added to the diagram, refer to Figure 8.15 below.

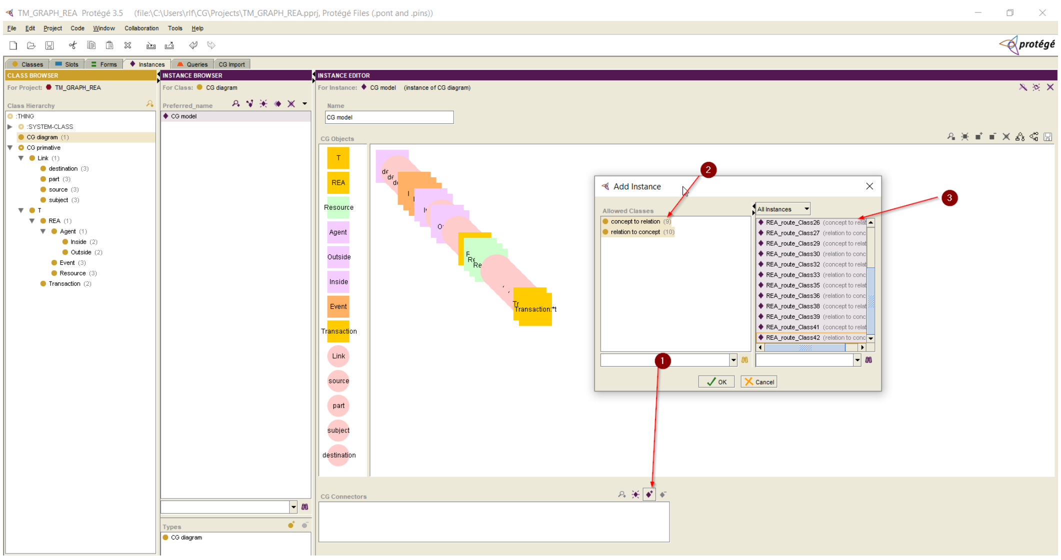

Figure 8.15: CG Import - step 8

Protégé now shows the REA diagram, before it is Auto-routed, refer to Figure 8.16 below.

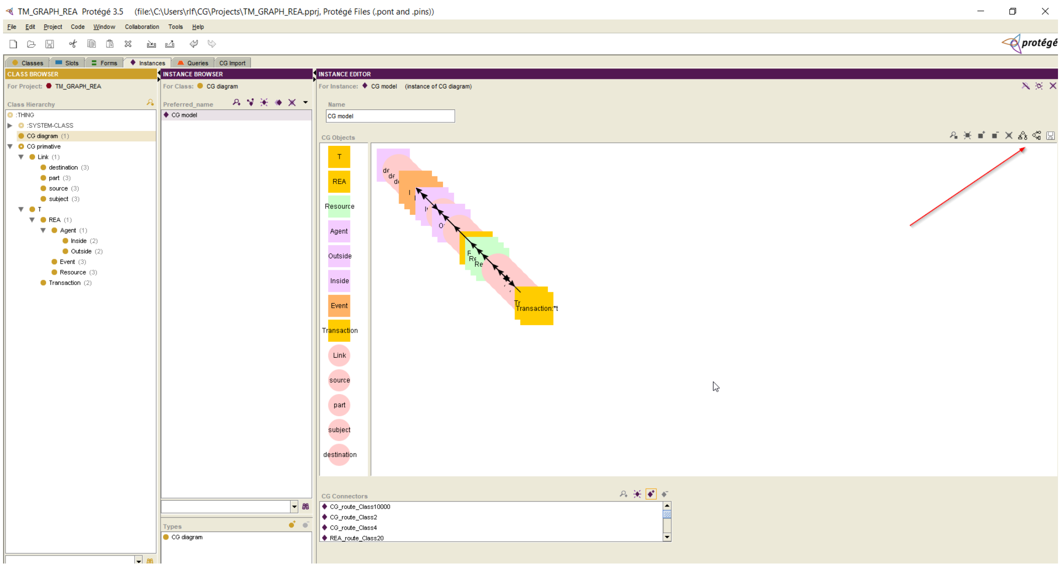


Figure 8.16: CG Import - step 9

Once auto-routed, the import of the design is complete the entities can still be moved around as required, refer to Figure 8.17 below.

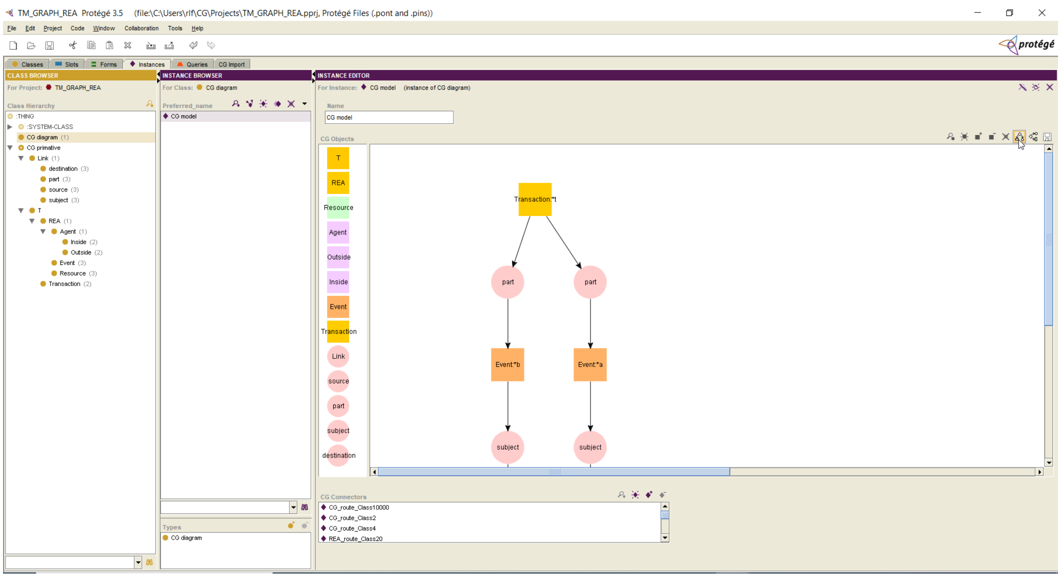


Figure 8.17: CG Import - step 10

### 8.3.4 ARTE 3: CGExport - Protégé Export Tool

As defined within the Table 3.6, one of the Architectural requirements (REQ A4) of the AREA KMS is interoperability, the possibility to also use other tools at different stages of design. To enable this the CGExport artefact was developed and can be used as defined below to export the current design in the ISO CL CGIF standard. The user selects the CGExport as shown in Figure 8.18 below.

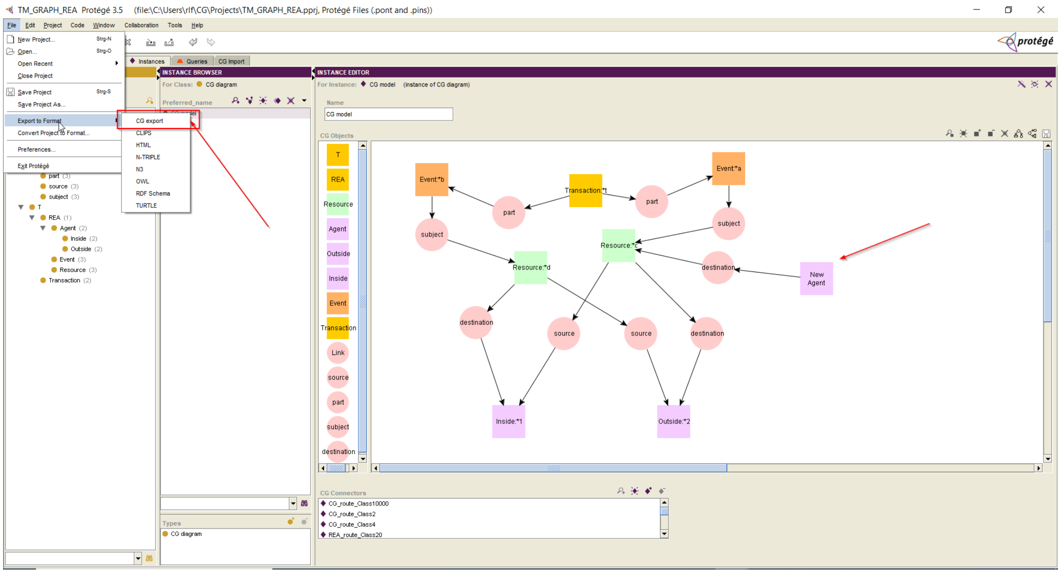

Figure 8.18: CG Export - step 1

Once complete CGExport shows the number of entities exported together with details of the CGIF file, refer to Figure 8.19 below.

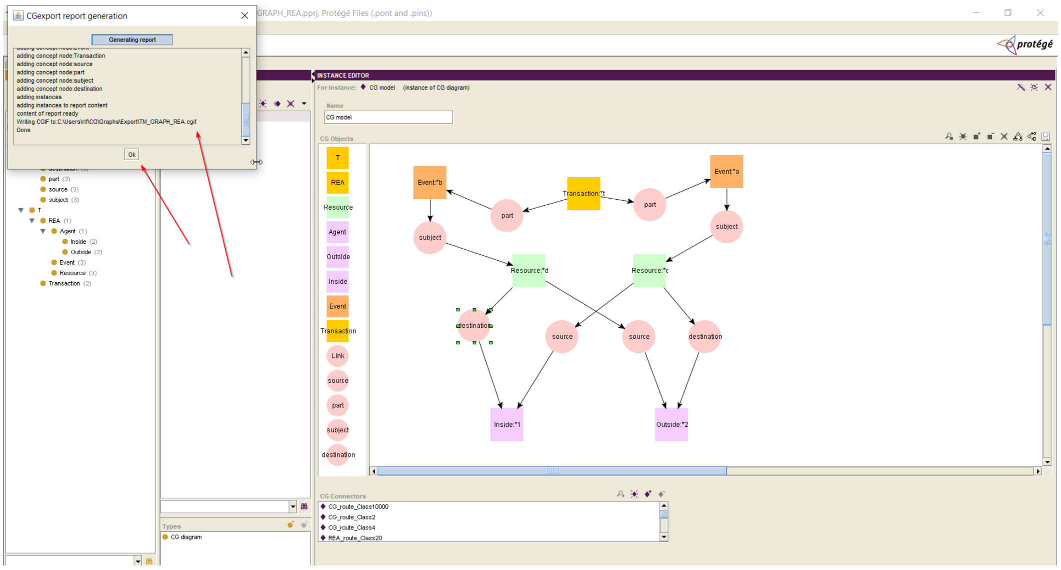

Figure 8.19: CG Export - step 2

For details of the content of the output in CGIF format refer to Section C.2.1.

### 8.3.5 ARTE 5: FCA Integration - FCAView

As defined within the Table 3.4, one of the Key requirements (REQ K3) of the AREA KMS is the possibility to use other tools to validate the model. To fulfil this requirement all the Protégé artefacts have been designed using an internal format which is compatible with the tool FCAView (Jiang, 2016), refer to Section 5.6 for more details of FCA. Therefore once the REA design has either been imported (CGImport) or designed using the GUI interface, the user can carry out FCA verification of the model, refer to Figure 8.20 below.

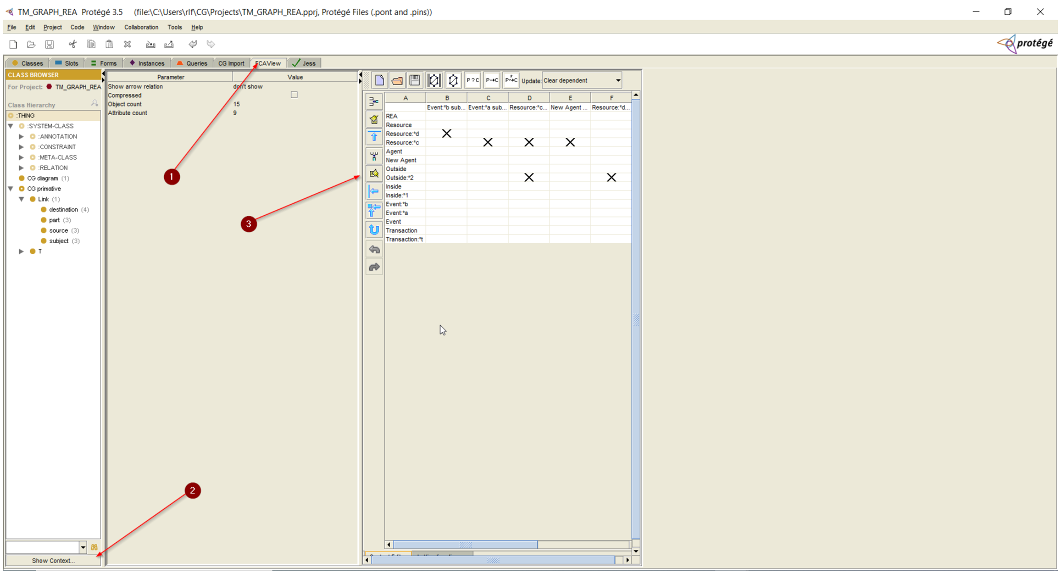

Figure 8.20: FCAView - step 1

After then selecting (2) "Show Context", the FCA lattice is shown, refer to Figure 8.21 below.

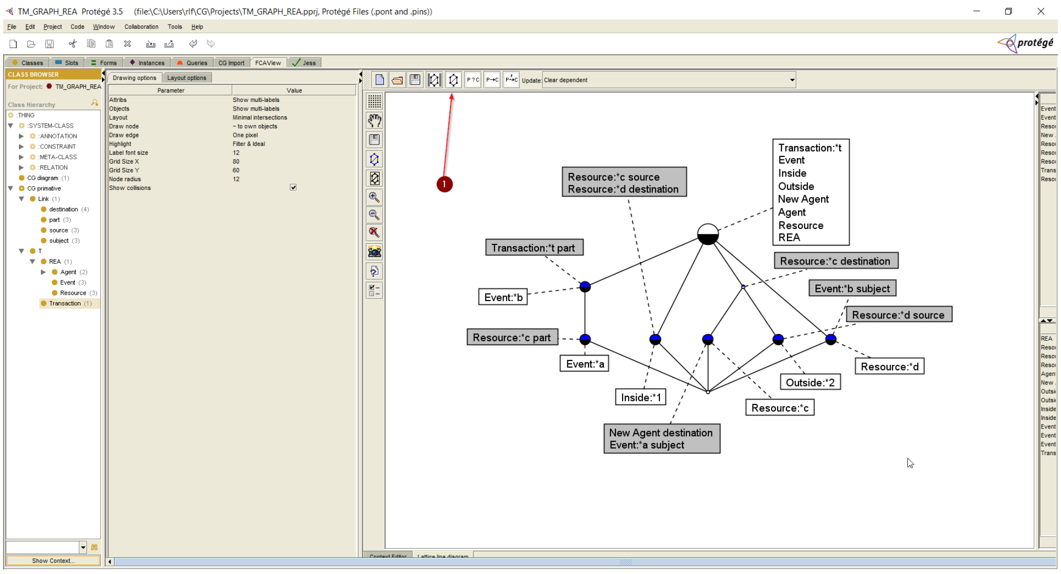


Figure 8.21: FCAView - step 2

The REA design can be viewed along side the FCA lattice refer to Figure 8.22 below, which enables the user to validate the model using this lattice diagram, thus enabling FCA.

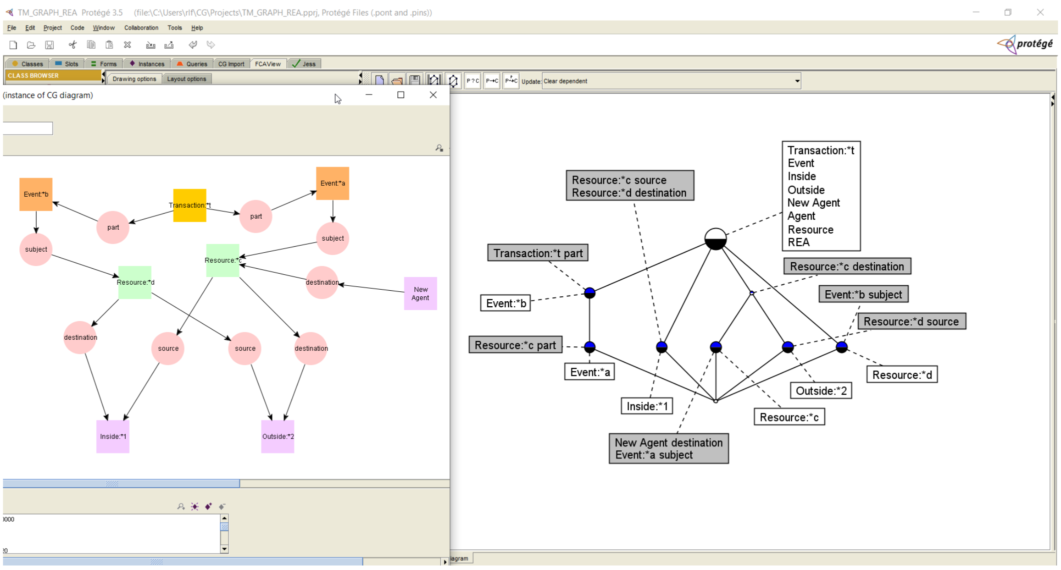


Figure 8.22: FCAView - step 3

Other options allow further details of the FCA lattice to be detailed, as shown in Figure 8.23 below.

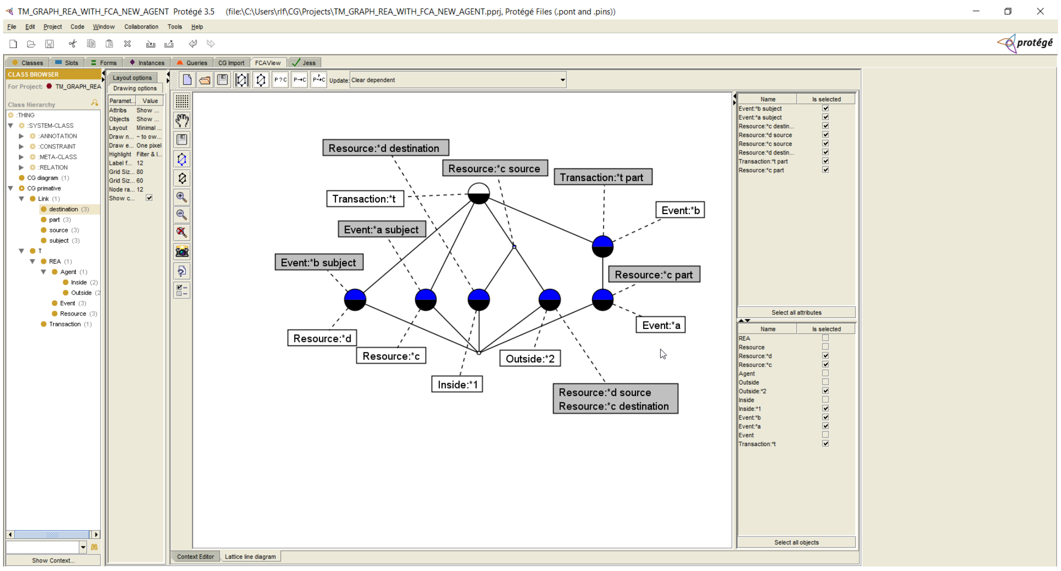


Figure 8.23: FCAView - step 4

### 8.3.6 ARTE 6: JESS Integration

Apart from using FCA to validate the model (detailed above in Section 8.3.5), JESS, provides a further set of functions for validation. Using the CG detailed in Section C.3.1 which was imported into Protégé together with the JESS script detailed in C.3.2. Thus demonstrating the use of JESS rules to validate the project as shown below in Figure 8.24. However the standard license of JESS when installed with Protégé, allows for only 30 days usage, to complete a more complex JESS demonstration/validation a full academic license would be required.

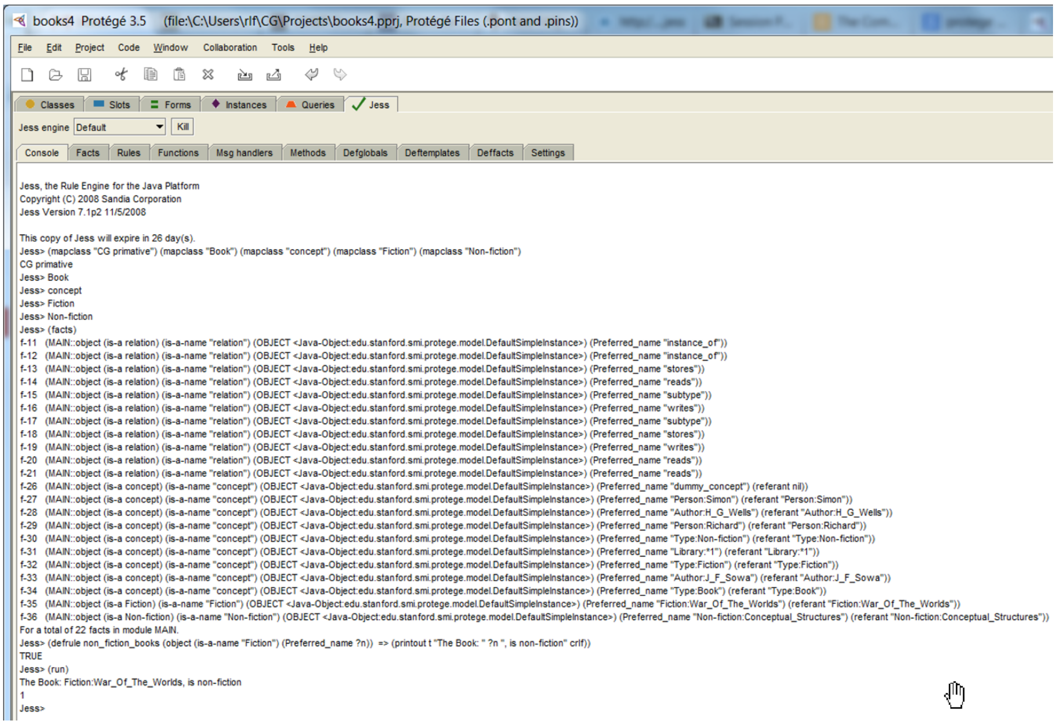


Figure 8.24: Demonstrating JESS rules

### 8.3.7 ARTE 7: READBexport - Protégé Export Tool

However as with all projects, time lines are finite and unfortunately the READexport work item/artefact was not completed, however this artefact provides an option for further work, discussed in Chapter 10.

## 8.4 Other Artefacts

### 8.4.1 LaTex Tools

The following LaTex macro, is used to allow the CGIF REA entities in Chapter C, to be colour coded, to aid readability.

```
\lstdefinelanguage{REA}{
morekeywords=[1]{subtype},
morekeywords=[2]{Resource},
morekeywords=[3]{Event},
morekeywords=[4]{Agent},
keywordstyle = [1]\color{Red},
```

```
keywordstyle = [2]\color{ForestGreen},
keywordstyle = [3]\color{Orange},
keywordstyle = [4]\color{Purple},
commentstyle=\color{blue},
sensitive=false, % keywords are not case-sensitive
morecomment=[l]{//}, % l is for line comment
morecomment=[s]{/*}{*/}, % s is for start and end delimiter
morestring=[b]" % defines that strings are
enclosed in double quotes
}
```

### 8.4.2 Notepad++

Using text editing tools to modify CGs in the ISO CL CGIF standard is straightforward and for example the open-source editor, Notepad++ (*Notepad++*, 2021) has automatic highlighting of key-words, for example in Figure 8.25 below all the "Resources" are highlighted. The development of a high-lighting Plug-in for Notepad++ which would highlight REA entities, would also be useful and provides an option for further work, discussed in Chapter 10.

```
/*first define the standard REA entities*/
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the entites */

/* Resources */


/* Events */


/* Agents */
[Inside][Outside]
(subtype Inside Agent)(subtype Outside Agent)

/* more types */
[Transaction]

/* define the new relationship-links */
[Link]
[part][source][subject][destination]
(subtype part Link)(subtype source Link)(subtype subject Link)(subtype destination Link)

/* define the types of the attributes */

/* the attributes themselves */

/* now the definition of the REA entites */
[Inside: *1][Outside: *2]
[Resource: *c][Resource: *d]
[Event: *a][Event: *b]
[Transaction: *t]
/* and their relationships */
(part ?t ?b)(part ?t ?a)
(subject ?b ?d)(subject ?a ?c)
(source ?c ?1)(source ?d ?2)
(destination ?d ?1)(destination ?c ?2)
```

Figure 8.25: Editing CGs in CGIF format with Notepad++

## 8.5 Case Study A - Card Payments

The AREA KMS is now demonstrated in relation to the implementation of a case-study of an ES processing financial card payments.

The basic process diagram for card payments, card-originated transactions is shown below in Figure 8.26.

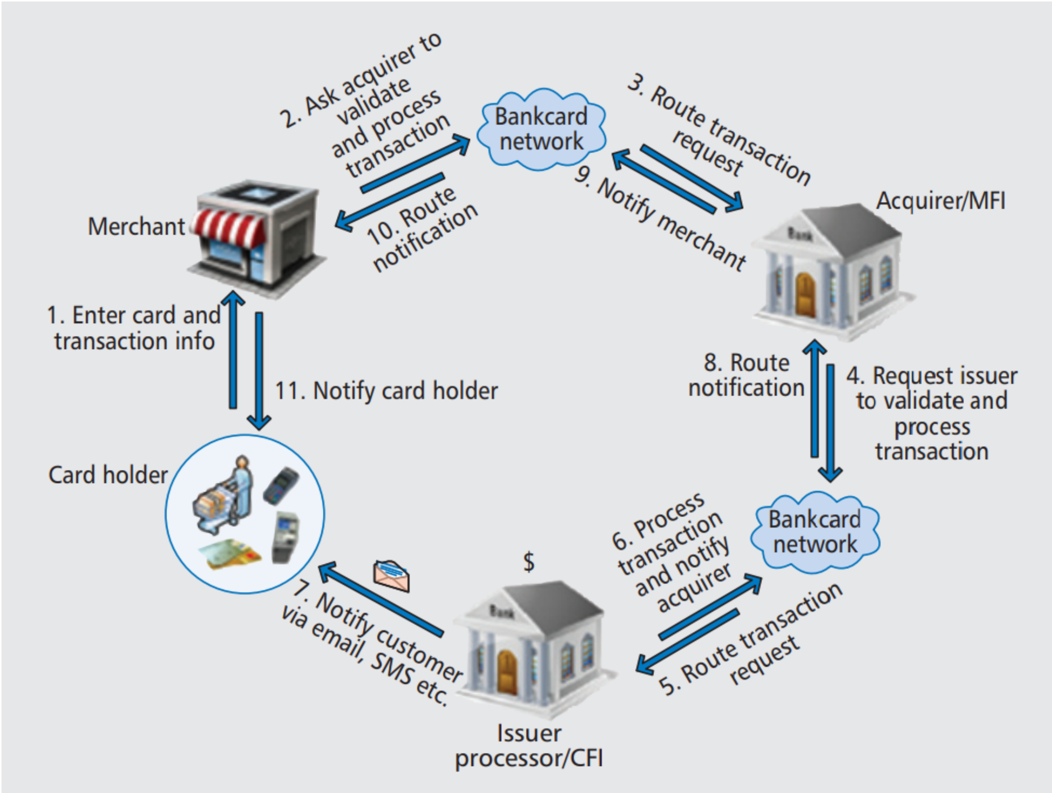


Figure 8.26: Basic process of a card-originated transactions (Mian et al., 2015)

Two points are worth noting when looking at the designs below: i) For the purposes of this thesis, so as to keep the design succinct not all of the design details are included for producing a complete solution, for example the Database transactions although crucial to a working system are not detailed. and ii) The TOA designs provide an EA solution for the perspective of institution A, in the diagrams below.

### 8.5.1 Enterprise Transactions

Enterprise Transactions allow for an (Agent) customer to make a card (debit or credit) (Event) payment either on-line, or at a Point Of Sale (POS) terminal or (Event) withdraw (Resource ) cash from an Automated Teller Machine (ATM) using the card from (Agent) Institution A. This enterprise transaction (of an ATM withdrawal) is detailed below example in Figure 8.27.

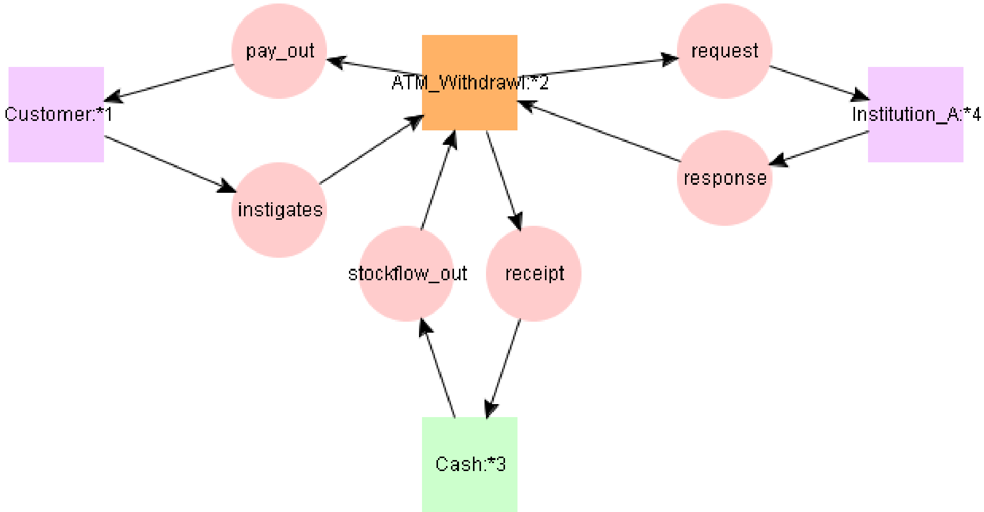


Figure 8.27: Enterprise Transaction - ATM Withdrawal[1]

### 8.5.2 Business Process transactions

To fulfil the Enterprise transactions, there are a set of standard messages or business transaction flows which are used. The card initiated transaction is transmitted from the POS or ATM (terminals), using a series of networks which routes the transactions through to the card issuer. The card issuer then authorises the transaction against the card holder's account. The transaction data contains information from the card (PAN, expiry date), from the terminal (transaction number, merchant data) and information added dynamically during the process and by the intervening systems (Mian et al., 2015).

The card issuer will authorize or decline the transaction and generate a response message which must be delivered back to the POS or ATM within a predefined time period usually around 30 seconds, otherwise the transaction times out.

The business transaction data which is transmitted over the series of networks is formatted using a ISO 8583 message format (*ISO 8583*, 2021). ISO 8583 defines

[1]This diagram was produced using the AREA KMS with the CGIF shown in Figure C.1.4

a common standard however there are variations and different systems may use the fields in different ways . Some fields are standards fields and have the same meaning for all systems however some fields are generic and can be used by each entity in a custom way. There are several versions of the ISO 8583 standard, based on the year of publications: 1987, 1993 and 2003. The 1987 version is still the most commonly used and for the purposes of this case study this version will be used.

**x0100/x0110 - Authorization message flow, Acquiring/Issuing Institution are the same** This is the most common business transaction or message flow, the customer requesting either a payment online, at a POS terminal or money withdrawal at an ATM. The authorization request message x0100 is sent to the card issuer for approval. The x0110 Response message is sent back to the terminal (POS, ATM, Internet) authorization of the purchase/money withdrawal.

The diagram detailed below in Figure 8.28, shows a very simple business transaction or authorisation message exchange, where a customer pays for goods at a merchant with a card. The merchant authorises the transaction using the merchants POS terminal which transmits the x0100 request to the acquirer, which responds with an x0110 response message. Since Institution (bank) A is both acquirer of the (terminal) request business transaction and issuer of the customers card, institution A can validate the card against the customers card details which it holds.

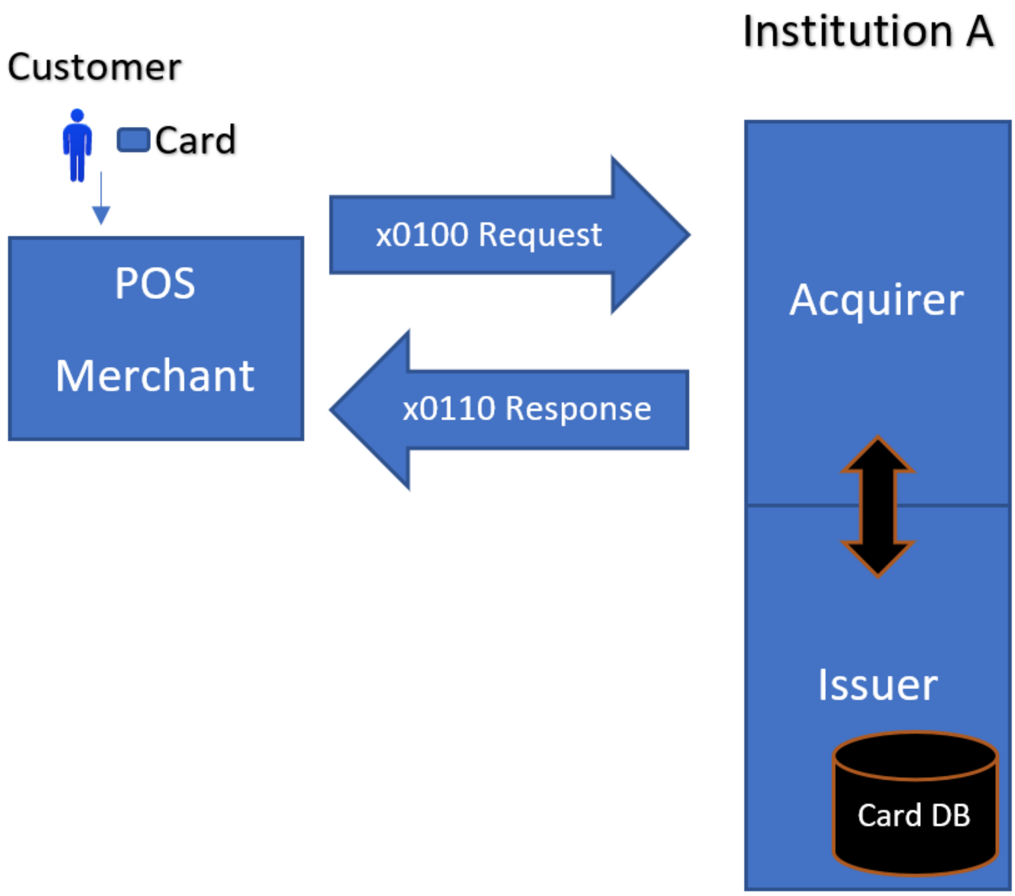


Figure 8.28: x0100/x0110 Message Exchange

When using the TM shown in Figure 3.3 and the AREA KMS a TOA design can be quickly produced. The auto-router in Protégé does not know about the sequence of the transaction/message flows, thus the request part (1) is on the right and the response (2) drawn on the left.

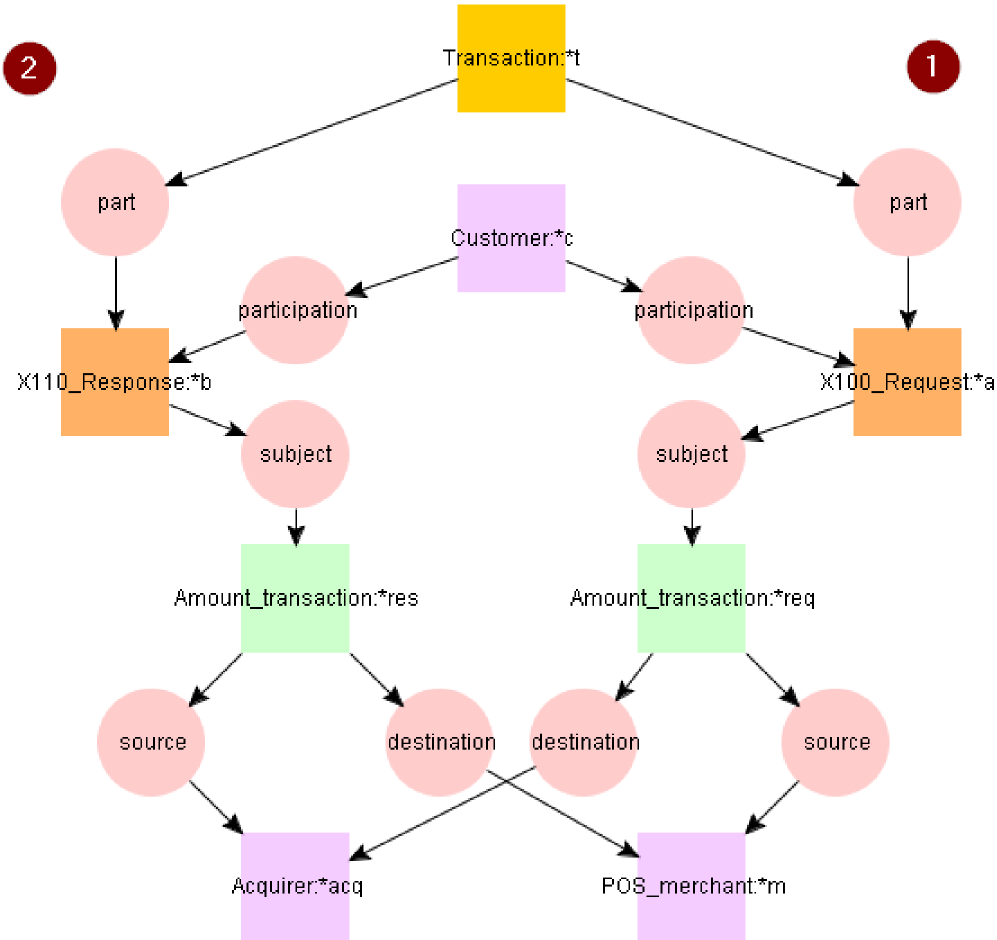


Figure 8.29: x0100/x0110 Authorisation message flow[2]

Looking at the details of the CGIF graph in Figure C.1.5, it can be seen that the details of the 0x0100 request message have been accurately added to Protégé. For example the CGIF statements defining the attributes, have been added to Protégé as shown below in Figure 8.30.

[2]This diagram was produced using the AREA KMS with the CGIF shown in Figure C.1.5

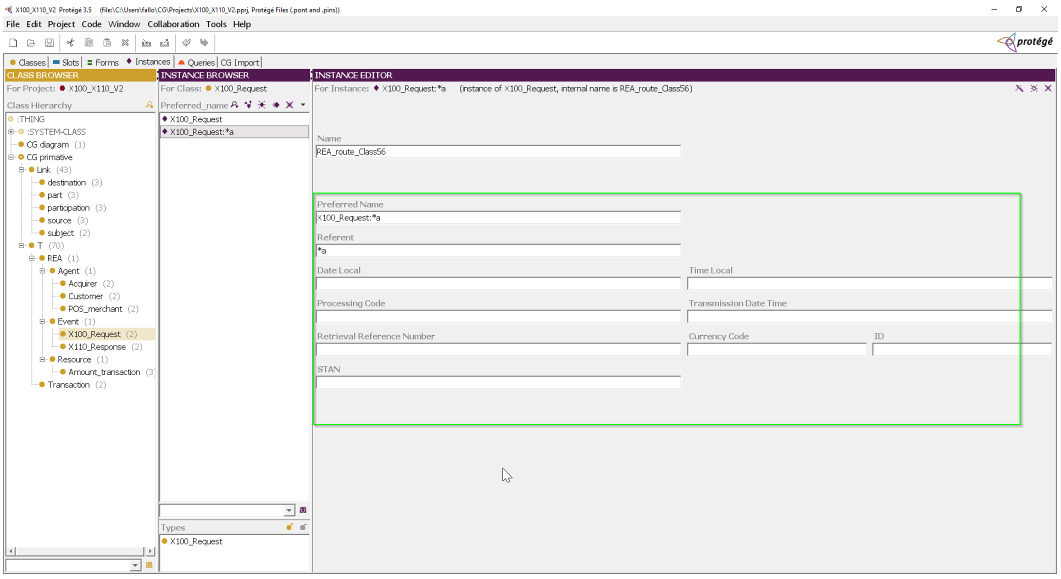


Figure 8.30: Attributes Added to Protégé

Using the FCAView from within the AREA KMS (refer to 8.3.5), it is possible to quickly see that there is large dependency on the type "string", shown in the Figure 8.31 below as (2). Clearly when looking at all the subtypes of *string* not all of them are correct (1), for example *date* and *time* types should be re-categorised.

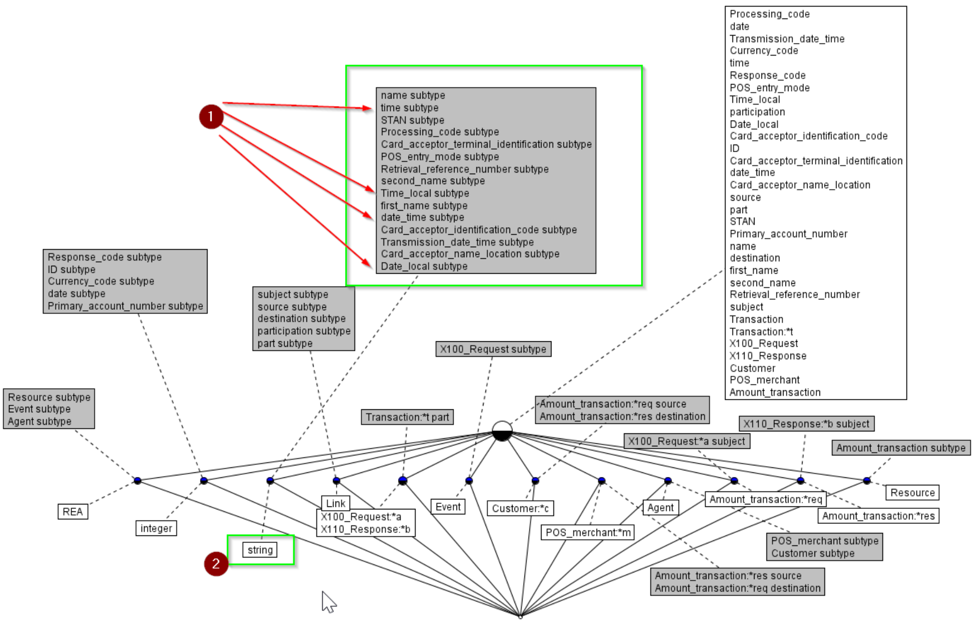


Figure 8.31: x100/x110 - Authorization message flow - FCA Analysis[3]

[3]This diagram was produced using the AREA KMS using FCAView with the CGIF shown in

**x0100/x0110 - Authorization message flow, Acquiring/Issuing Institution are different** The previous card payment use-case scenario described in Section 8.5.2, is relatively straightforward, the acquiring institution is also the issuing institution for the customers card. However the processing required and subsequent message flows become more complicated when the acquiring institution (bank) is not the institution which issued the card detailed in the transaction and presented at the merchant. In this case acquiring institution must send the transaction details via a payment network to the issuing bank of the customers card, this scenario is detailed below in Figure 8.32. Institution A, sends the transaction details using an authorization request message x0200, which is sent to the card issuer for approval, after checking the card details and the customers account the issuing institution B returns an x0210 Response message, with either an approval or denial.

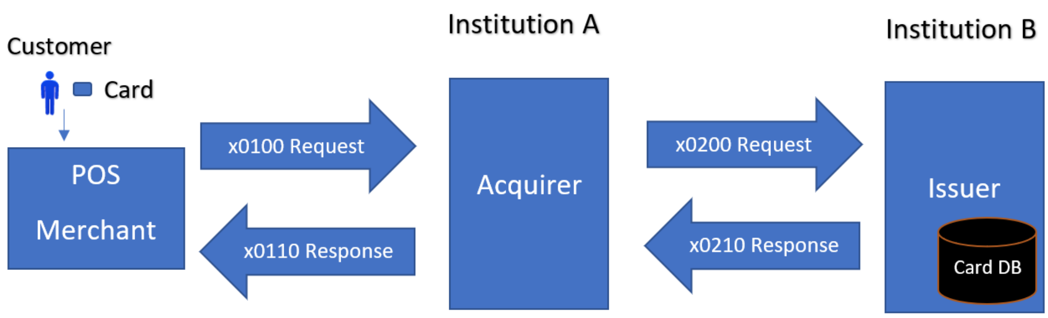


Figure 8.32: Authorisation message flow, different Issuing Bank

The added complexity of a separate issuer for the customers card is clearly seen in the REA/TOA design below in Figure 8.33, which was imported using CGimport and using the CGs in the ISO CL CGIF standard in Section C.1.6. This demonstrates how the AREA KMS can be used also for complex transaction scenarios using a TOA.

Figure C.1.5

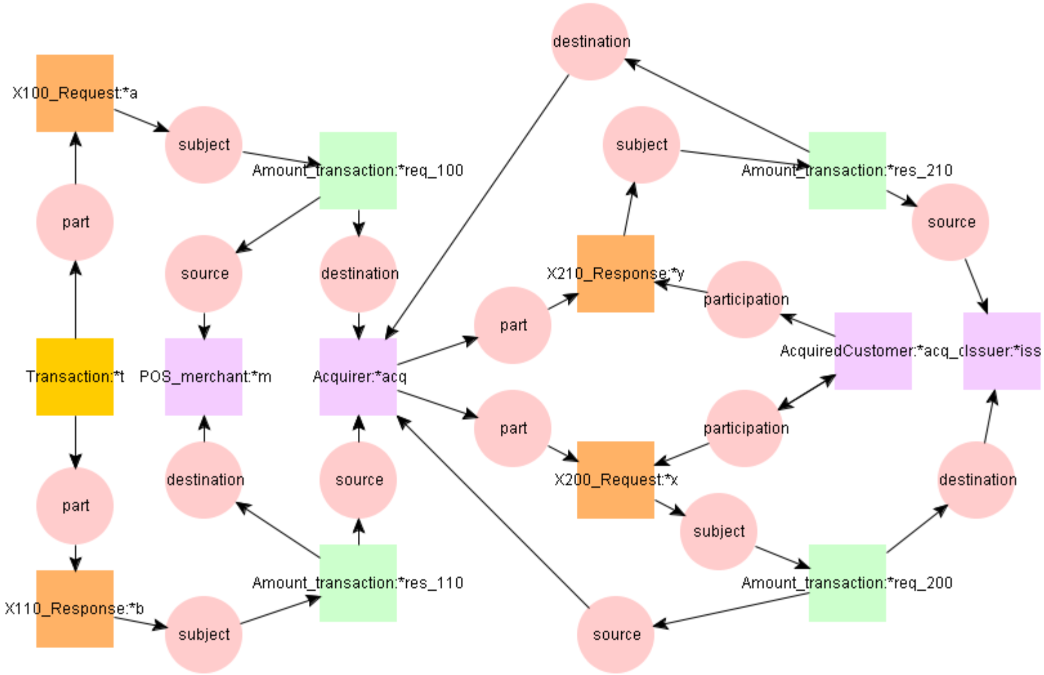


Figure 8.33: x0100/x0110 + x0200/x0210 Authorisation message flow[4]

## 8.6 Case Study B - SAP ERP

The AREA KMS is now demonstrated in relation to the implementation of a case-study whilst using a TOA for several business process transactions which occur on an SAP ERP system. Case studies require words and sentences to express business knowledge and define business transactions and rules. Through this verbalisation of the transactions knowledge is captured. Subsequently the words and sentences are used to provide reason and capture transactional logic, since each word of the sentence relates to a grammatical category and underlying concept (Sowa, 1984).

[4]This diagram was produced using the AREA KMS with the CGIF shown in Figure C.1.6

### 8.6.1 SAP transaction - Human Capital Management (HCM) Labour Requisition

This Section provides the narrative for the Labour Requisition process within the HCM module of SAP ERP. The Human Resources (HR) or HCM business process is defined as encompassing all that is required to acquire and then pay for employee labour (Dunn et al., 2005).

The labour requisition event is defined by Dunn et al. (2005) as the identification of a need for labour, where "Personnel Organisers" are usually responsible for determining this need through monitoring either one or all of enterprise growth (or the lack of), production plans, sales forecasts, employee turnover and other indications of labour requirements. Through previous research (Fallon and Polovina, 2013) and REA analysis, a further four (sub) events were identified within the main labour requisition event: "Requisition Request", "Advertisement", "Application" and "Hire".

Through defining these four REA Events in the ISO CL CGIF standard defined in Section C.1.1, the REA/TOA diagram in Figure 8.34 was produced using the AREA KMS.

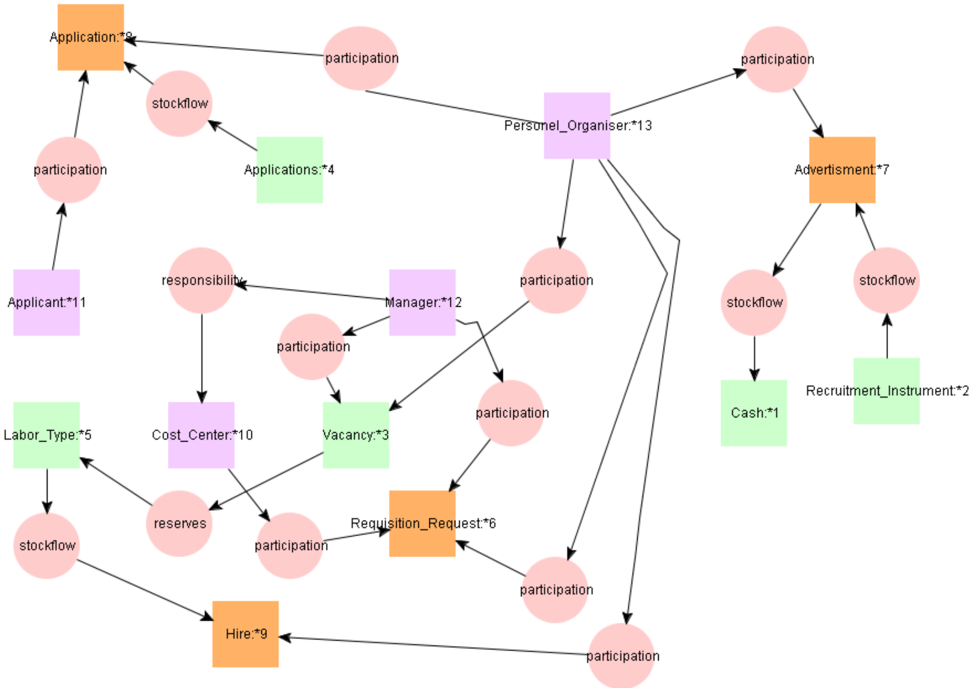


Figure 8.34: SAP transaction - HCM Labour Requisition[5]

Using the integrated artefact: ARTE 5, FCA integration, FCAview tab (refer to 8.3.5), FCA analysis was completed on the REA/TOA ontology with the following results detailed in Figure 8.35, note (1) the Agent "Personnel Organiser" is key to this business process as can be identified in the FCA lattice.

[5]This diagram was produced using the AREA KMS using the CGIF shown in C.1.1

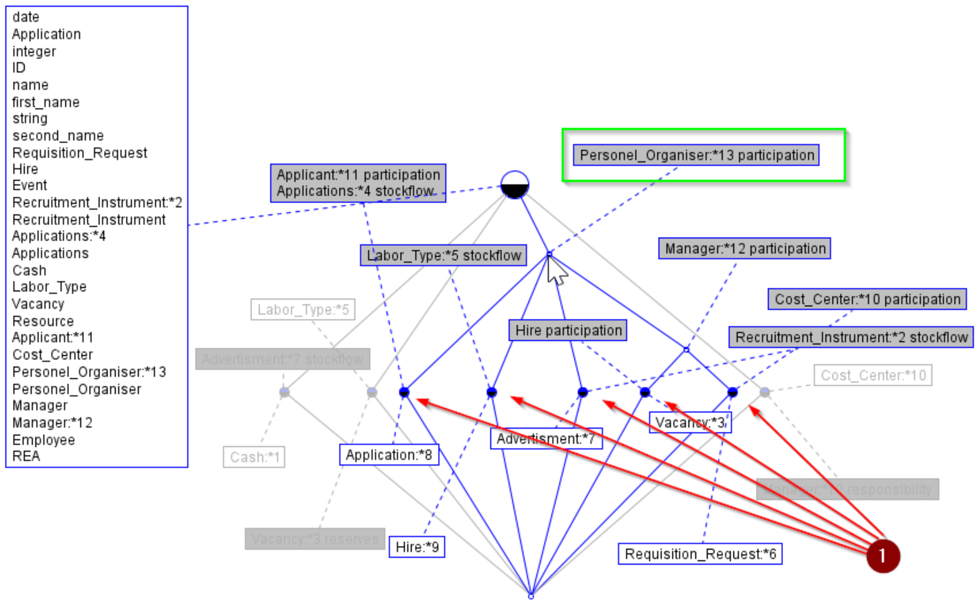


Figure 8.35: SAP Transaction HCM Labour Requisition FCA Output

### 8.6.2 SAP transaction - Goods Receipt

Using the data provided through the MSc. student assignments, from Student X, detailed in Section D.1.1, the CG model was defined in CGIF format, detailed in Section C.1.2. The results of importing this TOA model into the AREA KMS are detailed below in 8.36.

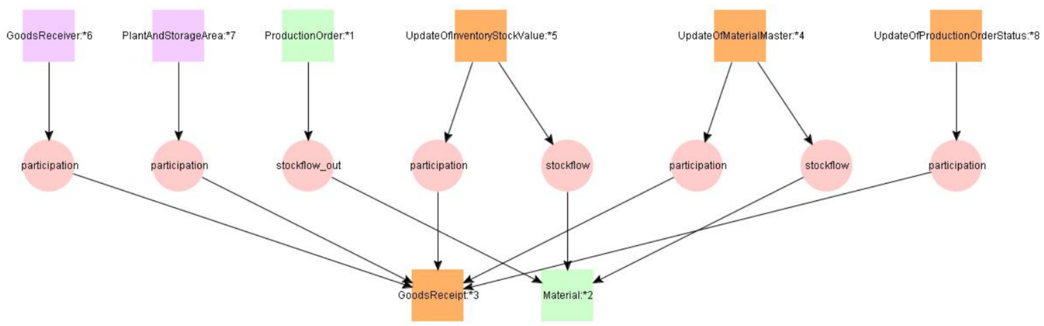


Figure 8.36: SAP transaction - Goods Receipt[6]

[6]This diagram was produced using the AREA KMS using the CGIF shown in C.1.2, and the original student data in 8.36

The REA/TOA diagram below in Figure 8.37 demonstrates how the sub-types (refer to 8.2.5 and 8.3.3) can also be displayed using the AREA KMS.

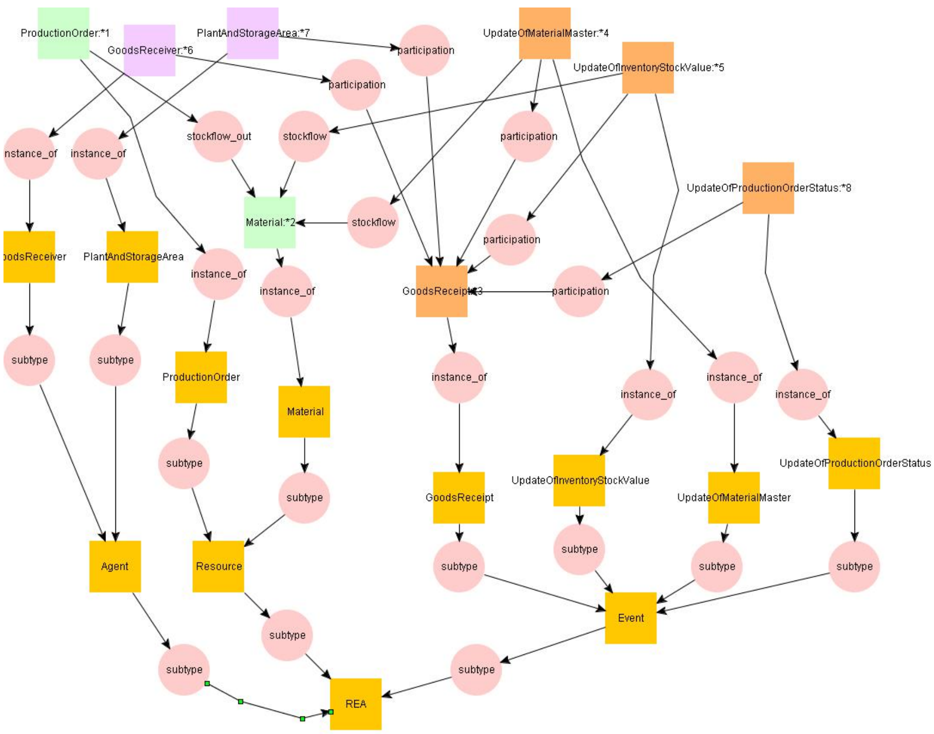


Figure 8.37: SAP transaction - Goods Receipt with Type Hierarchy[7]

Using the integrated artefact: ARTE 5, FCA integration, FCAview tab (refer to 8.3.5), FCA analysis was completed on the REA/TOA ontology with the following results in 8.38.

[7]This diagram was produced using the AREA KMS using the CGIF shown in C.1.2, and the original student data in D.1

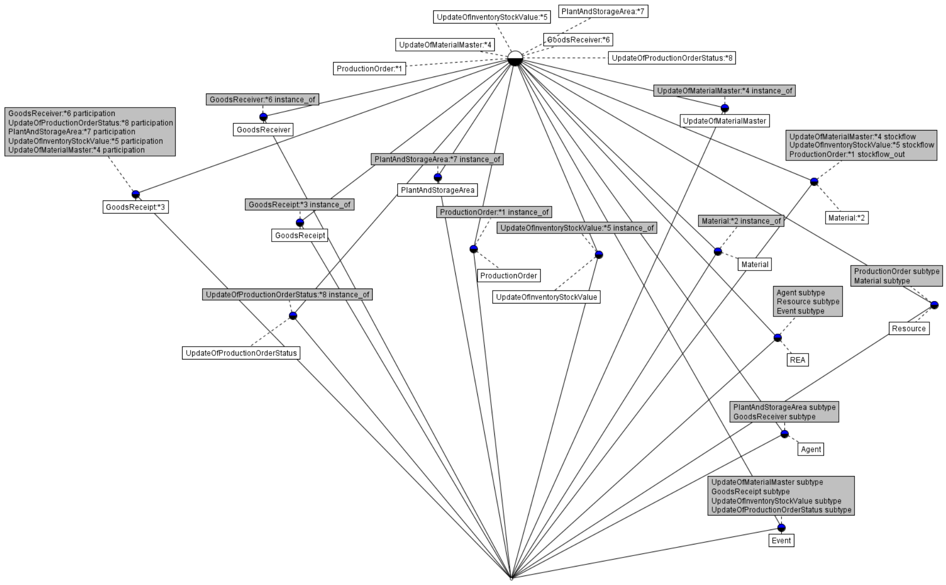


Figure 8.38: SAP transaction - Goods Receipt FCA Output

### 8.6.3 SAP transaction - Create Purchase Order/Purchase Requisition

Using the data provided through the MSc. student assignments, from Student Y, detailed in Section D.1.2, the CG model was defined in the ISO CL CGIF standard, detailed in Section C.1.3. The results of importing this TOA model into the AREA KMS are detailed below in 8.39.

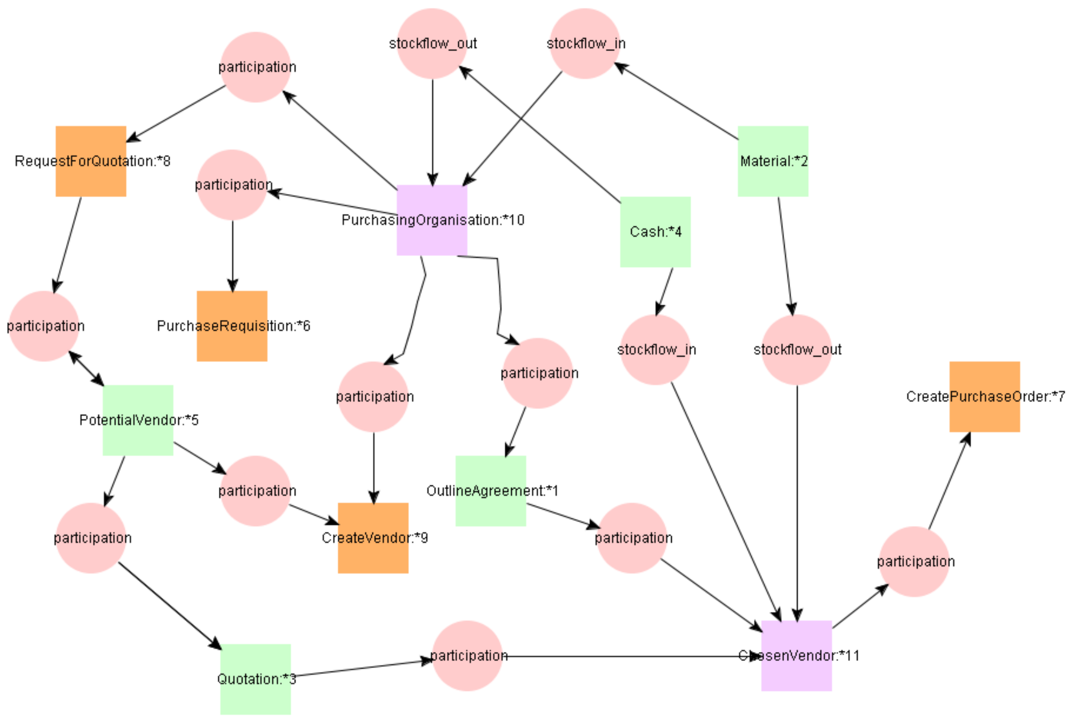


Figure 8.39: SAP transaction - Create Purchase Order/Purchase Requisition[8]

## 8.7 Conclusions in Chapter 8

This Chapter has demonstrated how both the individual artefacts and the AREA KMS as a whole have solved several instances of TOA design problems, thus fulfilling DSR step 4, “Demonstration”.

The artefacts have been demonstrated as a POC using two industrial case-studies and using data (partly) provided by MSc. students through their assignments.

Through this demonstration the feasibility has been shown, through enabling concrete assessment of the artefacts suitability to fulfil the intended purpose. Thus utility, quality, and efficacy of each of the design artefacts using rigorously presented evaluation

[8]This diagram was produced using the AREA KMS using the CGIF shown in C.1.3, and the original student data in 8.39

methods has also been demonstrated.

The construction, instantiation and demonstration of the AREA KMS, has also provided further evidence that, Conceptual Structures using the REA ontology adds value when defining a transaction oriented architecture within enterprise systems.

The demonstration provided has its limitations, for example further case studies could have been demonstrated. However even when considering the limitations, through the construction of AREA KMS this demonstration provides evidence of the utility of the artefacts of the solution (Hevner et al., 2004).

The critical nature of DSRM in IS comes via the identification of as yet undeveloped capabilities needed to expand IS into new realms not previously believed amenable to IT support (Markus et al., 2002), these requirements (for the AREA KMS) were identified in Section 3.5.3.

A significant result in IS research can only be claimed when there is a serious question about the ability to construct such an artefact, there is uncertainty about its ability to perform appropriately, and the automated task is important to the IS community (Hevner et al., 2004), these questions and validation were completed through the Action Research process detailed in Section 7.2

The construction of an artefact or prototype in an IS research setting is only a first, but necessary step towards its deployment. These first steps are important in DSRM, since it is often not even sure whether such a system could be constructed, thus a DSRM approach can also result in artefacts which unfortunately can not fulfil the initial goals. But it is also not uncommon for DSRM research to result eventually in commercial products which are then used in real life situations (Hevner et al., 2004). Through the demonstration (of the AREA KMS) in this Chapter these first steps have been taken and through a POC it has been shown how the AREA KMS can aid EA design using a TOA.

# Chapter 9

# Evaluation

**DSRM Step 5 - Evaluation.** Observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration. It requires knowledge of relevant metrics and analysis techniques.

## 9.1 Introduction

This Chapter details the "Research Evaluation", DSRM Step 5. A literature search first presents an overview of the current recommendations and guidelines provided when completing evaluation using DSRM research. DSRM evaluation is seen as crucial to effective DSRM research since artefacts must be evaluated against a defined purpose and consequently show a yielded utility to their usage. The artefacts must also provide a novelty which is demonstrated by the solution of some previously unforeseen problem in an effective and efficient manner (Hevner et al., 2004).

Also important to note is that for the purposes of clarity (keeping DSRM evaluation in a single chapter), in this Chapter both ex ante and post ante evaluation results are detailed, the difference between these two distinct timings are detailed below in Section 9.1.1. The two distinct phases of evaluation (ex ante and post ante) were completed on either side of the Implementation phase detailed in Chapter 7. Ex ante evaluation was completed to determine both the effectiveness of the research question and to evaluate the pre-existing artefacts, methods and protocols which could form a solution. Post ante evaluation was completed following the Implementation phase in Chapter 7 so that the artefacts comprising the solution and the solution in its entirety could be evaluated for their utility, quality, and efficacy of design.

### 9.1.1 Evaluation Timing

When using DSRM one of the main distinctions when completing evaluation, is to differentiate between evaluation carried out ex ante as opposed to ex post, this distinction arises solely from the timing of the evaluation.

Ex-ante evaluation provides the predictive evaluation which is performed in order to estimate and evaluate the impact of a future situation (Stefanou, 2001). When looking at IS research this means that ex-ante is often used to decide whether or not to either develop or purchase a software-product. More specifically for making a comparison and evaluation of competing software-products or making the decision to go ahead and develop a specific software-product.

Ex post evaluation is an assessment of "the value of the implemented system on the basis of both financial and non-financial measures" (Stefanou, 2001).

The timing of these two opposing methods is shown below in Figure 9.1 and can be viewed as the two extremes, since ex-ante evaluation occurs at the very beginning and ex post evaluation takes place at the very end. The terms ex ante and ex post evaluation reference only the timing of the evaluation not how the evaluation is carried out (Venable et al., 2016).

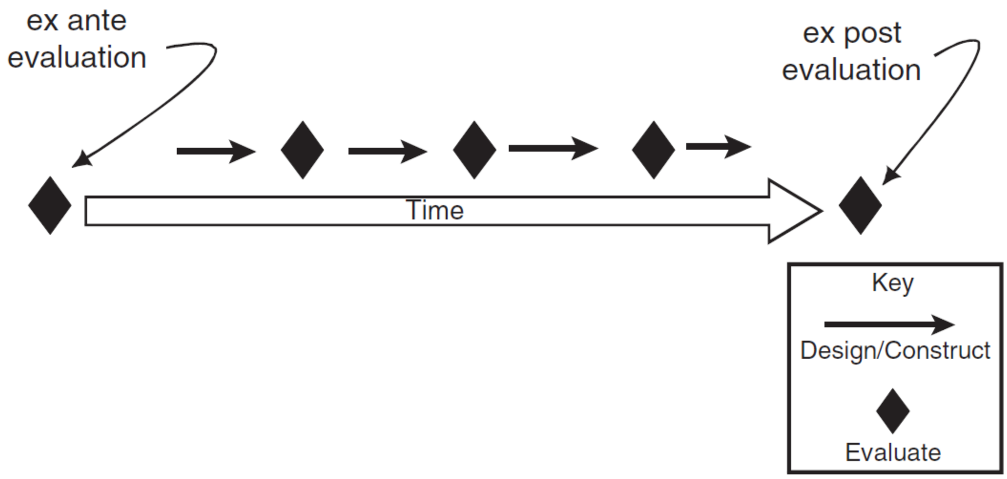


Figure 9.1: Ex ante–ex post evaluation time continuum (Venable et al., 2016)

### 9.1.2 Artificial versus Naturalistic Evaluation

Artificial evaluation encompasses several different areas of evaluation, including laboratory and field experiments, simulations, criteria-based analysis, theoretical arguments, and mathematical proofs. Artificial evaluation provides a stronger scientific reliability in the form of better repeatability (Venable et al., 2012).

Naturalistic evaluation explores the performance of a technological solution in its real-world setting for example within an enterprise. Because the evaluation is performed in a real-world environment it can encompass more of the complexities of human practice in real organizations. Naturalistic evaluation is always empirical and may be interpretive, positivist, and/or critical and includes (amongst others) the methods of case or field studies and action research. The naturalistic paradigm brings to DSRM evaluation the benefits of providing a stronger internal validity, since the results are completed in the real-world (Venable et al., 2012).

Both artificial and naturalistic evaluation have their strengths and weaknesses. Naturalistic evaluation is affected by confounding variables or the misinterpretation of evaluation, meaning that the results of an artefact's utility or efficacy during real usage can be imprecise or even untruthful. Conversely the abstraction away from a real-world setting for artificial evaluation can produce unreal evaluation results when comparing the real use of an artefact. Thus naturalistic evaluation can be defined as offering a more critical face of validity in a naturalistic setting or what could be called "the real proof of the pudding" (Venable et al., 2012).

### 9.1.3 Formative vs Summative Evaluation

When completing an evaluation a distinction is made between formative and summative evaluations. Formative and summative evaluations are differentiated by the functional purpose of the evaluation, as opposed to the nature or content of the evaluation.

Formative evaluation is used to produce empirically based interpretations which are subsequently used to provide a set of decisions or actions which will improve either the characteristics or performance of the evaluand. Formative evaluation is more often used as part of an iterative cyclical of research in order to measure the improvement of an evaluand as the development process progresses (Venable et al., 2016).

Summative evaluations are used to produce empirically based interpretations which can be used to evaluate specific criteria of an evaluand under different contexts. The focus of summative evaluation is to support the decisions which are required to influence the selection of an evaluand when it is been considered for a specific purpose. Summative evaluation is more often used when the evaluation of an evaluand is required either to appraise the situation prior to development or once the development is completed to measure the results. Intuitively ex post evaluations are generally summative and ex ante and intermediate evaluations always formative. However since the terms ex ante and ex post refer only to the timing of the evaluation, summative evaluation can also be required ex ante on an intermediate basis as part of a process of continuous approval. Conversely ex post evaluations can also have formative purposes (Venable et al., 2016).

### 9.1.4 Purpose of Evaluation

As defined previously in Section 9.1.3 the functional purpose of formative evaluations is to help improve the outcomes of the process under evaluation. Whereby the functional purpose of summative evaluation is to evaluate the extent which the outcomes match expectations. The central purpose of any particular evaluation activity is to provide evidence which is useful both formatively and summatively. The relationship and functional purpose between formative and summative evaluations can be aligned against naturalistic and artificial evaluations showing "a continuum along which any evaluation might be located, as shown on the x-axis" of Figure 9.2 below (Venable et al., 2016).

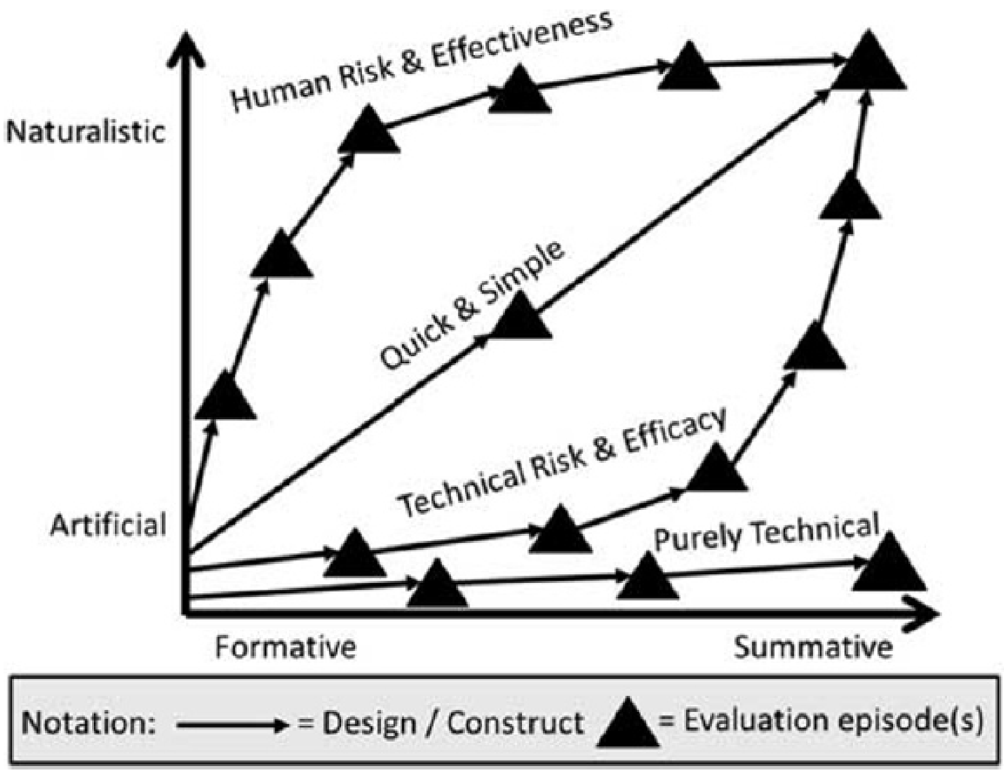


Figure 9.2: Framework for Evaluation in Design Science with Evaluation Strategies (Venable et al., 2016)

The DSRM literature identifies (at least) six different purposes for the evaluation steps of DSRM identified below (Venable et al., 2016):

1. Key purpose of evaluation, to determine how well a designed artefact(s) full-fills the main goal.

2. The substantiation of a design theory which provides evidence that the artefact aids the user in solving some problem or making some improvement.

3. Some comparative evaluation of the artefact (or design theory) in comparison with other artefacts (or design theories) showing an improvement in the state of the art.

4. Evaluate against a number of different quality criteria beyond the simple achievement of the main goal, such as functionality, completeness, consistency, accuracy, performance, reliability, usability and other relevant quality attributes

5. An artefact can also be evaluated "for other (undesirable) impacts" known as side effects.

6. The evaluation can also include a discussions determining what the knowledge outcomes are by discerning why an artefact works or not.

### 9.1.5 Evaluation Goals

There are at least four possibly competing goals which should be taken into consideration when designing an evaluation strategy for DSRM, the relevance of each of the goals can also be dependent on the stage of evaluation (Venable et al., 2016).

**Rigour** which can be seen from two perspectives of establishing a result: efficacy and effectiveness. Efficacy, typically using artificial evaluation to determine that it is *this* artefact which causes the observed outcome and not a side effect of some other independent variable or circumstance. Effectiveness, typically uses naturalistic evaluation to determine that the artefact instantiation works in a real situation.

**Risk** reduction and uncertainty are identified using formative evaluation to determine design uncertainties, technical risks. Social or use risks may also be identified such that the artefact will not fit well into the use or social situation, thus causing other problems.

**Ethics** is important in evaluation when safety critical systems and technologies are concerned, where other potential risks to animals, people, organisations, or the public, including future generations should also be considered.

**Efficiency** of the evaluation can be understood as balancing the above goals of the evaluation against the resources available for the evaluation (e.g. time and money). Costs can be kept lower using formative evaluation and usually naturalistic evaluation takes longer and will be more costly than artificial evaluation.

### 9.1.6 Criteria for selecting Evaluation Methods

Authors such as Venable et al. (2012) observed the absence of guidance in the DSR literature regarding the choice of strategies and methods for evaluation in DSR. Pries-Heje et al. (2008) proposed a solution using a 2-by-2 matrix as shown below in Figure 9.3 which contrasts artificial vs naturalistic (discussed in Section 9.1.2) evaluation against the second dimension of ex ante and ex post evaluation (discussed in Section 9.1.1).

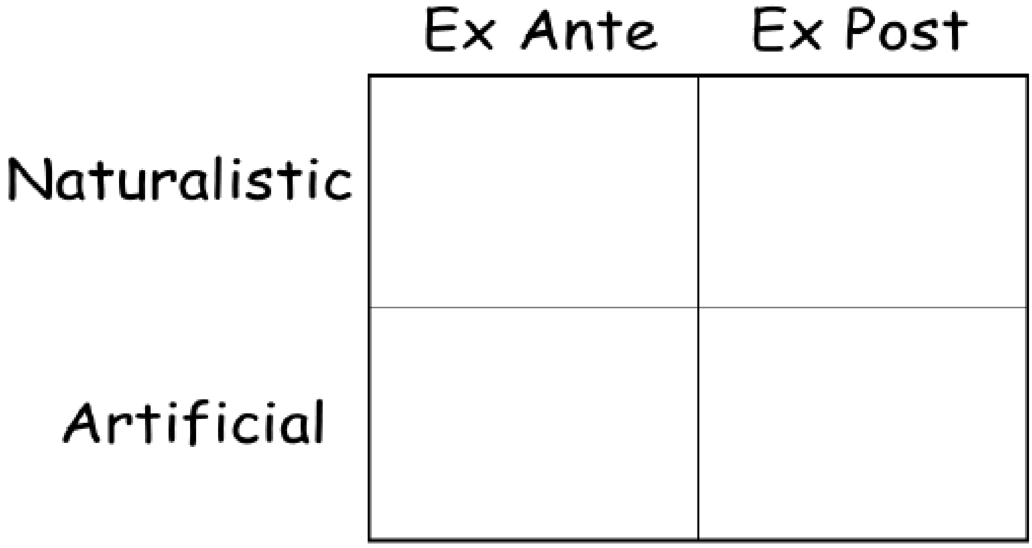


Figure 9.3: DSRM Evaluation Strategy Selection Framework (Pries-Heje et al., 2008)

Venable et al. (2012) developed two extensions, which added more detail to the evaluation strategy selection framework, the first extension shown below in Figure 9.4, takes the four contextual aspects of the original 2-by-2 matrix and combines and extends them considering various inputs to the DSRM evaluation design, such as cost and effectiveness of evaluation. The added criteria are then mapped from the ex ante vs ex post perspective against the artificial vs naturalistic perspective. This provides practitioners with more details from which the evaluation strategy can be defined (Venable et al., 2012).

| DSR Evaluation Strategy Selection Framework | | Ex Ante | Ex Post |
|---|---|---|---|
| | | •Formative<br>•Lower build cost<br>•Faster<br>•Evaluate design, partial prototype, or full prototype<br>•Less risk to participants (during evaluation)<br>•Higher risk of false positive | •Summative<br>•Higher build cost<br>•Slower<br>•Evaluate instantiation<br>•Higher risk to participants (during evaluation)<br>•Lower risk of false positive |
| **Naturalistic** | •Many diverse stakeholders<br>•Substantial conflict<br>•Socio-technical artifacts<br>•Higher cost<br>•Longer time - slower<br>•Organizational access needed<br>•Artifact effectiveness evaluation<br>•Desired Rigor: "Proof of the Pudding"<br>•Higher risk to participants<br>•Lower risk of false positive – safety critical systems | •Real users, real problem, and somewhat unreal system<br>•Low-medium cost<br>•Medium speed<br>•Low risk to participants<br>•Higher risk of false positive | •Real users, real problem, and real system<br>•Highest Cost<br>•Highest risk to participants<br>•Best evaluation of effectiveness<br>•Identification of side effects<br>•Lowest risk of false positive – safety critical systems |
| **Artificial** | •Few similar stakeholders<br>•Little or no conflict<br>•Purely technical artifacts<br>•Lower cost<br>•Less time - faster<br>•Desired Rigor: Control of Variables<br>•Artifact efficacy evaluation<br>•Less risk during evaluation<br>•Higher risk of false positive | •Unreal Users, Problem, and/or System<br>•Lowest Cost<br>•Fastest<br>•Lowest risk to participants<br>•Highest risk of false positive re. effectiveness | •Real system, unreal problem and possibly unreal users<br>•Medium-high cost<br>•Medium speed<br>•Low-medium risk to participants |

Figure 9.4: DSRM Evaluation Strategy Selection Framework (1st extension) (Venable et al., 2012)

The second extension proposed by Venable et al. (2012) is to relate the different evaluation strategies in the framework (Pries-Heje et al., 2008) against the different evaluation methods. Thus providing a bridge between the contextual factors relevant to the DSRM evaluation and the appropriate methods available to evaluate the DSRM artefacts as shown below in Figure 9.5.

| DSR Evaluation Method Selection Framework | Ex Ante | Ex Post |
|---|---|---|
| Naturalistic | •Action Research<br>•Focus Group | •Action Research<br>•Case Study<br>•Focus Group<br>•Participant Observation<br>•Ethnography<br>•Phenomenology<br>•Survey (qualitative or quantitative) |
| Artificial | •Mathematical or Logical Proof<br>•Criteria-Based Evaluation<br>•Lab Experiment<br>•Computer Simulation | •Mathematical or Logical Proof<br>•Lab Experiment<br>•Role Playing Simulation<br>•Computer Simulation<br>•Field Experiment |

Figure 9.5: DSRM Evaluation Strategy Selection Framework (2nd extension) (Venable et al., 2012)

## 9.2 Evaluation Strategy

When defining an evaluation strategy using DSR, the practitioner should carefully select the correct evaluation methods for evaluating the designed artefacts, this selection should take into account the methodologies which are already available in the knowledge domain. The process of selection involves matching appropriately against the designed artefact using the correct evaluation metrics. Descriptive methods of evaluation should only be used for especially innovative artefacts for which other forms of evaluation may not be feasible (Hevner et al., 2004).

In Sections 9.1.1 and 9.1.2, the different evaluation methods were presented. As determined by Venable et al. (2012) the DSRM evaluation strategy selected must take into account the different criteria required given the evaluand been evaluated and at the same time providing a priority for each of the different criteria. Conflicts can also be present when selecting evaluation methods, since for example, the requirement for the rigour of naturalistic evaluation can at the same time compete with the risks and the costs for evaluation participants or stakeholders. Thus when cost and risk reduction override (or preclude) rigorous evaluation of effectiveness in real world settings, an artificial evaluation strategy may be chosen as been more appropriate.

Several distinct steps of evaluation were identified for this research as detailed below in Table 9.1.

| **Step (EVAL)** | **Methodological approach** | **Eval. criteria** | **Eval. timing** |
|---|---|---|---|
| 1 | Validation of research justification | Novelty | Ex Ante |
| 2 | Formal analysis of usefulness of pre-existing artefacts, methods and protocols | Technical and operational feasibility | Ex Ante |
| 3 | Artefacts of the AREA KMS: Determination of the effectiveness of the prototypical implementation through evaluating each individual artefact | Technical and operational feasibility | Ex Post |
| 4 | Determination of the effectiveness of the prototypical implementation of the AREA KMS through two case studies | Technical and operational feasibility | Ex Post |
| 5 | Expert interview | Novelty | Ex Post |
| 6 | Field experiment, participant observation | Usefulness, completeness, alignment with business | Ex Post |

Table 9.1: DSRM Evaluation Steps Required

The evaluation steps detailed above in Table 9.1 show a diverse range of evaluands and evaluation timing. Therefore it would not be practical to define an evaluation strategy which would cover for all the eventualities of these (6) evaluation steps. Thus a separate evaluation strategy was defined for each evaluation step. Additionally for each individual strategy it was not a case of simply picking a single box (from the evaluation frameworks in Figures 9.4 and 9.5) but instead developing a hybrid strategy (more than one quadrant) to resolve conflicting goals (Venable et al., 2016).

Risk of time and costs to stakeholders were balanced against the rigour and efficiency of evaluation. Given that the solution to the problem is a POC and not a finely tuned software product, the solution must be proven to function but is not required to undergo intensive user testing which would be both time consuming and costly.

To provide an extensive and effective summative evaluation three separate groups of stakeholders or participants were identified: MSc. students, expert users and the author. The reason and range for the selection of different stakeholders are to keep costs and risk low but not to override (or preclude) rigorous evaluation of effectiveness in real settings. The strategy involves using a number of varied stakeholders which can provide an artefact effectiveness evaluation and also the desired rigour, and "proof of the pudding" via the case-studies, which also ensures the lowest risk of false positives.

Details of the separate (6) evaluation strategies for each of the (6) evaluation steps are detailed in Table 9.1.

### 9.2.1 EVAL 1: Research Justification and Validation for using REA and TOA in EA

An opportunity was presented to test the usage of REA and TOA in EA, by incorporating REA and TOA into an MSc. course: "Enterprise Systems" at Sheffield Hallam University.

This provided the opportunity to provide justification for this research and provide validation of using REA and TOA in EA, through ex ante evaluation in an artificial environment using a small number of similar stakeholders (12 MSc. students), providing a formative evaluation. Details of the evaluation criteria aligned against their priorities together with the advantages and disadvantages of each criteria are detailed below in Table 9.2.

| Priority | Evaluation Criteria | Advantages | Disadvantages |
|---|---|---|---|
| 1 | **Risk** (to participants) | Lowest risk to participants, since participation part of Learning Teaching and Assessment (LTA) | |
| 2 | **Cost** | Lowest costs | |
| 3 | **Users** (Students) | Student's feedback, will indicate if the usage of REA and TOA in EA has merit | Un-real users, may provide incorrect feedback – see false positives |
| 4 | **Speed** | Student's output readily available for evaluation | |
| 5 | **Risk** of false positives | Students might say what they expect we want to hear | |

Table 9.2: Evaluation Strategy - Research Justification

The results of the evaluation step are detailed in Section 9.3.1.

### 9.2.2 EVAL 2: Pre-existing Artefacts, Methods and Protocols

To form the basis of "How" a solution could be provided, a process of AR with multiple cycles was required to evaluate both existing artefacts and the current methods and protocols available, and this evaluation strategy for this ex ante evaluation is defined here. During each AR cycle, an assessment was required to determine which of the pre-existing artefacts was worth further investigation or not.

The ex ante evaluation process was completed in an artificial context where the purely technical artefacts, the software components and technical specifications were evaluated.

The artificial context provides the benefits of faster selection and lower cost, since only a few stakeholders were involved. The evaluation process examines purely technical aspects of reviewing software code and completing lab experiments to test the functionality of software components or currently available tools.

Each Action Research cycle, examines one specific evaluand as identified in the Diagnosis phase, each evaluand was either a method, concept, design theory or an actual currently available artefact.

Through the inherently iterative and incremental activity of both Action Research and ex ante evaluation, the resulting data produced was feed directly back into the next Action Research cycle and subsequently into the design and decision process which determined the artefacts required for the final solution (Hevner et al., 2004). The results of this evaluation step are detailed in Section 9.3.2.

### 9.2.3 EVAL 3: Artefacts of the AREA KMS

Important in validating the individual artefacts of the AREA KMS, is the definition of evaluation criteria against the performance of an artefact which is to be measured. Using DSRM practitioners must constantly assess the appropriateness of their metrics and the construct effective methods for evaluation (Hevner et al., 2004). Each artefact of the solution is examined in an artificial ex post summative evaluation.

The evaluation strategy defines the goal of the evaluating the efficacy of the individual artefacts of the AREA KMS, through examining each artefact individually and demonstrating the worth of each artefact through providing evidence addressing criteria such as validity, utility, quality, and efficacy (Gregor and Hevner, 2013). The results of the evaluation step are detailed in Section 9.3.3.

### 9.2.4 EVAL 4: AREA KMS Using Two Case Studies

The goal of this evaluation strategy is to determine whether the solution fulfils the requirements defined in Tables: 3.4, 3.2, 3.5 and 3.6. To fulfil this goal of evaluating the AREA KMS as a complete solution within an industrial context, the usage of the AREA KMS is demonstrated within two separate case-studies. The evaluation does not involve safety critical systems and technologies nor are there any potential risks to animals, people, organisations, or the public. Thus a highly rigorous evaluation is not a key goal nor were any of the stakeholders at risk (Venable et al., 2016).

The two separate case studies are detailed below in Table 9.3.

| | **Case B** | **Case A** |
|---|---|---|
| Case business model | Multiple business transactions flows in SAP ERP software | Card payments, one Enterprise Transaction flow, two different business process transaction flows |
| Case's usage of the AREA KMS | All aspects of the AREA KMS covered, Input, Query, Validate and Output | All aspects of the AREA KMS covered, Input, Query, Validate and Output |
| Contribution to validity of the AREA KMS | Usefulness, completeness, alignment with business: Improvement of Quality of SAP Best Practice models for "Create Purchase Order", "Goods Receipt" and "HCM Labour Requisition" | Usefulness, completeness, alignment with business card payment transaction flows: "Authorisation as Issuer" and "Authorisation as Acquirer" |

Table 9.3: Evaluation cases for EVAL 4: AREA KMS Using Two Case Studies

The evaluation strategy was separated into three separate stages, detailed below which highlight the trade off between the evaluation goals (rigour, risk, ethics and efficiency) identified in Section 9.1.5:

Using a naturalistic scenario through two separate real-world case studies, detailed in Section 8.6 and Section 8.5 and by keeping the number of stakeholders involved low (the author) the risk and costs to the evaluation were also kept low. However one could consider that the rigour and efficiency were high due to the (authors) many years of experience in the field of software development and software testing, this can of course be counter balanced against the obvious bias of an author validating his own work. The results of the evaluation step are detailed in Section 9.3.4.

The two case studies provide a naturalistic evaluation in an industrial setting which could be called "the real proof of the pudding" (Venable et al., 2012).

### 9.2.5 EVAL 5: Working Solution, Expert Interview

The strategy behind this evaluation was to complete an expert interview with an experienced technical stakeholder with the goal of providing evaluation through the technical interview as to whether the artefacts have novelty and usefulness within an artificial scenario. The risk and cost can be considered to be low, since the interviews are not time consuming, conversely the rigour could also be also assumed to be low, since the experts are not "hands-on" with the solution. However expert interviews can considered a very effective method for achieving prompt feedback as to the novelty and usefulness of the solution.

The expert interview was structured informally using the questions detailed in the Table 9.4 below as an informal interview guide. This allows the informal answers to be categorised later for analysis. The "Questions" are the actual questions addressed to the participant, with the "Theme Question" detailing the subject or reason why the question was asked, which provides context to the research project. This context provides an assistance to the interviewer so that the reason for the actual question is not simply "forgotten" during the interview. The "Source" field provides details of origin of the question which can be from literature or previous studies or other actions within the research (Botes et al., 2014).

| Question (QUES) ID | Question | Reason/Theme Question | Source |
|---|---|---|---|
| QUES 1 | Did you understand/appreciate how Conceptual Structures can be used in EA modelling ? | Determine novelty of the solution | Evaluation novelty |
| QUES 2 | Did you understand/appreciate how REA can be used in EA modelling ? | Determine novelty of the solution | Evaluation novelty |
| QUES 3 | Did you understand/appreciate how REA can be used together with Conceptual Structures in EA modelling ? | Determine novelty of the solution | Evaluation novelty |
| QUES 4 | Did you identify any problems with the usage of the AREA KMS? | Can the solution be improved upon | Evaluation fitness |
| QUES 5 | Did you identify any improvements which could be made to the AREA KMS? | Can the solution be improved upon | Evaluation fitness |
| QUES 6 | Do you know of any other tools similar to the AREA KMS, which would also be useful? | Determine whether other tools are available, but previously not discovered | Evaluation novelty |
| QUES 7 | Can you see an application for the AREA KMS within your organisation ? | Artefacts importance | Evaluation Usefulness |

Table 9.4: Evaluation cases for EVAL 5: Working Solution, Expert Interview

Following the expert interview the transcriptions of the interview were recorded and, once transcribed further analysis of the data was completed whereby each transcript was also coded using a set of codes to assist in drawing conclusions during the analysis of the data (Botes et al., 2014). The results of the evaluation step are detailed in Section 9.3.5.

### 9.2.6 EVAL 6: Field Experiment, Participant Observation

The strategy behind this evaluation was to use the goal of evaluating the artefacts in an artificial environment via a field experiment. Using MSc. students as the stakeholders in the field experiment, to provide an (independent) evaluation of the artefacts of the solution. The rigour behind this evaluation could be considered as medium since the stakeholders (students) were using the artefacts hands-on. The ethics of involving students in the evaluation were taken care of through requesting permission and ethics approval from individual students, refer to appendix E

Both the costs and risks could be considered low, due to the fact that the stakeholders were students. However the effectiveness could be considered high, since results were produced very quickly. The results of this evaluation step are detailed in Section 9.3.6.

## 9.3 Evaluation Results

### 9.3.1 EVAL 1: Research Justification and Validation for using REA and TOA in EA

An opportunity was presented to test the usage of REA and TOA in EA, by incorporating REA and TOA into an MSc. course: "Enterprise Systems" at Sheffield Hallam University.

This provided the opportunity to provide justification for this research and provide validation of using REA and TOA in EA, through ex ante evaluation in an artificial environment.

**Learning, Teaching and Assessment (LTA)** The final assignment presented the students with the following TOA problem to the students, detailed below in Table 9.5.

| |
|---|
| *A recognized problem of implementing ERP systems is that of aligning the off-the-shelf packaged software with the business requirements of the organization implementing the ERP solution. This alignment process is commonly called gap analysis, during this process often the decision has to be made as to whether the organization has to implement standard business processes as currently defined within the off-the-shelf solution or to carry out software customization. The students were given an assignment where they were required to produce an "as-is" model of a business transaction within a SAP ERP module and to a include a report which directly compared the REA (McCarthy 1982) "as-is" model of the business process against another modelling technique.* |

Table 9.5: Student TOA Assignment, Problem Definition

LTA acted as an environment for problem solving, learning and the study of REA and TOA in action. The combination of the two secondary research methodologies Action Research and case study ensured a positive pedagogic outcome for the students providing both fulfilment of the learning objectives together with development and further understanding of Enterprise Systems and TOA. The strategy of moderated assessment provided experimental data which was iteratively developed in a controlled and observable situation which enabled qualitative analysis of the students learning process as they produced data which was analysed against the research objectives.

Permission and ethics approval, refer to appendix E, was obtained for the use of assignments in this research. The introduction of this leading edge research topic was used to enrich the learning syllabus. Marking was aligned and reviewed against learning objectivities and required students to learn new skills and apply critical thinking, this was not influenced by the research aims which analysed the assignments in a different manner Watmough (2013).

**Pedagogy** To assess the effectiveness of the LTA process the marks achieved and learning objectives where also measured against both the findings and feedback from the students. The assignment presented to the students provided them with the opportunity to work on a real-world problem, whilst at the same time producing qualitative data which is incorporated into this research for analysis.

**Discussion** This Section draws on the work and findings of the students documented in appendix D.1, note only a small subset of the students results are presented. The intended learning outcome for the students was a positive one, they displayed a greater analytical ability at the end of the course and were able to understand the fundamental theories of REA and TOA and could apply them against the problem provided, that of an off-the-shelf ERP solution.

There were certain students who found it difficult to grasp what is a technically challenging problem that of both understanding the architecture and function of SAP ERP and at the same time applying REA fundamentals to this new found knowledge. However the verbal feedback provided by the students indicated that the blend of practical application and leading edge research was both challenging and informative.

**Analysis of Students Findings** All of the students concluded that Conceptual Structures using the REA ontology provided a good basis for understanding the architecture of SAP ERP.

When comparing REA against another modelling techniques (chosen individually by the students), REA received a positive critique.

Student X, determined that "REA diagrams provide management with an interesting insight into which value addition activities exist in the organisation"

Student Y, concluded that "REA enables business to better map processes together with the physical database structure and the simplicity of the idiom means that models can be created for any package relatively quickly. Whereas when comparing with BPMN, which has numerous different elements which mean modelling is much more complex. Though REA has some inadequacies around business logic and level of detail".

### 9.3.2 EVAL 2: Pre-existing artefacts, methods and protocols

The results of the ex ante evaluation of pre-existing artefacts, methods and protocols is documented in chapter 7 as part of the process of Action Research detailed in Section 7.2.

### 9.3.3 EVAL 3: Artefacts of the AREA KMS

This Section details the evaluation results of evaluating the individual artefacts of the AREA KMS, using the evaluation strategy defined in Section 9.2.3 above. The evaluation includes only those artefacts which are part of the final solution (the AREA KMS), other artefacts such as 3to2 etc. are not evaluated here. Each artefact is evaluated to demonstrate its worth providing evidence addressing criteria such as validity, utility, quality, and efficacy Gregor and Hevner (2013).

A large part of the evaluation uses data obtained from the demonstration in Chapter 8. Artificial evaluation was used since this is more appropriate for rigorously evaluating the artefacts. Summative evaluation was used following the end of the implementation in Chapter 7 to provide the greatest rigour in the evaluation also increasing the reliability of the knowledge developed (Venable et al., 2016). The details of the evaluation of each of the (7) artefacts are presented below, with details of the evidence and the evaluation result, graded from 1 until 5, where: 1-Artefact fulfilled the criteria, 5-Artefact did not fulfil the criteria.

**ARTE 1: CG template for Protégé** This Section details the results of the validation for ARTEfact 1, CG template for Protégé.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Process and understand CGs | Refer to general requirement REQ G1, in Table 3.5 | 1 |
| Utility | Why is the artefact required | Required to enable modelling of generic TM, refer to Section 3.3 and 3.5.3 | 1 |
| Quality | Measured against other tools | the AREA KMS is one of the first EA design tools to allow import and processing of CG's | 1 |
| Efficacy | How good is the artefact at producing required result | Numerous examples of CG's imported refer to appendix C | 1 |

Table 9.6: Evaluation Results ARTE 1: CG template

**ARTE 2: REA template for Protégé** This Section details the results of the validation for ARTEfact 2, REA template for Protégé.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Process and understand REAs | Refer to general requirement REQ G2, in Table 3.5 | 1 |
| Utility | Why is the artefact required | Required to enable modelling of generic TM, refer to Section 3.3 and 3.5.3 | 1 |
| Quality | Measured against other tools | One of the first EA design tools to allow import and processing of CG's in CGIF | 1 |
| Efficacy | How good is the artefact at producing required result | Numerous examples of REA entities imported refer to appendix C | 1 |

Table 9.7: Evaluation Results ARTE 2: REA template

**ARTE 3: CGImport - Protégé Import Tool** This Section details the results of the validation for artefact 3, CGimport a Protégé import tool.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Allow the import of both CG's and REA entities | Refer to requirements REQ G1, REQ G2, REQ G3, REQ G7, REQ G8 in Table 3.5 and REQ H3, in Table 3.2 | 1 |
| Utility | Why is the artefact required | Required to enable modelling of generic TM, refer to Section 3.3 | 1 |
| Quality | Measured against other tools | One of the first EA design tools to allow import of CG's using ISO CGIF standard | 1 |
| Efficacy | How good is the artefact at producing required result | Numerous examples of REA entities imported refer to appendix C | 1 |

Table 9.8: Evaluation Results ARTE 1: CG template

**ARTE 4: CGExport - Protégé Export Tool** This Section details the results of the validation for ARTEfact 4, CGexport a Protégé export tool.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Output/export both CGs and REA entities | Refer to key requirement REQ G2 and REQ G7, in Table 3.5 and REQ A4 in Table 3.6 | 1 |
| Utility | Why is the artefact required | Required to enable modelling of generic TM, refer to Section 3.3 | 1 |
| Quality | Measured against other tools | One of the first EA design tools to allow export of CG's using ISO CGIF standard | 1 |
| Efficacy | How good is the artefact at producing required result | CG and REA entities exported refer to appendix C.2.1 | 1 |

Table 9.9: Evaluation Results ARTE 4: CGExport

**ARTE 5: FCA Integration - FCAView** This Section details the results of the validation for artefact 5 FCA integration using FCAView in Protégé.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Ability to validate the model | Refer to key requirement REQ K3 in Table 3.4 and REQ H2 in Table 3.2) | 1 |
| Utility | Why is the artefact required | Required to provide full EA modelling including validation, within the Knowledge Management System (KMS), refer to Section 3.3 | 1 |
| Quality | Measured against other tools | Previously FCA validation only possible manually, export from one tool then import into another tool | 1 |
| Efficacy | How good is the artefact at producing required result | Several examples of FCA analysis from within Protégé refer to Section 8.3.5 | 1 |

Table 9.10: Evaluation Results ARTE 5: FCA Integration

**ARTE 6: JESS Integration** This Section details the results of the validation for ARTEfact 6, JESS integration. The efficacy of the JESS artefact received only a 3, since the JESS standard license is only for 30 days, thus not allowing for a detailed evaluation, refer to Section 8.3.6.

| Criteria | Description | Evidence | Result |
|---|---|---|---|
| Validity | Ability to validate and query the model | Refer to key requirement REQ K3, REQ K2 in Table 3.4 and REQ H2 in Table 3.2 | 1 |
| Utility | Why is the artefact required | Required to provide full EA modelling including validation and query, within the design tool, refer to Section 3.3 | 1 |
| Quality | Measured against other tools | JESS offers an integrated validation capability | 1 |
| Efficacy | How good is the artefact at producing required result | Examples of JESS analysis from within Protégé refer to Section 8.3.6 | 3 |

Table 9.11: Evaluation Results ARTE 5: JESS Integration

**ARTE 7: READBexport - Protégé Export Tool** Validation not possible/required, artefact incomplete, refer to Section 8.3.7.

### 9.3.4 EVAL 4: The AREA KMS using Two Case Studies

Using the comparison of the requirements for the AREA KMS defined in Tables: 3.5, 3.2, 3.4 and 3.6 against the two case studies: Case Study B refer to Section 8.6 and Case Study A refer to Section 8.5, an evaluation is provided detailed in Table 9.12 below. The details of the requirements are presented together with the column "Complete" which identifies on a scale of 1 (fully complete) to 5 (not complete) whether the requirements have been fulfilled. The column Evidence/Comments provides details of the evidence which confirms or comments on the evaluation.

| **REQ ID** | **Requirement** | Complete | Evidence/Comments |
|---|---|---|---|
| REQ G1 | **Process** and interpret CGs stored as CGIFs | 1 | All of the data imported from CGIFs in Appendix C |
| REQ G2 | **Process** and interpret REA attributes stored as CGIFs | 1 | All of the data imported from CGIFs in Appendix C |
| REQ G3 | **Allow** for machine readable data capture | 1 | AREA KMS uses ISO CGIF standard which is machine readable e.g. refer to Section 5.4.2 |
| REQ G4 | **Allow** for human readable data capture | 1 | AREA KMS uses ISO CGIF standard which is easier for humans to read than XML, and the Protégé GUI detailed in Section 4.3.2 |
| REQ G5 | **Enable** reverse engineering and design recovery applications | 1 | Using CGIF models can be both imported and exported from Protégé |
| REQ G6 | **Allow** data analysis for discovering the Hidden Knowledge in Transaction Data | 1 | FCAView (refer to Section 8.3.5) and JESS (refer to Section 8.3.6) provide for model validation. Case Study A details effective FCA refer to Figure 8.35 |
| REQ G7 | **Promote** automated development | 1 | CGimport and CGexport allow models to be data-driven |
| REQ G8 | **Promote** iterative development | 1 | CGimport and CGexport allow models to be iterative, since the same model is used for the business model as for the database model |
| REQ G9 | **Enable** full development life cycle | 1 | AREA KMS and the model can be used to define also the database design. Refer to the artefact READBexport detailed in Section 8.3.7 |
| REQ H1 | **Utilise** a notation which is rich, expressive and can tolerate both quantitative and qualitative high-level domain concepts | 1 | CG's allow for the definition of an REA model and ontology. Case study A shows how a real-world problem can be effectively solved using the AREA KMS, refer to Section 8.5 |

Table 9.12: Evaluating Requirements Against Case studies, part 1

| **REQ ID** | **Requirement** | Complete | Evidence/Comments |
|---|---|---|---|
| REQ H2 | **Provide** a mechanism whereby models can be queried, reasoned against and verified | 1 | FCAView (refer to Section 8.3.5) and JESS (refer to Section 8.3.6) provide for model reasoning and verification |
| REQ H3 | **Support** the implicit capture and explicit expression of ontological data | 1 | CGs and REA allow for a TOA design to be modelled. Refer to Figure 8.28 showing how Card payment transactions can be effectively modelled |
| REQ H4 | **Impose** a rigour upon the modelling process | 1 | Solution uses ISO CL standards which means models can be shared with other tools e.g. CharGer refer to Section 3.5.1 |
| REQ K1 | **Input** of CGs into Knowledge Repository (KR) | 1 | Refer to REQ G1 above |
| REQ K2 | **Query** of CGs in KR | 1 | Refer to REQ G6 above |
| REQ K3 | **Validate** CGs in KR | 1 | Refer to REQ G3 above |
| REQ K4 | **Output** of CGs from KR | 1 | READBexport and CGexport allow models to be exported |
| REQ A1 | **GUI interface** - provide a GUI interface | 1 | Protégé provides a GUI interface as detailed in Section 4.3.2 |
| REQ A2 | **Use common standards** - use common non-proprietary industry standards | 1 | ISO CL CGIF standard used as detailed in Section 5.4.2 |
| REQ A3 | **Open source-software** - based on open-source software | 1 | Protégé has an open-source license as detailed in Section 4.3.2 |
| REQ A4 | **Interoperable** - must be interoperable with other tools | 1 | the AREA KMS uses the ISO CL CGIF standard which means models can be shared with other tools e.g. CharGer refer to Section 3.5.1 |
| REQ A5 | **Capture layers** - be able to capture the layers identified within EA (Scheruhn et al., 2015). | 5 | This would be a very useful feature, but unfortunately not implemented and must therefore be added to future work |

Table 9.13: Evaluating Requirements Against Case studies, part 2

### 9.3.5 EVAL 5: Working Solution, Expert Interview

This Section presents the details of an expert interview, with an experienced technical stakeholder, with 30 years experience in IT, the transcripts of which are partially detailed in appendix D.2. Generally a positive feedback was provided by Participant A (refer to D.1), who could see a "usage for the AREA KMS with EA (modelling)". The participant was however not "overly impressed" with the graphics of Protégé, which were deemed to be "outdated". Other negative feedback was also provided for the automatic routing of the REA entities which was considered "not very user friendly".

### 9.3.6 EVAL 6: Field Experiment, Participant Observation

Through an opportunity the AREA KMS was presented to the students of an MSc. course - "Architecture for Enterprise Applications" at Sheffield Hallam University. AREA KMS was incorporated into the MSc. and enabled the students to understand the principles of Model Visualisation (MV) and Model Automatisation (MA). The artefacts of the AREA KMS were tested by the students providing the students with the opportunity to work on a significant ontology design system: Protégé, whilst at the same time producing qualitative data which is analysed and incorporated into this research.

**Learning, Teaching and Assessment (LTA)** The work which the students completed was a field experiment and due to the complexity of the problem domain was not incorporated into the final assignment.

**Pedagogy** Given the fact that Protégé was developed at Stanford University, it has a strong pedagogic foundation and is designed for active learning and research development. To assess the effectiveness of the LTA process the data was returned informally from the students. The students were presented with the script and set of tasks detailed in appendix D.3.

**Discussion** The students found the problem domain complex and the challenge was for some students too complex, for others the problem was completing the tasks within a short time-frame. The problem been that the students were required to understand several complicated topics at the same time: EA, TOA and Protégé.

**Analysis of Students Findings** All of the students concluded that the AREA KMS and Protégé were tools which could aid EA design and would be worth further investigation. However due to the complexity of the problem domain, significant qualitative data was not returned. More time with the students would have been necessary and more assistance with the background theories.

## 9.4 Limitations to the Evaluation

Given that the evaluation strategy for this research was split into (6) separate unique steps, this section presents the limitations associated with each step.

**EVAL 1** When looking at the limitation for this formative evaluation step 1, one must first look at the participants who conducted the evaluation and who produced the resulting data, MSc. students. These students had already been engaged in authentic project experiences working for external clients in real-world settings. However one could still argue that there is still a concern about the validity of these students justifying the research question, albeit the evaluation returned positive results.

Due to the assignment question posed, that of comparing a TOA architecture against another methodology this had the result that the students were able to provide comparative inputs using secondary sources which were collected during this formative evaluation.

A further high risk to this evaluation step, is that of false positives since the students might (feel obliged to) say what they expect the tutor wants to hear. These limitations are acknowledged, however one could argue that the mix of students and the "fresh" ideas provided justify this form of evaluation.

**EVAL 2** This formative evaluation step working in an artificial context with the Director of Studies Dr. Simon Polovina, in what can be defined as a single supervisor model, together with the assistance of multiple domain experts who supplied feedback and information detailed in Appendix B. This formative evaluation step 2, worked effectively and lead to a large data sample, which allowed for the successful completion of multiple Action Research cycles. However one could determine one limitation, which was the fact that there was only one stakeholder working on the Action Research cycles, using multiple Action Research practitioners would inevitably have produced different results.

**EVAL 3** Although this summative evaluation step 3, returned positive results in an artificial setting, the limitation that the author was validating his own work is accepted, which must include some bias. However to evaluate the technical efficacy would have been prohibitively expensive if the evaluation used real users and real systems in a real setting. It is common practice in (low risk) industrial settings for the programmer to validate their own code and given that the critical goal of the evaluation was to rigorously establish that the artefacts had utility and benefit against a defined purpose and have consequently shown a yielded utility to their usage, this limitation is accepted as necessary.

**EVAL 4** Although the two case studies presented detailed real-world problems. We concede the limitation that for a more detailed analysis, the evaluation must also include more combinations of the artefacts working end-to-end on a real-world projects. However this would be too costly due to the time involved and one could also argue that this is not required for a POC.

**EVAL 5** The summative evaluation step 5, had some methodological limitations, for example the study relied on the input and knowledge of a small non-random sample of one single expert and therefore the interview results were not used in subsequent interviews to check for consensus among experts. The limitation must be accepted, that multiple interviews with different experts, may have produced more interesting results and that there may have been some bias in the expert's responses, however the artefacts have been evaluated against a defined purpose and consequently shown a yielded utility to their usage during EVAL step 3.

**EVAL 6** Limitations in this summative evaluation step, influenced directly on the results, the students did not have sufficient time to invest in what is a complex topic, thus the evaluation produced minimal results.

## 9.5 Conclusions in Chapter 9

This chapter has presented a comprehensive ex ante and ex post evaluation process consisting of (6) individual steps. The evaluation began by completing a literature search to determine the latest recommendations for DSRM evaluation. Using this information a hybrid evaluation framework was developed, capable of evaluating different evaluands through different timings (ex ante and ex post), producing both formative and summative evaluation results in both an artificial and natural environments.

Of course the evaluation steps completed were not without their limitations, which have been detailed above in Section 9.4, not withstanding the limitations of the individual evaluation steps, there are also some more limitations to take into account when looking at the results of this research as a whole. The question must be raised as to the lack of demonstration on a real-life project, which leaves room to wonder how the project method would work in a real-life industrial project.

One could also make the argument that due to the limited number of evaluations one could complete further evaluation iterations on the individual steps of the ex post evaluation of the AREA KMS. Particularly further evaluation of the solution as a whole would provide further validation of the approach. Another avenue for future work would be to develop other novel evaluation strategies and to explore further the value of hybrid strategies. However when one takes into account that the evaluation is for a POC, the evaluation has fulfilled the original goal of both supporting the research objectives and providing evidence that the artefacts aid the user in solving some problem or making some improvement.

However even taking into account the limitations presented, this Chapter has successfully shown how the artefacts of the AREA KMS have provided a novelty which has been demonstrated by providing the solution to "some previously unforeseen problem in an effective and efficient manner" (Hevner et al., 2004).

# Chapter 10

# Conclusions and Further Work

**DSRM Step 6 - Communication.** Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences

## 10.1 Introduction

This Chapter details the "Research Communication", DSRM Step 6: and provides the final key step of DSRM that of the final communication of the research, through providing the conclusion to what extent the aim and research objectives have been fulfilled. First the hypothesis is addressed to determine whether it has been supported. The contributions are detailed together with an identification of further areas of research.

## 10.2 Hypothesis

The hypothesis of this research is that: "Conceptual Structures using the REA ontology adds value when defining a Transaction Oriented Architecture (TOA) within Enterprise Systems (ES)".

In Section 3.5.3 the mental model of the Requirements Management Wheel (RMW) (shown in Figure 3.9) was introduced, which provides a solution through defining a framework for an Enterprise Architecture (EA) based on Transaction Oriented Architecture (TOA) using the REA ontology. The RMW uses Conceptual Structures (CGs) as the interface layer (input, output, query, validate) which enables both a high-level and low-level concept of Transactions to be captured using Conceptual Graphs. The Knowledge Repository in the centre of the RMW is based on a Closed World Assumption, following the finding that a CWA would provide best-practice for EA design, for further details of the merits of a CWA KR, refer to Section 4.3.2.

As a POC the artefact, AREA KMS based on CGs using Protégé has been implemented to validate the theory of the RMW mental model. Providing a demonstration of how the (EA) Requirements can be defined, validated and accessed (Input, Output, Query and Validate) by each of the different phases A-H using CGs (defined using the ISO CL CGIF standard refer to Section 5.4.2) as the interface layer.

The implementation of two industrial case-studies, using the AREA KMS, has demonstrated that Conceptual Structures are suited to the purpose of populating a hierarchy of types thus enabling the definition of a TOA ontology. AREA KMS allows the TOA to be qualified with domain experts and speeds up the development process since all the necessary tools are incorporated into a single application. AREA KMS offers significant advantages, allowing the practitioner more time to be able to focus in on areas which require more detailed analysis. AREA KMS has been demonstrated to support the three TOGAF ADM phases, B: Business Architecture, C: Information Systems Architecture and D: Technology Architecture. Finally, the use of the AREA KMS has been demonstrated to support both the transaction metaphor, which can considered to be "sufficiently abstract to be domain independent" (Hill, 2006) and the concept of the Transaction Pyramid (TP) (refer to Section 3.4) which defines three tiers of transactions: Enterprise, Business and Database. Thus evidence has been provided using AREA's Knowledge Repository which uses Conceptual Structures through a) the ISO Common Logic standard's Conceptual Graph Interchange Format (CGIF) to store and transmit the TOA using an REA ontology, and b) Formal Concept Analysis (FCA) for validation. Demonstrating how using the REA ontology adds value when defining an Enterprise Architecture using a Transaction Oriented Architecture for an Enterprise

System, therefore the hypothesis is supported through the evidence provided.

## 10.3 Research Approach

The primary research methodology DSRM has already a tradition in REA research since through the design cycles it offers relevance and rigour, providing the practitioner the ability to contextualize the design artefact(s) by referring to a practical problem in the real world (Geerts, 2011).

Prior to implementation of the AREA KMS, two (2) ex ante evaluation steps were completed to provide: (i) formative evaluation and justification for the research and provide validation of the research objectives in an artificial environment, (ii) provide the basis of "How" a solution could be provided, using the secondary research methodology Action Research, through a process of multiple cycles, evaluating both existing artefacts and the current methods and protocols available, delivering an assessment of the pre-existing artefacts suitability to form a KMS.

Following implementation of the AREA KMS, four (4) post ante evaluation steps were completed to provide: (i) evaluate the individual artefacts of the AREA KMS, (ii) evaluate the AREA KMS as a complete solution within an industrial context, through demonstrating AREA KMS using the secondary research methodology using two case-studies, (iii) Complete an expert interview with an experienced technical stakeholder providing evaluation as to whether the artefacts have novelty and usefulness, and (iv) evaluate the AREA KMS in an artificial environment via a field experiment, to provide an (independent) evaluation of the artefacts of the solution.

The combination of using DSRM as the primary research framework, integrated together with Action Research as a secondary research methodology to provide a more granular basis during DSRM Step 3, Implementation, together with the secondary research methodology of the case-study approach to provide a structure for DSRM Step 4, Demonstration and DSRM Step 5, Evaluation, proved to be a productive research approach.

Moreover due to these benefits of enabling and discovering knowledge within a real-world setting which allows for an intervention and improvement this IS research project has used a pragmatic approach enabled through the Action Research process.

## 10.4 Contributions

This research builds upon several previous pieces of research, primarily that of Polovina (1993) and then (Hill, 2006) and (Launders, 2011), whose development of that work into the concept of the TrAM. Polovina's work was in turn motivated by the work of Geerts and McCarthy (1991).

The two key stakeholders who will benefit from this research are: (i) academic EA researchers, who can use the contributions of this research to add and enable further advancements in EA and (ii) commercial EA practitioners who may use the insights gained in this research in commercial products. The results of this research provide the stakeholders with a theoretical path to using the Transaction Pyramid (TP) and Requirements Management Wheel (RMW) to defining an EA based on a TOA and using Conceptual Graphs. The Automated REA (AREA) Knowledge Management System (KMS) demonstrates through a POC how the stakeholders can define a TOA EA in practice.

The contributions of this research, have come through investigation and identification of design artefacts and models required for the specification of semantics required for a TOA within EA, and are detailed below. Each contribution is aligned against the research objectives as stated in Section 1.5 and identified either as a theoretical or practical contribution.

| |
|---|
| *1. How can REA/TOA ontology design be improved?* |

*Use of the Transaction Pyramid (TP) detailed in Figure 3.5, provides a theoretical contribution which defines three tiers of transactions which constitute a TOA:* Detailing how a TOA can be represented by three tiers of transactions: Enterprise, Business Process and Database.

*Use of the Requirements Management Wheel (RMW) shown in Figure 3.9 provides a theoretical contribution to define an EA based on a TOA and using Conceptual Graphs:* To provide a TOA perspective of EA Knowledge Requirements when using the TOGAF ADM (refer to Figure 2.2) the concept of the RMW has been introduced. RMW adds two extra layers to provide the framework for a Knowledge Requirements System (KRS). The first layer adds the Conceptual Graph (CG) interface layer using the ISO CL CGIF standard (refer to Section 5.4.2). The second layer adds the key functions required for a KMS: Input, Output, Validate and Query.

> *2. What is the best-practice for storing Conceptual Graphs (CGs) in a Knowledge Repository (KR)?*

*Use of the ISO CL CGIF standard, for representing an EA based on TOA in a Knowledge Repository (KR):* Although previously not implemented within a software solution, using CGIF provides a practical contribution which offers several advantages over the RDF standard using XML. The CGIF specification provides all that is required for defining CG's within a knowledge repository, and is both machine readable and easy for humans to read, where as RDF based on XML is also machine readable but difficult for humans to read.

> *3. Which Knowledge Repository (KR) structure: Closed World Assumption (CWA) or Open World Assumption (OWA) would provide best-practice for supporting a TOA EA?*

*Use of a Closed World Assumption (CWA) Knowledge Repository (KR) solution for supporting a TOA EA:* A CWA provides a practical contribution which offers clear advantages over a OWA solution when defining an ontology for a TOA EA, critically since the Enterprise Database will also be a product (output) from the AREA KMS (refer to Section 4.3.2).

> *4. How can the ISO CL CGIF standard be used to support type hierarchies when providing a framework for a TOA EA?*

*Use of the ISO CL CGIF standard to support type hierarchies in a TOA EA:* Through working together with domain experts a clear path has been identified provides a practical contribution to providing a type hierarchy using ISO CL CGIF standard (refer to 7.5.5).

> *5. Through a process of Action Research (AR), produce a Proof Of Concept (POC) for an Knowledge Management System (KMS) TOA tool based solution, using currently available open source software together with artefacts developed to specifically solve the problems which are encountered and identified.*

**Automated REA (AREA) Knowledge Management System (KMS)** artefact developed as a fully fledged EA modelling tool based on Protégé which provides a practical contribution to EA modelling. Providing evidence that the use of the RMW aids TOA design for an EA. Using CGs as the interface layer the RMW, supports type hierarchies for ontology construction including REA (Fallon and Polovina, 2016). Through the Action Research process detailed in Section 7.2 the AREA KMS was implemented as a POC. Moreover, the proposed solution has been demonstrated, AREA KMS in Chapter 8 and through the evaluation presented in Chapter 9, evidence has been provided that the AREA KMS fulfils many of the requirements.

**CGImport** artefact developed for AREA KMS: Conceptual Graph (Protégé) import utility providing a practical contribution to supporting the REA ontology and TOA (Fallon, 2015*c*)

**CGImport** artefact developed for AREA KMS: Conceptual Graph (Protégé) import utility providing a practical contribution to supporting the REA ontology (Fallon, 2015*b*)

**FCATab** artefact integrated into AREA KMS: Providing a means to check the transaction model using FCA inferencing with the Integration of FCAView utility to providing a practical contribution to support TOA model validation directly within Protégé (Jiang, 2016)

**JESS** artefact integrated into AREA KMS: Providing integration of JESS utility providing a practical contribution to support TOA model validation directly within Protégé, by allowing for Graph querying (Eriksson, 2003)

**3to2** artefact developed, as a stand alone CG to FCA utility: Providing a practical contribution to supporting CG to FCA conversion and back again, allowing for round trip engineering (Fallon, 2015*a*)

## 10.5 Limitations

This section looks at some of the limitations which have appeared through this research process: the first that of time-constraints, due to the fact that this research has been completed on a part-time basis, whilst working full-time, over several years combined with the speed of change within IS, may mean that there have been advancements which have not been included in the assessment of currently available artefacts which is detailed within the Action Research cycles in Section 7.2.

The secondary research methodology Action Research offers many benefits, however due to the ad hoc basis of looking at multiple cycles, it is easy to get dragged into other projects which seem like a "good idea at the time", but which take time and resources and which have delayed the production of this final thesis.

Looking at the limitations outlined in the evaluation detailed in Section 9.4, clearly there are several areas which could have been evaluated further, for example JESS needs both further demonstration and evaluation, however this topic has added to further work in the Section below.

## 10.6 Conclusion

Economic exchanges or transactions are omnipresent within contemporary society and extend across enterprises, industries and countries. The ability of the REA ontology to provide a basis for modelling these economic events within EA should not be underestimated. REA provides a basis to aggregate the data at higher and higher levels of abstraction which can provide enterprises and individuals with the correct perspective or view of the necessary transactional (enterprise, business process and database) data without the need for data repetition or data spread. The requirement to seamlessly interconnect economic transactions will necessitate more and more integration and automation, which will also promote the requirement for intelligent agents, and here again REA and a TOA would provide a solution.

The introduction of the Transaction Pyramid (TP) defining three levels of transactions for a Transaction Oriented Architecture (TOA): enterprise, business process and database, provides an aid to the enterprise architect when defining Enterprise Architecture.

Through the implementation of a POC of the AREA KMS, together with the Requirements Management Wheel, it has been demonstrated that it is possible to build an TOA Enterprise Architecture based system which integrates the transaction data of multiple diverse trading partners.

Essential to TOA designs, is that they should be data-driven, diagrams are only useful for human understanding and computers do not read diagrams, conversely data-driven designs must also be easy for human understanding and RDF using XML is not. Using the ISO CL CGIF standard within the core of the AREA KMS, evidence has been provided which shows how both these requirements have been fulfilled.

Through the evaluation of the feasibility of the individual artefacts, the TOA design has been demonstrated. Through the two industrial case-studies, two diverse domains have been selected, and produced evidence which demonstrates how, constructs and models were developed and a TOA demonstrated, providing evidence how TOA enhances Semantics and ontology in an EA.

Since the implementation of AREA KMS, advancements have been made and further REA extensions been suggested (refer to Section 3.2.5), such as adding the Location entity to enable the "Internet of Things" and $REA^2$ to provide both internal and external views of the transaction in the same REA model. Which leads to the question, whether the AREA KMS could be utilised to provide a tool for these new extensions?

Given the extended length of this research work, changes have also been made to the original standards and (referring to email B.52) "the second edition of CL was finally published this year (2018), over ten years since the first edition" was published. Although the "changes in the (CGIF) standard have been fairly minimal, considering how the world has evolved during that time". Which provides evidence of the difficulties of both defining and implementing working (ISO) standards.

Finally on a personal note, this research work has promoted personal learning on two fronts: The first through providing the ability to analyse and evaluate, switching from a rather more practical viewpoint to a more hypothetical one. Secondly, providing new methods to complete a more analytical approach to evaluation.

## 10.7 Further Work

This research has led to a better understanding of the domain of EA and resulted in the identification of topics for further work, these are described in this Section.

Currently, the AREA KMS covers the three TOGAF ADM phases:B: Business Architecture, C: Information Systems Architecture and D: Technology Architecture. Consideration should be made about the inclusion of the other five phases: A,E,F,G and H into the AREA KMS (refer to Section 2.2).

It was identified during the evaluation, expert interview (refer to Section 9.3.5), that the Protégé graphics are old and looking out of date, since they rely on JAVA graphics implementation. A solution to this problem, would be to continue to use Protégé KR for the AREA KMS, but develop a cloud solution which would provide a new graphical (cloud) interface, through accessing the AREA KR.

With regards to possible future improvements to AREA KMS: (i) the artefact READBexport would improve the scope of the functionality and provide as output a Database Schematic (refer to Section 8.3.7), (ii) JESS provides real scope for model validation, and further demonstration and evaluation would be recommended.

# References

Andrews, S. (2017*a*), 'CG-FCA'.
**URL:** *https://sourceforge.net/projects/cgfca/* (accessed 29/04/2021)

Andrews, S. (2017*b*), 'In-Close'.
**URL:** *https://sourceforge.net/projects/inclose/* (accessed 29/04/2021)

Andrews, S. and Polovina, S. (2018), Exploring, Reasoning with and Validating Directed Graphs by Applying Formal Concept Analysis to Conceptual Graphs, *in* 'Graph Structures for Knowledge Representation and Reasoning : 5th International Workshop'.

Appelbaum, D., Kogan, A., Vasarhelyi, M. and Yan, Z. (2017), 'Impact of business analytics and enterprise systems on managerial accounting', *International Journal of Accounting Information Systems* **25**, 29–44.

Baijens, J., Helms, R. and Iren, D. (2020), Applying Scrum in Data Science Projects, *in* '2020 IEEE 22nd Conference on Business Informatics (CBI)', Vol. 1, IEEE, pp. 30–38.

*BBC Ontology* (2021).
**URL:** *https://www.bbc.co.uk/ontologies/bbc* (accessed 04/04/2021)

Benbasat, I., Goldstein, D. K. and Mead, M. (1987), 'The case research strategy in studies of information systems', *MIS quarterly* **Vol.11 (3)**, 369–386.

Berners-Lee, T., Hendler, J. and Lassila, O. (2001), 'The semantic web', *Scientific american* **284**(5), 34–43.

Botes, R., Goede, R. and Smit, I. (2014), Demonstrating an interpretive data collection and analysis process for a DSR project, International Academic Conference on Engineering, Internet and Technology.

Chein, M. and Mugnier, M.-L. (2008), *Graph-based knowledge representation: computational foundations of conceptual graphs*, Springer Science & Business Media.

*Cogitant* (2021).
**URL:** *https://cogitant.sourceforge.io/about.php* (accessed 04/04/2021)

*CoGUI* (2020).
**URL:** *http://www.lirmm.fr/cogui/* (accessed 15/02/2021)

Colomb, R., Raymond, K., Hart, L., Emery, P., Welty, C., Xie, G. T. and Kendall, E. (2006), The object management group ontology definition metamodel, *in* 'Ontologies for software engineering and software technology', Springer, pp. 217–247.

*DataGenie Tab* (2005).
**URL:** *http://faculty.washington.edu/gennari/Protege-plugins/DataGenie/index.html* (accessed 29/04/2021)

Davenport, T. H. et al. (2000), *Mission critical: realizing the promise of enterprise systems*, Harvard Business Press.

Delugach, H. S. (2021), 'CharGer'.
**URL:** *https://www.cs.nmsu.edu/hdp/CGTools/proceedings/papers/CharGer.pdf* (accessed 15/02/2021)

Desfray, P. and Raymond, G. (2014), *Modeling enterprise architecture with TOGAF: A practical guide using UML and BPMN*, Morgan Kaufmann.

Dumitriu, D. and Popescu, M. A.-M. (2020), 'Enterprise Architecture Framework Design in IT Management', *Procedia Manufacturing* **46**, 932–940.

Dunn, C., Gerard, G. J. and Grabski, S. V. (2016), 'Resources-events-agents design theory: A revolutionary approach to enterprise system design', *Communications of the Association for Information Systems* **38**(1), 29.

Dunn, C. L., Hollander, A. S. and Cherrington, J. O. (2005), *Enterprise information systems: A pattern-based approach*, McGraw-Hill/Irwin.

*EnterprisePLUS* (2021).
**URL:** *https://www.enterpriseplus.tools/index.php?title=Main* (accessed 04/04/2021)

Eriksson, H. (2003), Using JESSTab to integrate protege and JESS, Vol. 18, IEEE, pp. 43–50.

EssentialProject (2021), 'Essential meta model'.
**URL:** *https://enterprise-architecture.org/docs/introduction/essential_meta_model/* (accessed 27/02/2021)

Fallon, R. L. (2012), Evaluating the extent to which REA can enhance ERP systems, using SAP as an exemplar, Master's thesis, Sheffield Hallam University.

Fallon, R. L. (2015*a*), '3to2'.
**URL:** *https://github.com/RichardFallon/3to2* (accessed 29/04/2021)

Fallon, R. L. (2015*b*), 'CGexport'.
**URL:** *https://github.com/RichardFallon/CGExport* (accessed 29/04/2021)

Fallon, R. L. (2015*c*), 'CGimport'.
**URL:** *https://github.com/RichardFallon/CGImport* (accessed 06/06/2015)

Fallon, R. L. and Polovina, S. (2013), REA analysis of SAP HCM; some initial findings, *in* 'Proceedings of the 3rd CUBIST (Combining and Uniting Business Intelligence with Semantic Technologies) Workshop co-located with the 11th International Conference on Formal Concept Analysis', CEUR-WS.org.

Fallon, R. L. and Polovina, S. (2016), Automated REA (AREA): a software toolset for a machine-readable resource-event-agent (REA) ontology specification, *in* 'CEUR Workshop Proceedings', Vol. 1637, Tilburg University, pp. 10–18.

Fox-Martin, A. (2016), 'SAP – the worlds leading business software company'.
**URL:** *https://www.sap.com/docs/download/investors/2016/2016-05-23-presentation-dbaccess-asia-conference-singapore-adaire-fox-martin.pdf* (accessed 02/03/2020)

*Frames and OWL side by side* (2021).
**URL:** *https://protege.stanford.edu/conference/2006/submissions/slides/7.2wang_protege2006.p*
(accessed 14/04/2021)

Gailly, F., Laurier, W. and Poels, G. (2008), 'Positioning and formalizing the REA enterprise ontology', *Journal of Information Systems* **22**(2), 219–248.

Ganter, B. and Wille, R. (1999), Concept lattices of contexts, *in* 'Formal Concept Analysis', Springer, pp. 17–61.

Geerts, G. L. (2011), 'A design science research methodology and its application to accounting information systems research', *International Journal of Accounting Information Systems* **12**(2), 142–151.

Geerts, G. L. and McCarthy, W. E. (2002), 'An ontological analysis of the economic primitives of the extended-REA enterprise information architecture', *International Journal of Accounting Information Systems* **3**(1), 1 – 16.

**URL:** *http://www.sciencedirect.com/science/article/pii/S1467089501000203* (accessed 06/02/2021)

Geerts, G. L. and O'Leary, D. E. (2014), 'A supply chain of things: The EAGLET ontology for highly visible supply chains', *Decision Support Systems* **63**, 3–22.

Geerts, G. and McCarthy, W. E. (1991), 'Database accounting systems', *Information Technology Perspectives in Accounting: and Integrated Approach, Eds. B. Williams and BJ Sproul, Chapman and Hall Publishers* pp. 159–183.

Goldkuhl, G. (2011), Design research in search for a paradigm: Pragmatism is the answer, *in* 'European Design Science Symposium', Springer, pp. 84–95.

Goldkuhl, G. (2012), 'Pragmatism vs interpretivism in qualitative information systems research', *European journal of information systems* **21**(2), 135–146.

Gregor, S. and Hevner, A. R. (2013), 'Positioning and presenting design science research for maximum impact', *MIS quarterly* **Vol.37 (2)**, 337–355.

Hacking, I. (1979), 'What is logic?', *The journal of philosophy* **76**(6), 285–319.

Hammer, E. M. (1998), 'Semantics for existential graphs', *Journal of Philosophical Logic* **27**(5), 489–503.

Hay, D. C. (2010), *Data model patterns: A metadata map*, Elsevier.

Hevner, A. R., March, S. T., Park, J. and Ram, S. (2004), 'Design science in information systems research', *MIS quarterly* **Vol.28 (1)**, 75–105.

Hill, R. (2006), A requirements elicitation framework for agent-oriented software engineering, PhD thesis, Sheffield Hallam University,.

Holsapple, C. W. and Sena, M. P. (2005), 'ERP plans and decision-support benefits', *Decision Support Systems* **38**(4), 575–590.

*HP NonStop SQL* (2021).
**URL:** *https://www.hpe.com/us/en/servers/nonstop.html* (accessed 11/05/2021)

Hruby, P. (2006), *Model-driven design using business patterns*, Springer Science & Business Media.

*ISO 8583* (2021).
**URL:** *https://www.iso.org/standard/15871.html* (accessed 20/04/2021)

*ISO/IEC24707 CL Framework* (2018).
**URL:** *https://standards.iso.org/ittf/PubliclyAvailableStandards/c066249_ISO_IEC_24707_2018.*
(accessed 15/02/2021)

Järvinen, P. (2007), 'Action research is similar to design science', *Quality & Quantity* **41**(1), 37–54.

Jiang, G. (2016), 'FCAview'.
**URL:** *https://wiki.nci.nih.gov/display/Protege/FCAView+Protege+Tab+Plug-in* (accessed 29/04/2021)

Kaplan, B. and Maxwell, J. A. (2005), Qualitative research methods for evaluating computer information systems, *in* 'Evaluating the organizational impact of healthcare information systems', Springer, pp. 30–55.

Kotusev, S. (2016), 'The critical scrutiny of TOGAF', *British Computer Society (BCS), URL: http://www. bcs. org/content/conWebDoc/55892* .

Launders, I. (2011), The Transaction Graph for Requirements Capture in Semantic Enterprise Architectures, PhD thesis, Sheffield Hallam University.

Laurier, W., Kiehn, J. and Polovina, S. (2018), 'REA 2: A unified formalisation of the resource-event-agent ontology', *Applied Ontology* **13**(3), 201–224.

*LEADing Practice* (2020).

**URL:** *https://www.leadingpractice.com/about/* (accessed 21/08/2020)

Lee, J., Kwon, Y. S., Färber, F., Muehle, M., Lee, C., Bensberg, C., Lee, J. Y., Lee, A. H. and Lehner, W. (2013), SAP HANA distributed in-memory database system: Transaction, session, and metadata management, *in* '2013 IEEE 29th International Conference on Data Engineering (ICDE)', IEEE, pp. 1165–1173.

Magoulas, T., Hadzic, A., Saarikko, T. and Pessi, K. (2012), 'Alignment in enterprise architecture: A comparative analysis of four architectural approaches', *Electronic Journal of Information Systems Evaluation* **15**(1), 88.

Mani, N., Helfert, M., Pahl, C., Nimmagadda, S. L. and Vasant, P. (2018), *Domain Model Definition for Domain-Specific Rule Generation Using Variability Model*, Springer International Publishing, pp. 39–55.

Markus, M. L., Majchrzak, A. and Gasser, L. (2002), 'A design theory for systems that support emergent knowledge processes', *MIS quarterly* **Vol.26 (3)**, 179–212.

*MaxDB Transactions* (2021).

**URL:** *https://maxdb.sap.com/doc/7_7/44/d776a368113ee3e10000000a114a6b/content.htm#:~:t database transaction is a,the transaction began (ROLLBACK).* (accessed 11/05/2021)

Mayall, A. and Carter, J. (2015), 'The Essential Project: Harnessing Conceptual Structures to Expose Organizational Dynamics', *International Journal of Conceptual Structures and Smart Applications* .

McCarthy, W. E. (1982), 'The REA accounting model: A generalized framework for accounting systems in a shared data environment', *Accounting review* pp. 554–578.

Mian, A. N., Hameed, A., Khayyam, M. U., Ahmed, F. and Beraldi, R. (2015), 'Enhancing communication adaptability between payment card processing networks', *IEEE Communications Magazine* **53**(3), 58–64.

Minto, B. (1987), 'The pyramid principle-logic in writing and thinking'.
**URL:** *http://www.barbaraminto.com/concept.html* (accessed 14/02/2021)

Musen, M. A. (2015), 'The protégé project: a look back and a look forward', *AI matters* **1**(4), 4–12.

Ngu, A. H., Carlson, M. P., Sheng, Q. Z. and Paik, H.-y. (2010), 'Semantic-based mashup of composite applications', *IEEE Transactions on Services Computing* **3**(1), 2–15.

Nielsen, P. A., Avison, D., Lau, F. and Myers, M. (1999), 'Action Research', *Communications of the ACM* **42**(1), 84–97.

*Notepad++* (2021).
**URL:** *https://notepad-plus-plus.org/downloads/* (accessed 18/04/2021)

Olesen, K. and Myers, M. D. (1999), 'Trying to improve communication and collaboration with information technology: an action research project which failed', *Information Technology & People* **12**(4), 317–332.

*OMG MDA Guide rev. 2.0* (2014), Web.
**URL:** *https://www.omg.org/cgi-bin/doc?ormsc/14-06-01* (accessed 29/04/2021)

*Ontology Definition Metamodel* (2014), Web.
**URL:** *https://www.omg.org/spec/ODM/1.1/PDF* (accessed 29/04/2021)

*OWL 2 Web Ontology Language* (2009).
**URL:** *https://www.w3.org/TR/2009/REC-owl2-overview-20091027/* (accessed 15/01/2021)

Peffers, K., Tuunanen, T., Rothenberger, M. A. and Chatterjee, S. (2007), 'A design science research methodology for information systems research', *Journal of management information systems* **24**(3), 45–77.

Perry, C. (1998), 'Processes of a case study methodology for postgraduate research in marketing', *European journal of marketing* **32**(9/10), 785–802.

Pfaender, A. (2013), *Logic*, Vol. 3, Walter de Gruyter.

Polovina, S. (1993), Bridging accounting and business strategic planning using conceptual graphs, *in* 'Conceptual structures: Theory and implementation', Springer, pp. 312–321.

Polovina, S. (2013), 'A transaction-oriented architecture for enterprise systems', *International Journal of Intelligent Information Technologies (IJIIT)* **9**(4), 69–79.

Polovina, S., Scheruhn, H.-J., Weidner, S. and Von Rosing, M. (2016), Highlighting the gaps in enterprise systems models by interoperating CGs and FCA, *in* 'CEUR Workshop Proceedings', Vol. 1637, Tilburg University, pp. 46–54.

Polovina, S., von Rosing, M. and Laurier, W. (2014), Conceptual structures in leading and best enterprise practices, *in* 'International Conference on Conceptual Structures', Springer, pp. 293–298.

Pries-Heje, J., Baskerville, R. and Venable, J. R. (2008), Strategies for design science research evaluation., *in* 'European Conference on Informat', pp. 255–266.

*ProtegeDocgen* (2008).
**URL:** *https://protegewiki.stanford.edu/wiki/ProtegeDocgen* (accessed 26/04/2021)

*Protege-Frames User's Guide* (2008).
**URL:** *https://protegewiki.stanford.edu/wiki/PrF_UG_all* (accessed 06/02/2021)

*Protege Wiki* (2021).
**URL:** *https://protegewiki.stanford.edu/wiki/Main_Page* (accessed 06/02/2021)

Rajagopalan, S. (2010), 'TOGAF and SAP EAF Relationship'.
**URL:** *https://blogs.sap.com/2010/11/30/togaf-and-sap-eaf-relationship-part-1/* (accessed 02/02/2020)

Rumsey, R. (2021), 'Communicate the options'.
**URL:** *https://www.designbetter.co/business-thinking-for-designers/communicate-the-options* (accessed 14/02/2021)

Sastry, K. S. (2001), An object oriented simulator for conceptual graphs, Master's thesis, Virginia Polytechnic Institute and State University.

Scheruhn, H., von Rosing, M. and Fallon, R. L. (2015), *Information Modelling and Process Modelling*, Vol. 1, Elsevier, pp. 511–550.

Sengupta, K., Krisnadhi, A. A. and Hitzler, P. (2011), Local closed world semantics: Grounded circumscription for OWL, *in* 'International Semantic Web Conference', Springer, pp. 617–632.

Sowa, J. F. (1984), *Conceptual structures: information processing in mind and machine*, Addison-Wesley Longman Publishing Co., Inc.

Sowa, J. F. (1992), 'Conceptual graphs as a universal knowledge representation', *Computers & Mathematics with Applications* **23**(2-5), 75–93.

Sowa, J. F. (2000), Ontology, metadata, and semiotics, *in* 'International conference on conceptual structures', Springer, pp. 55–81.

Stefanou, C. J. (2001), 'A framework for the ex-ante evaluation of ERP software', *European Journal of Information Systems* **10**(4), 204–215.

Susman, G. and Evered, R. D. (1978), 'An Assessment of the Scientific Merits of Action Research', *Administrative science quarterly* **23**(4), 582–603.

*TOGAF, Ver. 9.2* (2020).
**URL:** *https://pubs.opengroup.org/architecture/togaf9-doc/arch/* (accessed 06/06/2020)

Vandenbossche, E. (2007), 'A pattern for global payment optimization via REA ontology'.

Venable, J., Pries-Heje, J. and Baskerville, R. (2012), A comprehensive framework for evaluation in design science research, *in* 'International Conference on Design Science Research in Information Systems', Springer, pp. 423–438.

Venable, J., Pries-Heje, J. and Baskerville, R. (2016), 'FEDS: a framework for evaluation in design science research', *European journal of information systems* **25**(1), 77–89.

von Rosing, M., Arzumanyan, M. and Sr., J. A. Z. (2017), 'The relationship between ontology and modelling concepts: Example role oriented modelling', *International Journal of Conceptual Structures and Smart Applications* .

von Rosing, M., Scheer, A.-W., von Scheel, H., Svendsen, A. D., Kokkonen, A., Ross, A. M., Bøgebjerg, A. F., Olsen, A., Dicks, A., Gill, A. Q., Bach, B., Storms, B. J., Smit, C., Clemmensen, C., Swierczynski, C. K., Utschig-Utschig, C., Moorcroft, D., Jones, D. T., Coloma, D., Boykin, D., Muhita, D. H., Gonçalves, D., Maggi, F. M., Zhao, F., Senghore, F., Dandashi, F., Cummins, F., Stoffel, F., von Scheel, G., von Rosing, G., Doucet, G., Meiling, G., Jansson, G. O., Scheruhn, H., Bohn, H., de Man, H., Kuil, H., Vester, H. N., Gammelgaard, J., Womack, J. P., Ross, J. W., Greer, J., Nielsen, J. T., Zachman, J. A., Bertram, J., Golden, J., Rogers, J. M., Erasmus, J., von Scheel, J., Waters, J., Tomlinson, J., Gräslund, K., Bartels, K., Swenson, K. D., Teske, K. D., Govender, K., Vitt, K., Skurzak, K., Spurrell, L., Dugan, L., Tange, L., Clausager, M., Hove, M., Rybrink, M., Fonseca, M., Stanford, M., Dumas, M., Kirchmer, M., Arzumanyan, M., Tisdel, M. D., van den Hoven, M., Munck, M., Marin, M. A., von Rosing, M., Palmer, N., Kemp, N., Faltin, N., Chakravartti, P., Kemp, P., Franz, P., Lebacq, P., Hilliard, R., Fallon, R. L., Conzo, R. N., Peacock, R., Batdorf, R. N., Snyman, S. J., Davis, S., Polovina, S. M., White, S., Durbin, S., Willoughby, S., Vollbehr, S., Boosz, T., Olsen, T. C., Hoebeek, T., Preston, T., Foldager, U., Abele, V., Snels, V., Rebhan, V., Laurier, W., Gunnarsdottir, Y., Orlov, Y., Maamar, Z., Balasubramanian, E., Phuong, M. and Dumond, R. (2015), *Business Process Trends*, Vol. 1, Elsevier, pp. 187–216.

von Rosing, M. and von Scheel, H. (2016), 'Using the business ontology to develop enterprise standards', *International Journal of Conceptual Structures and Smart Applications (IJCSSA)* **4**(1), 48–70.

Wachsmuth, G. (2007), Metamodel adaptation and model co-adaptation, *in* 'European Conference on Object-Oriented Programming', Springer, pp. 600–624.

Wang, H., Noy, N., Rector, A., Musen, M., Redmond, T., Rubin, D., Tu, S., Tudorache, T., Drummond, N., Horridge, M. et al. (2006), Frames and OWL side by side, *in* 'Presentation Abstracts', Citeseer, p. 54.

Watmough, M. (2013), Discovering the hidden knowledge in transaction data through formal concept analysis, PhD thesis, Sheffield Hallam University.

Yin, R. K. (1994), *Designing Single-and Multiple-Case. Improving educational management: Through research and consultancy*, SAGE.

Zachman, J. (2008), 'The Zachman Framework', Web.
**URL:** *https://www.zachman.com/about-the-zachman-framework* (accessed 02/02/2021)

Zhang, Y. (2017), From Matching to Querying: A Unified Framework for Ontology Integration, PhD thesis, University of Southern California.

Zuber-Skerritt, O. and Perry, C. (2002), 'Action research within organisations and university thesis writing', *The learning organization* .

# Appendix A

# Data Collection - DSRM Step 2 - Define the objectives for a solution

This Appendix contains part of the data collected for DSRM Step 2 - Define the objectives for a solution, which includes the following data:

- **Conceptual Graphs** in CGIF format used to define the requirements
- **REA Ontology** defined in CGIF format and RDF to compare the same Graph defined in the two different formats.

## A.1 Conceptual Graphs

### A.1.1 Simple CG in Graphical form

[Concept1] [Concept2] (Relation Concept1 Concept2)

### A.1.2 Type Hierarchy in Conceptual Graphs

[Resource][Event][Agent][REA] (subtype Resource REA)(subtype Agent REA)(subtype Event REA)

### A.1.3 Mammal Type Hierarchy

[Horse][Mammal][Animal] (subtype Horse Mammal)(subtype Mammal Animal)

## A.2 REA Ontology

### A.2.1 The Transaction Model (TM) Graph (CGIF)

Detailed below is the Transaction Model (TM) Graph (Hill, 2006) in the ISO CL CGIF standard, which is the same graph as defined below in Section A.2.2 defined in RDF. When comparing the two formats, CGIF provides for a more succinct and human readable version.

```
[Resource][Event][Agent][REA]
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)
[Inside][Outside]
(subtype Inside Agent)(subtype Outside Agent)
[Transaction]
[Link][part][source][subject][destination]
(subtype part Link)(subtype source Link)(subtype subject Link)
(subtype destination Link)
[Inside: *1][Outside: *2]
[Resource: *c][Resource: *d]
[Event: *a][Event: *b]
[Transaction: *t]
(part ?t ?b)(part ?t ?a)
(subject ?b ?d)(subject ?a ?c)
(source ?c ?1)(source ?d ?2)
(destination ?d ?1)(destination ?c ?2)
```

### A.2.2 Transaction Model Ontology (Hill, 2006) (RDF/XML)

Detailed below is the Transaction Model (TM) Graph in RDF format as defined by Hill (2006).

```
<?xml version="1.0" ?>
<rdf:RDF xmlns="http://www.owl-ontologies.com/Ontology1155310434.owl
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xml:base="http://www.owl-ontologies.com/Ontology1155310434.owl">
```

```
<owl:Ontology rdf:about=""/>
<owl:Class rdf:ID="Transaction">
<owl:equivalentClass>
<owl:Restriction>
<owl:onProperty>
<owl:ObjectProperty rdf:ID="hasPart"/>
</owl:onProperty><owl:minCardinality rdf:datatype=
"http://www.w3.org/2001/XMLSchema#int"
>2</owl:minCardinality>
</owl:Restriction>
</owl:equivalentClass>
<owl:disjointWith>
<owl:Class rdf:ID="EconomicEvent"/>
</owl:disjointWith>
<owl:disjointWith>
<owl:Class rdf:ID="EconomicResource"/>
</owl:disjointWith>
<owl:disjointWith>
<owl:Class rdf:ID="OutsideAgent"/>
</owl:disjointWith>
<rdfs:subClassOf>
<owl:Restriction>
<owl:someValuesFrom>
<owl:Class rdf:about="#EconomicEvent"/>
</owl:someValuesFrom>
<owl:onProperty>
<owl:ObjectProperty rdf:about="#hasPart"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf rdf:resource=
"http://www.w3.org/2002/07/owl#Thing"/>
<rdfs:comment rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
>the␣satisfactory␣exchange␣of␣scarce␣resources␣between
two␣agents␣via␣opposing␣events</rdfs:comment>
<owl:disjointWith>
<owl:Class rdf:ID="InsideAgent"/>
</owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#OutsideAgent">
<rdfs:subClassOf>
<owl:Class rdf:ID="BDIAgent"/>
</rdfs:subClassOf>
<rdfs:comment rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
>the␣perspective␣of␣the␣transaction␣from␣the␣agent</rdfs:comment>
<owl:disjointWith>
<owl:Class rdf:about="#InsideAgent"/>
</owl:disjointWith>
```

```
<owl:disjointWith rdf:resource="#Transaction"/>
<owl:disjointWith>
<owl:Class rdf:about="#EconomicResource"/>
</owl:disjointWith>
<rdfs:subClassOf>
<owl:Restriction>
<owl:someValuesFrom>
<owl:Class rdf:about="#EconomicResource"/>
</owl:someValuesFrom>
<owl:onProperty>
<owl:ObjectProperty rdf:ID="isDestinationOf"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Restriction>
<owl:someValuesFrom rdf:resource="#OutsideAgent"/>
<owl:onProperty>
<owl:TransitiveProperty rdf:ID="isSourceOf"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
<owl:disjointWith>
<owl:Class rdf:about="#EconomicEvent"/>
</owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#EconomicResource">
<rdfs:comment rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
>the␣scarce␣resource␣to␣be␣exchanged</rdfs:comment>
<owl:disjointWith rdf:resource="#Transaction"/>
<owl:disjointWith rdf:resource="#OutsideAgent"/>
<owl:disjointWith>
<owl:Class rdf:about="#InsideAgent"/>
</owl:disjointWith>
<owl:disjointWith>
<owl:Class rdf:about="#EconomicEvent"/>
</owl:disjointWith>
</owl:Class>
<owl:Class rdf:about="#InsideAgent">
<owl:disjointWith>
<owl:Class rdf:about="#EconomicEvent"/>
</owl:disjointWith>
<rdfs:subClassOf>
<owl:Restriction>
<owl:someValuesFrom rdf:resource="#EconomicResource"/>
<owl:onProperty>
<owl:TransitiveProperty rdf:about="#isSourceOf"/>
</owl:onProperty>
</owl:Restriction>
```

```
</rdfs:subClassOf>
<owl:disjointWith rdf:resource="#Transaction"/>
<rdfs:subClassOf rdf:resource="#BDIAgent"/>
<owl:disjointWith rdf:resource="#OutsideAgent"/>
<owl:disjointWith rdf:resource="#EconomicResource"/>
<rdfs:comment rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
>the␣perspective␣of␣the␣transaction␣from␣the␣agent</rdfs:comment>
<rdfs:subClassOf>
<owl:Restriction>
<owl:someValuesFrom rdf:resource="#EconomicResource"/>
<owl:onProperty>
<owl:ObjectProperty rdf:about="#isDestinationOf"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#EconomicEvent">
<rdfs:subClassOf>
<owl:Restriction>
<owl:onProperty>
<owl:ObjectProperty rdf:ID="hasSubject"/>
</owl:onProperty>
<owl:someValuesFrom rdf:resource="#EconomicResource"/>
</owl:Restriction>
</rdfs:subClassOf>
<owl:disjointWith rdf:resource="#OutsideAgent"/>
<rdfs:subClassOf rdf:resource=
"http://www.w3.org/2002/07/owl#Thing"/>
<owl:disjointWith rdf:resource="#InsideAgent"/>
<owl:disjointWith rdf:resource="#Transaction"/>
<owl:disjointWith rdf:resource="#EconomicResource"/>
<owl:equivalentClass>
<owl:Restriction>
<owl:onProperty>
<owl:ObjectProperty rdf:about="#hasSubject"/>
</owl:onProperty>
<owl:minCardinality rdf:datatype=
"http://www.w3.org/2001/XMLSchema#int"
>1</owl:minCardinality>
</owl:Restriction>
</owl:equivalentClass>
</owl:Class>
<owl:ObjectProperty rdf:about="#hasPart">
<rdfs:range rdf:resource="#EconomicEvent"/>
<owl:inverseOf>
<owl:ObjectProperty rdf:ID="isPartOf"/>
</owl:inverseOf>
<rdfs:domain rdf:resource="#Transaction"/>
</owl:ObjectProperty>
```

```
<owl:ObjectProperty rdf:ID="isEventSubjectOf">
<rdfs:domain rdf:resource="#EconomicResource"/>
<rdfs:range rdf:resource="#EconomicEvent"/>
<owl:inverseOf>
<owl:ObjectProperty rdf:about="#hasSubject"/>
</owl:inverseOf>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#isPartOf">
<rdfs:domain rdf:resource="#EconomicEvent"/>
<rdfs:range rdf:resource="#Transaction"/>
<owl:inverseOf rdf:resource="#hasPart"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#isDestinationOf">
<owl:inverseOf>
<owl:TransitiveProperty rdf:about="#isSourceOf"/>
</owl:inverseOf>
<rdfs:domain>
<owl:Class>
<owl:unionOf rdf:parseType="Collection">
<owl:Class rdf:about="#OutsideAgent"/>
<owl:Class rdf:about="#InsideAgent"/>
</owl:unionOf>
</owl:Class>
</rdfs:domain>
<rdfs:range rdf:resource="#EconomicResource"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasSubject">
<rdfs:range rdf:resource="#EconomicResource"/>
<rdfs:domain rdf:resource="#EconomicEvent"/>
<owl:inverseOf rdf:resource="#isEventSubjectOf"/>
</owl:ObjectProperty>
<owl:TransitiveProperty rdf:about="#isSourceOf">
<owl:inverseOf rdf:resource="#isDestinationOf"/>
<rdfs:range>
<owl:Class>
<owl:unionOf rdf:parseType="Collection">
<owl:Class rdf:about="#OutsideAgent"/>
<owl:Class rdf:about="#InsideAgent"/>
</owl:unionOf>
</owl:Class>
</rdfs:range>
<rdf:type rdf:resource="http://www.w3.org/2002/07/owl#ObjectPropert
<rdfs:domain rdf:resource="#EconomicResource"/>
</owl:TransitiveProperty>
</rdf:RDF>
<!-- Created with Protege (with OWL Plugin 2.2, Build 331)
http://protege.stanford.edu -->
```

# Appendix B

# Data Collection - DSRM Step 3 - Implementation

This Appendix contains the data collected for DSRM Step 3 - implementation, which includes the following data:

- **PhD Supervision forms** detailing part of the Action Research process
- **Emails** collected as part of Action Research process during the implementation step

## B.1 Supervision Forms

This Section details (excerpts) from the PhD supervision forms which document the research process.

| Date | Progress | Sup |
|---|---|---|
| 12.06.12 | First meeting, CGIF convertor for CharGer required | SP |
| 17.04.13 | CG tools too immature, so only focussing on CoGui, as best of this breed to capture CG | SP |
| 12.05.14 | Investigate the possibility of modifying CGFCA.CPP to convert from Protégé 'frames' to FCA | SP |
| 04.10.14 | Progress CG to FCA, 3to2 - complete REA template in Protégé - complete. CG export from Protégé - complete CG to FCA in Protégé - complete Recommendations made: Contact CharGer to import CGIF files Contact ConExp NG to read .CXT files | SP |
| 07.03.16 | Evaluation approaches (such as action research in classroom studies) discussed "real world" evaluation methods (involving people) may unnecessarily complicate the evaluation. DSRM approach cited in RF's paper embraces "lab-based" evaluation including the use of simulations and logical proofs | JH |
| 21.11.16 | Write-up still outstanding, delays due to work commitments | SP |
| 01.02.18 | Meeting with Leading Practice to discuss incorporation of FCA analysis into E+ Write-up still outstanding, delays due to work commitments, part-time did not happen instead a new client was added to freelance work | SP |
| 10.05.19 | Presented second case study; integration of CG and FCA into E+. Including diagrams using Fiori/OpenUI5 and D3 graphical tool | SP |
| 16.08.19 | Write-up still outstanding, still delays due to work commitments Postpone further E+ integration until progress has been made with write-up | SP |
| 03.06.20 | Reduced progress due to extra work-load, due to Covid-19, requested covid extention | SP |

Table B.1: PhD Supervision forms (extract)

Key: SP - Dr. Simon Polovina, JH - Dr. Jacob Habgood

## B.2 Emails

This Section details the emails exchanged with academics working in the field of Conceptual Graphs. The emails have been anonymised and provide details of the Action

Research process as detailed in Section 6.3.

### B.2.1 Requirement for a TOA Knowledge Management System (KMS)

| |
|---|
| "I think this has been staring me in the face for some time, but I've only just realised that we should be concentrating on the transfer of the TM into rules for an agent's knowledge base.<br>Therefore in terms of a framework we could first identify the agents (from roles/stakeholders/actors/responsibility groupings), create the appropriate TMs and then create a knowledge base. Thus the automation should apply to the conversion of TM to rules, which would be an excellent project. We could take CharGer files and get them mapped into Jadex/Jess (rule engines for agents).<br>This means that TrAM would complement every existing design methodology by providing not only a means of generating an ontology, but also by making the ontology of use to an agent be describing the rules in agent-speak. Additionally the rules are codec agnostic, so for FIPA requests the rules would be retrieved from the knowledge base and expressed in FIPA ACL, for semantic stuff, FIPA SL, etc.<br>Another benefit is that it side-steps our current difficulty in trying to identify all of the agents from the TM (there is potential but it is some way off yet), as we use more established means. It also demonstrates automation, in an area that is likely to produce more repeatable results." |

Table B.2: Email, re:requirement for TOA KMS, From SHU Academic, 21 March 2006 21:07

| |
|---|
| "I came across this old email (which) refer to Conceptual Graphs (CGs), for which there are rudimentary tools such as CoGui (`http://www.lirmm.fr/cogui/`) and CharGer (`https://www.cs.nmsu.edu/~hdp/CGTools/proceedings/papers/CharGer.pdf`). You may decide to capture the Transaction Model, TM (which Ivan refers to as the Transaction Graph, TG) through tools that are closer to SAP. These might be BPMN as encountered in NWCE and collaborative environments such as via StreamWork (http://www.sdn.sap.com/irj/scn/weblogs?blog=/pub/wlg/25360). That wouldn't be as expressive as CGs, and you may have to include an elementary mapping between the two, with a roadmap for a more expressive mapping. That would support the contribution of your thesis." |

Table B.3: Email, re:requirement for TOA KMS, From Simon Polovina, 9 Dec 2011, 18:11

### B.2.2 CoGui

| |
|---|
| Is Cogitant still being maintained? Harry the author of CharGer has given administrator rights to it to one of my research students (Richard Fallon), who plans to connect Cogitant as its engine too and through CharGer take advantage of CGIF and CG Actors. With your COGXML to RDF(S) converter we then have a suite of tools that can interoperate across all the formats of interest." |

Table B.4: Email, re:implement CGIF, To CoGui, 8 March 2012 17:46

| |
|---|
| "No currently Cogitant is not being maintained by us at LIRMM. (we are) working on a full Java (thus Cogui incorporated reasoning engine) that currently has some problems when dealing with rules but works for CG projection perfectly." |

Table B.5: Email, re:implement CGIF, from CoGui, 26 March 2012 17:41

| |
|---|
| "So just to clarify are you replacing Cogitant with your own CG reasoning engine in Cogui? What was wrong with Cogitant so you decided not to continue with it?" |

Table B.6: Email, re:implement CGIF, to CoGui, 26 Mar 2012 17:57

| |
|---|
| "Cogitant is the fastest solver we have (an informal statement since no paper was written on the topic since no big cg benchmarks were ever concieved). It is written in c++ and cogui in java. This meant that everytime we used it in classes there would be univ machine configs (linux and macs) on which it wwas a pain running it. In mtp we don't have many it officers and those who are there are always busy. Thus we thought we will make our own java cogui embedded solver and spare ourself the hassle every start of academic year.<br>Finally, the cgif part is advancing (using Martin's' grammar since Sowa's is hard to deal with fast). Once we have it running and almost debugged (alpha testing) we'll contact u for the beta:)" |

Table B.7: Email, re:implement CGIF, from CoGui, 27 Mar 2012 08:40

| |
|---|
| "As you'll read the CoGui guys are pressing ahead with the CGIF converter and you could contact (CoGui) to see if he can point you to the Cogitant CGIF code." |

Table B.8: Email, To Msc Student SHU, 27 March 2012 11:35

| |
|---|
| "I still recommend that we (you, thanks) 'clean up' CharGer and its CGIF as we described, and get it to work with Cogitant as the engine. We have control of CharGer and this will be particularly when we (you) come to look at interoperating it with Essential Project thro' XMI. The ideal of course with the CoGui guys as I've said is we can interoperate CharGer with CoGui." |

Table B.9: Email, From Simon Polovina, 27 Mar 2012, 12:52

| |
|---|
| “Further to below what’s your progress on the CGIF converter for CoGui / COGXML?<br>My research student, Richard Fallon (cc.-ed), has looked at (MSc Students) code and noted it lacks proper software engineering (e.g. following OO principles)<br>As a tidying up exercise and to demonstrate CGIF interoperability between 2 CG tools, Richard is also looking at CharGer and to address any remaining bugs in its CGIF converter. As such it will also provide a test for these 2 tools. That said however he only plans to do the bare minimum on the CharGer side as it is legacy code now, so the emphasis will be working with you on CoGui.<br>Please note Richard’s research is on applying Common Logic through CGIF for Enterprise Applications so the above activity is peripheral but necessary to his main task. So if you can take care of the CGIF-COGXML side of things I’m sure Richard will be able to help you as you need it. Please can you confirm this arrangement if that’s ok with you?<br>Getting CGIF working will also enable us to convert between CG and FCA.” |

Table B.10: Email, to CoGui, 13 Jun 2012, 11:29

| |
|---|
| “This message to clarify a few things. Moreover, the embedded version of Cogitant in Cogui is compiled with the free version of Visual C + +. Then, about the interpretation that is made of our discussions. Cogui solver is now fully fonctionnal (projection and rule application) but i wish to reiterate that I think Cogitant remains the fastest solver and it needless memory. The amount of memory used is not measurable with Cogui since the use of Cogitant requires the construction of a second representation of the data in memorywhen the cogui solver works (of course) with the native Cogui representation of the data.” |

Table B.11: Email, from CoGui, 03 May 2012 10:04

| |
|---|
| “the cogxml-cgif converter will work as follows. I have a KB in cogxml representing a family tree. I thus have a hierarchy of family roles (mother, grandmother etc), a hierarchy of relations, a set of rules (uncle is brother of father) and a set of facts. For a set of queries we obtain a certain number of results. If we export this in cgif we loose the hierarchies of types and relations. Thus, when we ask the same queries we obtain other answers!!! This poses a problem. We translate a cogxml file in cgif, we reopen it in cogui and we cannot longer answer queries we could before. And this is true also for rdfs where the have this notion of hierarchies. Thus we take an rdfs file, flat it out in cgif and if we re-export in rdfs we no longer have the same thing.<br>U mentioned providing a test for such conversion- this kind of scenario would be a fundamental part of such test!<br>I thus feel a bit confused re the real usage of such converter between two formats that express different things. The best (and again, smth that will be part of the test of such converter) would be to see what are the different layers of what we want to express (a bit like rdf, rdfs, owl2 etc. distinctions) and then for each expressivity level look at what is the best interchange format. For instance, if u only have simple graphs with no support u can use cgif and interoperate with rdf; if u have graphs and a support u have cogxml and interoperate with rdfs etc etc.” |

Table B.12: Email, From CoGui, 14 Jun 2012, 14:13

| |
|---|
| “Yes CGIF doesn’t support hierarchies of types and relations. We could adopt one of the possibilities below for the conversion:<br>One possibility is use the relation ’subtype’ or ’subrel’, as Heaton did in his work John Heaton page 58, and which I have used in the past. Thus the hierarchies of types and relations would be supported in CGIF.<br>The second possibility is to export the hierarchies of types and relations as a separate file, or as a comment inside the cgif file. This was the approach used by CharGer to retain the spatial information about the visual display of the graphs in its cgif file.<br>The third possibility is we just demonstrate that COGXML complies with Common Logic in its ability to read in and export CGIF. In this case the hierarchies of types and relations are lost, and on import flat hierarchies of types and relations would be created the way that Owain’s tool for his final year project had to. (Of course we could use the options in the second possibility above to retain info about the hierarchies of types and relations.)<br>My preferred option is the first possibility for the conversions, as it uses CGs to describe hierarchies of types and relations, and its elegancy demonstrates the power of CGs which we trying to promote.” |

Table B.13: Email, To CoGui, 15 June 2012 16:23

| |
|---|
| "I agree with you, the first solution looks like the best for what we are trying to do!<br>Let's'go one step fwd though and see if we could not "normalise" the subtype and subrel in one general representation of a rule. At the end of the day all of the support of a cg (concept type or relation type) could be seen as rules (if it is a cat then it is a mammal; if i love somebody then i like somebody etc.). In this way, depending on the type of rules we have in the kb, we can have different expressivities (we catch here rdfs, owl, rdf, datalog, common logic) and it opens widely our tools for the rule based languages communities bringing new blood in iccs!" |

Table B.14: Email, From CoGui, 18 Jun 2012, 16:12

| |
|---|
| "That sounds perfect!<br>It might also be useful to refer to the discussion in John Heaton's thesis in the pages directly after the page ref I give below, as I imagine that may help to strengthen the theoretical basis for it as well.<br>Using John Heatons thesis page 58), and which I have used in the past. Thus the hierarchies." |

Table B.15: Email, To CoGui, 18 June 2012 15:14

| |
|---|
| "As another thought from my unrelated query below to the CoGui developer, if we wrote cgfca in Java then it could simply be added as a script in CoGui and executed just like below?" |

Table B.16: Email, to CoGui, 21 May 2014, 10:25

### B.2.3 Cogitant

| |
|---|
| "Further to below please can you provide me with any further info as to the future plans for Cogitant?" |

Table B.17: Email, to Cogitant Developer, 27 Mar 2012 10:25

| |
|---|
| "Cogitant 5 (was developed as part of a PdD in 2001) Cogitant can't compete with a more modern library, with a full-time developer Of course, Cogitant is still maintained, and if you have questions about it." |

Table B.18: Email, From Cogitant Developer, 27 Mar 2012 10:25

| |
|---|
| (regarding the comments about) Cogitant.<br>"While the application claims to be cross-platform on all major operation systems, this isn't strictly true."<br>Since cogitant has been tested (by me so i'm sure) on several OS (GNU/Linux, MS Windows XP/Vista/2000, Solaris/OpenSolaris, FreeBSD, MacOS X) i can call it cross-platform.<br>"If compiling on a Windows system you require a GNU compiler collection". And later : "The main reason for the change was due to the Cogitant application having issues on the test machine which was running on windows. Despite being cross-platform the application required some environment tools which were problematic when trying to use them ..."<br>"This led to compiling errors which meant it could not be used in the project."<br>Well, i would be interested by these errors, because i try to publish a correct code, and as far as i know, my published code does not contain compiling errors (i don't say there are no bug! ;-) ). And i always try to help users when they have questions about Cogitant.<br>(not saying that the) choice of Java as a programming language is a bad choice. I just say that some critics about Cogitant are a little bit severe. |

Table B.19: Email, from Cogitant Developer, 02 May 2012 16:21

### B.2.4 Protégé - Frames or OWL

| |
|---|
| "(we were wondering regarding Essential Project) and where Frames is preferred if "Meta-modeling is important". Does that sum up why Essential hasn't gone to Protégé 4.x?" |

Table B.20: Email, re: OWL vs. Frames, to EssentialProject , 30 Apr 2014, at 21:17

| |
|---|
| “Thanks for this link, I think I may well have looked at this back in about 2006 / 2007 but could have missed it. I agree that slide 22 [ Frames or OWL? – Some Guidelines, pretty much sums up the model that the Protege team describe in a similar article on their website and after a lot of deliberation, we concluded that OWL was not the right approach for what we were trying to do. Although this has over time lead to something of a divergence with the Protege development path, we are still convinced that we have taken the right approach. This may mean at some point that we have to take responsibility for the ‘data management’ side of the Essential toolset, e.g. by continuing to make Protege 3.x available and running or build something based on it.<br>It was when we were in the early experimental stages of using Protege - looking at both OWL and Frames - that we saw some aspects of the operation of Protege OWL that just wouldn’t work for what we were looking for. I think the points about focussing on data acquisition and constraints on slots are probably key. The door is there for “the right people” to extend classes, define new classes etc. really easily but during the ‘data acquisition’ phase it’s about using the constraints of the meta model to ensure consistent semantics are applied to the data so that we can then use it reliably. If people are making up their own terms as they’re capturing content (and people still try to do this with Essential) - as they normally do when capturing in diagramming tools, Excel, Powerpoint etc. - we end up with content that is often un-usable.” |

Table B.21: Email, re: OWL vs. Frames, From EssentialProject , 01 May 2014 10:39

| |
|---|
| “that’s most insightful! I’m going to get feedback from (CoGui) about developing a mapping between CoGui (http://www.lirmm.fr/cogui/) and Protégé Frames. It already does so with RDF, RDF(S) and Datalog but not (yet) with OWL. I sense they are better headed in the Frames direction, especially for the metamodel reason! (Unless of course you believe there’s a superior alternative in case I’ve missed something J ). We can then bring Conceptual Graphs to bear as well as Formal Concept Analysis e.g. in visualising, validating and reasoning with the models” |

Table B.22: Email, re: OWL vs. Frames, To EssentialProject , 01 May 2014 13:36

| |
|---|
| “(regarding OWL vs. Frames ) Have you a worked example so that I can get my head around this issue? I get the gist of it, but a simple demo would help if you can help.” |

Table B.23: Email, re: OWL vs. Frames, To EssentialProject , 21 May 2014, at 14:25

| |
|---|
| “The simple answer is, no, I don’t have a worked example for this. Let me make sure I understand what the problem is. I’m assuming that the issue is whether to use OWL or Frames. I found a useful link while I was looking at this, that you might find helpful. http://www.obitko.com/tutorials/ontologies-semantic-web/formal-representation.html You’ll notice the links on the left of this page (Formal Representation) work through Frames, Conceptual Graphs, Semantic Networks etc. I think the heart of the issue, though, is around what you are trying to achieve. For us, it’s about managing a knowledge base that gets its semantics from the Classes (meta model). I found this posting to the Protege support which I found interesting, in particular that with OWL, things that we would normally think of as instances of a Class were being defined as Classes themselves in OWL. http://protege-project.136.n4.nabble.com/OWL-vs-Frames-Semantic-relations-of-the-same-kind-between-differend-classes-td3524822.html One thing that occurred to me in the context of the support email is that Frames seems far more object-oriented with a clearer distinction between Classes and Instances. OWL seems a bit more blurred. I tried a simple convert of our baseline repository to OWL / RDF format and while it preserved all our Classes, the instances lost most of their values (the template slot values). The discussion seems to revolve around this reported limitation of OWL: ”No direct language support for n-ary relationships. For example modelers may wish to describe the qualities of a relation, to relate more than 2 individuals or to relate an individual to a list. This cannot be done within OWL. They may need to adopt a pattern instead which encodes the meaning outside the formal semantics.” That is certainly an issue for the sorts of qualified relationships that we define in our Frames-based meta model. The bottom line is that in many ways the pros / cons / differences are quite subtle from a conceptual perspective and I think the decisions about which approach to use are made based on what you’re trying to do. There’s obviously a lot more coverage of OWL but that’s probably thanks to the sharing motivation of OWL. We’re trying to define a meta model that enables us to manage knowledge. It’s tricky, though, as we share our meta model and would love it to be a defacto standard for describing enterprises. How is that different to what people are trying with OWL? I’m not sure but the management of the instances within Protege is far more intuitive for Frames than for OWL.” |

Table B.24: Email, re: OWL vs. Frames, From EssentialProject , 22 May 2014 14:44

| |
|---|
| “A little brain teaser for you J To what extent could the issue below be overcome in OWL/RDF/SPARQL... ? Essential Project [ http://www.enterprise-architecture.org/ ] is a nice semantic tool.” |

Table B.25: Email, re: OWL vs. Frames, To CG practitioner, 21 May 2014 14:32

| |
|---|
| “Just going through my emails. In short: RDF(S) allows metamodelling, whereas OWL does not.” |

Table B.26: Email, re: OWL vs. Frames, from CG practitioner, 23 May 2014 15:42

### B.2.5 Common Logic and CGs

| |
|---|
| "Is anyone working on the OMG's Ontology Definition Metamodel (ODM), particularly in relations to Conceptual Graphs (CGs)?<br>I'm wondering for example how TOGAF's Content Metamodel (http://pubs.opengroup.org/architecture/togaf9-doc/arch/chap34.html) and how its Entities and Relationships could be captured in ODM thus interoperated between Frames, OWL, and Common Logic. As I'm a CGs guy I've been expressing the work I've done thus far using that medium e.g.:<br>A slide show from 2006 describes the differences between Frames and OWL `http://protege.stanford.edu/conference/2006/submissions/slides/7.2wang_protege2006.pdf` including the remark that Frames is preferred where metamodeling is important (e.g. for the TOGAF content metamodel that I refer to above). Protégé stopped supporting Frames post v3.5 and uses OWL now, and I wonder if the baby has been thrown out with the bathwater so to speak in this respect.<br>It strikes me that ODM might provide the interoperability vehicle to take advantage of the best that that each of the formalisms offer (Frames, OWL, Common Logic, CGs), so I'm interested in finding out more hence my posting to this forum." |

Table B.27: Email, re:CGs and CL, to CG Work Group, 30 Oct 2014, 05:45

| |
|---|
| "1. All of the notations can be mapped to Common Logic (or the IKL superset of CL).<br>2. So-called semantic differences (e.g., unique name assumption) can be resolved by using different terminology: names in NLs are not unique. To avoid confusion, delete the term 'unique name assumption' and introduce 'unique identifiers'.<br>3. For the past 40 years of R & D + debate + confusion about semantic interoperability, logic, ontology, and related issues" |

Table B.28: Email, re:CGs and CL, From CG Work Group, 30 Oct 2014, 05:45

### B.2.6 CHARer and CGIF

| |
|---|
| “(regarding CharGer) ”The CGIF translator was written by a third student, as part of a class, and I admit I didn’t test his results thoroughly.” Due to role has effectively meant (no one is) continuing with CharGer, hence the shared dropbox folder. CGIF is how I foresee CGs interoperating with the stuff I describe in the TOA draft paper I sent you.<br>Via http://iso-commonlogic.org/ you can download the PDF that has the CGIF Appx in it. As you will see it, and CGs, are part of the ISO Common Logic standard. At http://www.open-sea.org/ who may find material that outlines how it may interoperate with enterprise systems.<br>So would you like to dive in and see what you can do?” |

Table B.29: Email, re:CGIF and CharGer, from Simon Polovina, 8 March 2012 17:46

| |
|---|
| “I’ve now had time to look at CharGer and build a 3.7 version under Eclipse, which works. I have general understanding of what/how it works but from comments/my observations I have some questions;<br>is what we require a minor fix of the file format problem or a complete overhaul of the CG processing? (from the developer of CharGer) CharGer’s “back end” should be completely rewritten and Notio completely removed. What is the real problem with Notio - or more to the point what should be used in its place - perhaps the OpenCG project (-which has also no recent updates), or something else?<br>(from the developer of CharGer) CharGer’s main value right now is its use as a display and interchange tool I don’t have enough knowledge (yet) of CG to know what direction to take it in?” |

Table B.30: Email, re:CGIF and CharGer, To Simon Polovina, 16 March 2012 21:45

| |
|---|
| "Thanks that's good! First of all check CharGer's CGIF and check if it's compliant with http://iso-commonlogic.org/ CGIF in Appendix B. (You can download the PDF of the CL standard and you can see the spec for CGIF in Appendix B if you haven't got it already).<br>Note also below in CharGer, that if you tick the Include CharGer info with CGIF box, CharGer will also save the spatial (i.e. layout) info, as CGIF doesn't include how the CGs should be laid out visually. But that part is CharGer specific. For now I think we just need to be aware of it. As for the processing let's concur with (CharGer's developers) view that CharGer is a display and interchange tool. Thus remove Notio. No point in putting in OpenCG as I think that's died too. The only tool it's worth linking to is Cogitant – see http://www2.lirmm.fr/cogui/ and you'll see they have their own front end tool called CoGui but it doesn't have CGIF. We could import and export Cogitant's/CoGui's COGXML format. Also we need to begin looking at XMI options, so we can interoperate it with EA tools, namely Essential Project (http://www.enterprise-architecture.org/) as I'm in communication with these guys particularly in relation to TOGAF 9's metamodel. That's also where REA and the Transaction Concept comes in." |

Table B.31: Email, re:CGIF and CharGer, from Simon Polovina, 18 Mar 2012

| |
|---|
| "the progress so far; Downloaded cogitant and generated a DLL (first attempt with mingw didn't work, but finally got it working with Microsoft) - that's the first thing to note that this DLL must always be supplied and 'only' a subset of the C++ functions are available - I'm not yet sure if this causes any 'important' restrictions. Can now load this DLL from a Java program and call the relevant routines. CharGer is (a little chaotic) Graphs are stored concurrently in a 'CharGer' format and a 'notio' format this makes the whole code-set very confusing. The only thing which currently makes any sense (-this may change) would be to throw away the processing of a 'CharGer' format and a 'notio' format and use only cogitant to store/process graphs. To do this requires a lot of work, with the result that CharGer is then only really a graphical front-end to cogitant processing, the question which I have, is would it be better to spend this effort making coggui do the CGIF processing, which might be quicker to do?" |

Table B.32: Email, re:CharGer or CoGui, To Simon Polovina, 27 Mar 2012, 15:33

| |
|---|
| "Thanks Richard for the update.<br>Maybe we could inform (CoGui developers) how you are getting on with CoGui / Cogitant so we keep each other in the loop and maybe save work on their/our part? Re CharGer now you've looked at it, and it is in too much of a state I'd agree the energy isn't worth it after all.<br>Could you just get CharGer to ensure it exports and imports decent CGIF and that's it? Maybe there could also be option for CharGer to save in CGIF format (+ CharGer's spatial info) and use that as it's file format in place of CGX, which thus stays there for backward compatibility. Yes forget anything else (e.g. new backend engine) and if even doing my CGIF suggestion is too hard we can drop it too.<br>Ideally it would be nice to have 2 different tools (e.g. CharGer and CoGui) interoperating CGIF as that provides some kind of validation in itself, as then we can check our CGIF c/o CharGer with the CoGui guys' CGIF and vice versa as an objective test. Plus CharGer does have CG Actors (the diamond thingys) for arithmetic plus data lookup (albeit basic), plus we can draw negative contexts (Peirce logic) in CharGer. These are two items that CoGui doesn't have but CGIF includes. (I don't think Cogitant has them either.) Hence my suggestion of at least being able to do that much. But as I say only if it can be done without inordinate effort.<br>Of course (y)our end game is interoperability with an EA tool and our targeted one being Essential Project. That's where I foresee an XMI that captures the full expressivity of CGIF thus Common Logic in EA." |

Table B.33: Email, re:CharGer or CoGui, From Simon Polovina, 27 Mar 2012, 18:52

| |
|---|
| "starting some serious CharGer development this summer with three students. We've added about 35MB of source files under "2013 Development". I haven't seen any activity from any of you since this was created, so i presume this won't interfere with any ongoing efforts. If I should go ahead and remove you all from the Dropbox shared folder, just let me now." |

Table B.34: Email, re:CharGer developments, From CharGer, 14 May 2013 03:09

### B.2.7 CGIF - Knowledge Representation

| |
|---|
| "We have an opportunity to add some convenient definitions to Annex B of the CL standard that would *not* increase the expressive power of CGIF. Every statement would be an abbreviation for a CGIF statement that is valid in the standard of 2007 (and the new version).<br>- Since type hierarchies aren't part of CL, the request is for supertypes - in CGs to be represented as: - - [Type: Employee] [Type:Manager] (subtype Employee Manager) - - where this is to express the relation that "subtype of Employee is - Manager") Does this mean that all users of CGIF who want to use type - hierarchies will use exactly this form to represent hierarchies?<br>- While I'm at it, do you have an idea as to how relation hierarchies - should also be specified?<br>Since a type label in CGIF names a monadic relation, a hierarchy of relations with any number of arguments would include type labels as a special case. Common Logic supports quantifiers over relations and sequence markers for polyadic relations. Therefore, we can use those options to define a hierarchy over relations. Exactly the same notation could be used for type labels (monadic relations).<br>....<br>As I said, this notation is succinct and readable, but it does not add any expressive power beyond what is currently possible with CGIF." |

Table B.35: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 05:45

| |
|---|
| "Re: hierarchies – of course, the logicians can more fully explain this, but the short explanation isn't that sorted logics (i.e., logic with types) are undesirable, only that they are not universally accepted as part of logic ("common" logic). The solution is usually to declare a relation (e.g., [Harry: *x][Person: *y] (type ?x ?y) ) but that requires a non-standard relation to be effectively "standardized" – that is, widely accepted to mean just what a type hierarchy implies. There are other meta-logical issues – e.g., single vs. multiple supertypes, etc." |

Table B.36: Email, re:CGIF and CL, from CG Work Group, 13 Oct 2014, 14:17

| |
|---|
| "It would be [Type: Employee] [Type: Manager] (subtype Employee Manager) and wouldn't need to be hard-coded, but interpreted accordingly by the tools. This is essentially how Heaton approached it in this thesis (https://dl.dropboxusercontent.com/u/1419494/417019-jehphd.pdf). Also there is CG is CGIF so that should inherently support type and relation hierarchies, as that is part of CG. Actually I may just have answered how we do it, without altering the existing standard? " |

Table B.37: Email, re:CGIF and CL, from CG Work Group, Mon, 13 Oct 2014, 14:17

| |
|---|
| “I also agree that we need a way to represent type and relation hierarchies in CGIF. However I do not agree that it should be in XML. To be honest I did not understand why having a way to define (represent) a hierarchy in CGIF was undesirable.” |

Table B.38: Email, re:CGIF and CL, from CG Work Group, Mon, 13 Oct 2014, 15:30

| |
|---|
| “Thanks for the correction - the only difficulty from a standards point of view is that to exchange CGs through CGIF, both have to agree that this is the way a hierarchy is represented. There would need to be additional rules that allow a referent in one concept (i.e., ”Employee”) to appear as a type in other concepts (i.e, [Employee: Harry]).<br>My difficulty with using the actual referent names is that they aren’t necessarily unique. What happens when there are two different Simons? Or (perish the thoughts) two Harry’s?” |

Table B.39: Email, re:CGIF and CL, from CG Work Group, Mon, 13 Oct 2014, 16:48

| |
|---|
| “The referents in my example are the Type Labels, as they are of type Type. As far as I understand it they are thus second order. Re clashes it would be the same for any Type label that we already hard-code in our CGIF. John Heaton even went as far as making the type labels variables, thus providing a way around in CG.<br>Also it’s worth remembering that in XML for example, instances (or anything) can be disambiguated through namespaces (Using the URI, the Internet of Things), and I believe that CoGui uses namespaces for such purposes. So there can be Simons or Harrys, just different ones This of course could be extended to type labels (and relation labels). And of course we don’t have to use XML to use namespaces.” |

Table B.40: Email, re:CGIF and CL, from CG Work Group, Mon, 13 Oct 2014, 16:56

| |
|---|
| "All the points in this thread and the cogxml thread are well taken. But the point I want to emphasize is that the CL standard is only intended to specify the CL abstract syntax and semantics and the methods for defining dialects of CL.<br>The 2007 standard also includes three annexes for specifying three useful dialects: CLIF, CGIF, and XCL. The new version will include some updates and extensions to the body of the standard and the three annexes.<br>There have also been some proposals for one or more additional annexes. The one I am working on specifies sorted (or typed) logics, which are widely used in many KR notations – including CGs.<br>How can CGIF express the semantics of CL but not mention type hierarchies. Is the standard complete?<br>The body of CL does not mention type hierarchies. But it does permit "quantifier restrictions" by means of monadic relations. In Annex B, I specify type labels by names of monadic relations. Since CL allows quantified variables to refer to relations, you can specify a hierarchy of relations in any of the three dialects: CLIF, CGIF, or XCL.<br>¿ CGIF is of little use to me until it can capture the type and ¿ relation hierarchy You can use the 2007 version of CGIF to specify the hierarchy. To clarify the matter, I could add a short section to Annex B to define abbreviations, such as A¡B as a synonym for<br>[If (A *x) [Then (B ?x)]] [ [If (B *y) [Then (A ?y]]]<br>Another option is to define such abbreviations in Annex D for order- sorted logics and say that CGIF may be used as an order-sorted logic.<br>Harry There are other meta-logical issues – e.g., single vs. multiple supertypes, etc.<br>The claim that multiple inheritance confuses people may be true for some procedural languages. But for any system of logic, it's not only meaningless, it's an invitation to disaster:<br>1. Any definition of relations (or sorts or types) has implications.<br>2. Those implications generate a lattice, as in FCA.<br>3. Whether you acknowledge the implications or not, they exist.<br>4. Prohibiting multiple inheritance is like wearing blinders to avoid seeing anything dangerous.<br>This is a problem with logics such as OWL, which allows classes to be specified by definition *and* by subclass statements. That is why many OWL developers use FCA to check OWL for contradictions.<br>My recommendation is to use FCA instead of OWL, and use a more expressive language to add the more complex axioms.<br>And of course we don't have to use XML to use namespaces.<br>Yes. There is some discussion about this issue for the new version of the CL standard. XCL explicitly uses XML, and we want to be able to use the same conventions without requiring XML as prerequisite.<br>And by the way, I'm not against the *ML family of languages. I use HTML for all my word processing and LibreOffice to convert HTML to other formats." |

Table B.41: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 20:10

| |
|---|
| "I was following this discussion(below), but I wasn't sure what the conclusion was? Am I correct in understanding that a Type in CGIF should be represented as follows? [Type: Employee] [Type: Manager] (subtype Employee Manager) And that this is not yet identified within the standard - but will be in the next revision'? The reason for asking is that the Protégé CGIF import is now working (I will forward it for to test in the next day or so) and I could incorporate this already?" |

Table B.42: Email, re:CGIF and CL, from Richard Fallon, 30 Oct 2014, 11:29

| |
|---|
| "Yes that's right Richard. From my understanding we can use the 2007 version of CGIF to specify the hierarchy in this way. Harry please could you thus support this in the CGIF export for the Type Hierarchy in CharGer? Needed by mid-November " |

Table B.43: Email, re:CGIF and CL, from Simon Polovina, 30 Oct 2014, 20:55

| |
|---|
| "let me be sure I understand what is being asked:<br>Since type hierarchies aren't part of CL, the request is for supertypes in CGs to be represented as:<br>[Type: Employee] [Type:Manager] (subtype Employee Manager)<br>where this is to express the relation that "subtype of Employee is Manager") Does this mean that all users of CGIF who want to use type hierarchies will use exactly this form to represent hierarchies. All CG systems that read CGIF files would have to interpret it this way and all CG systems that write CGIF would have to export in this form. My discomfort is that the four of us have just "standardized" one way (out of several) to represent this. That is my difficulty with conventions as opposed to standards. For example, I could use any of these forms with the appropriate conventional agreements:<br>[Type: Employee] [Type:Manager] (supertype Manager Employee) or [Type: Employee] [Type:Manager] (subtype Manager Employee)<br>I'm not trying to be difficult here, but I am always hesitant to "hard wire" arbitrary decisions into software." |

Table B.44: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 20:42

| |
|---|
| "[Type: Employee] [Type:Manager] (supertype Manager Employee) or [Type: Employee] [Type:Manager] (subtype Manager Employee)<br>Yes both of the above would be suitable, as they are isomorphic and denote the same hierarchy relationship.<br>That's just like:<br>Manager isA Employee<br>This capability is needed if Richard and I are do anything with CGIF." |

Table B.45: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 20:55

| |
|---|
| “While I’m at it, do any of you have an idea as to how relation hierarchies should also be specified?” |

Table B.46: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 21:20

| |
|---|
| Thanks for the quick response! I still await an answer to the question, though. Does anyone care which of these CharGer implements? And does that create a de facto “standard” way to do this? |

Table B.47: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 21:27

| |
|---|
| “Re your question “While I’m at it, do any of you have an idea as to how relation hierarchies should also be specified?” I would have to think about it; “ |

Table B.48: Email, re:CGIF and CL, from CG Work Group, 30 Oct 2014, 22:11

| |
|---|
| “There are two parts — one is to generate it, the other is to read it. So far CharGer doesn’t read CGIF very well, but generating is much easier. I think I can implement generating in a couple of days. Reading will take building a real parser which will take a month or two.” |

Table B.49: Email, re:CGIF and CL, from CharGer, 30 Oct 2014, 22:33

| |
|---|
| “Just generating it for now would be great! Richard can then import it into Protégé. Await to hear when done.” |

Table B.50: Email, re:CGIF and CL, to CharGer, 30 Oct 2014, 00:50

| |
|---|
| “FYI: I am in the process of implementing types into Protégé, as per our discussion (-from what I understand, it still has to be added to the standard), using the following syntax; CGIF looks like:<br>[Type: A] [Type: B] (subtype B A) [B: *x2] [A: x1] (link x1 ?x2) .<br>Is that correct?” |

Table B.51: Email, re:CGIF and CL, To Simon Polovina, 30 Oct 2014, 21:02

| |
|---|
| As it happens, the second edition of Common Logic was finally published this year, over ten years since the first edition. The changes in the standard have been fairly minimal, considering how the world has evolved during that time. The XML version "XCL" has been vetted in a standardized XML form. None of us was very happy with the first edition's XCL because it was pushed as a "selling point" without anyone actually having any XML expertise to offer. For CL (not CGs), the XML version always seemed the best for me, because it is able to exactly and completely represent the abstract syntax of CL, without limitations, extensions, constraints, etc.<br>Here's a good summary of CGIF's problems. CLIF takes 10 pages or so to describe how it maps onto the syntax and semantics of CL. XCL takes 12 pages, though much of it is whitespace and Relax NG comments. CGIF takes up 22 pages, which include some EBNF features that even some EBNF experts don't really use or understand. An "extended" language is layered on top of a "core" language. |

Table B.52: Email, CGIF problems, 26 November 2018 02:28

### B.2.8 FCA

| |
|---|
| "The CoGui cogxml to FCA converter has raised in priority. (We need) to capture the Process MM in CoGui. I can export into Protégé (OWL i.e. v4.x not 3.5, which is Frames for Essential). " |

Table B.53: Email, re:CG's and FCA from Simon Polovina, 19 May 2014, 18:39

| |
|---|
| "It's more than just a converter as it converts as described in:<br>§ Simon Polovina; Andrews, Simon (2013) "CGs to FCA Including Peirce's Cuts"¡http://www.igi-global.com/article/cgs-to-fca-including-peirces-cuts/80384¿, International Journal of Conceptual Structures and Smart Applications (IJCSSA)¡http://www.igi-global.com/ijcssa¿, 1(1), IGI-Global Publishing, 90-103. [https://www.dropbox.com/s/qqkn640ofiarq4i/CG-FCA-FT.pdf] § Andrews, Simon;Simon Polovina (2011) "A Mapping from Conceptual Graphs to Formal Concept Analysis"¡http://homepages.gold.ac.uk/polovina/publications/iccs2011-cgtofca-paper.pdf¿. In: Conceptual Structures for Discovering Knowledge¡http://www.springer.com/computer/ai/book/978-3-642-22687-8¿ (The 19th International Conference on Conceptual Structures, ICCS 2011, Derby, UK) Andrews, Simon;Simon Polovina; Hill, Richard; Akhgar, Babak (Eds.), Lecture Notes in Computer Science, Vol. 6828 (Subseries: Lecture Notes in Artificial Intelligence), Springer, 63-76.<br>It also has relevance for Linked Data & OWL (Protégé 4.x) but for Essential it's Frames (Protégé 3.x). How we apply the approach to Frames is a good question but worth it as we know..."<br>Simon |

Table B.54: Email, re:CG's and FCA from Simon Polovina, 13 May 2014 09:56

### B.2.9 CG Actors, Peirce logic

| |
|---|
| "Further to my remark in my previous reply i.e.: Ø ... Plus CharGer does have CG Actors (the diamond thingys) for arithmetic plus data lookup (albeit basic), plus we can draw negative contexts (Peirce logic) in CharGer. These are two items that CoGui doesn't have but CGIF includes. (I don't think Cogitant has them either.) Hence my suggestion of at least being able to do that much. But as I say only if it can be done without inordinate effort.<br>NB although CharGer can process CG Actors it only allows us to draw cuts as the processing of them is too combinatorial explosive – see John Heaton Thesis for an attempt at processing this Peirce logic. You can also borrow Conceptual structures : information processing in mind and machine / John F. Sowa (http://catalogue.shu.ac.uk/record=b1427757 S20a) being Sowa's original book on CG.<br>He also did a later one: Knowledge representation : logical, philosophical, and computational foundations." |

Table B.55: Email, re:CG's and Peirce logic from Simon Polovina, 28 Mar 2012, 15:56

### B.2.10 Enterprise Plus

| |
|---|
| "As discussed short-medium term the following 3 main enhancements need to be implemented; - FCA against relationships defined with the model - FCA meta-model using objects and relationships, displaying boxes - FCA architecture view showing the relationships defined within domain channels - hierarchical view Looking first at the short-medium term goals, I would recommend the following; 1. Adding an 'extra' button to the "MyObjects" view for FCA. 2. The resulting view (from the FCA button) should use the current GUI interface, thus a new model (type) is generated (and stored) depicting the FCA view 3. An auto router tool/library is required which allows the user to produce a diagram with all connections 'neatly' display, this should be available on the "Arrange" menu and is thus available to 'other' views. As I mentioned what I would also like to do for my Phd is to make a high level comparison between the tools which I have already implemented in Protégé and EnterprisePlus - without giving away any secrets." |

Table B.56: Email, re:implementing FCA, to E+, 10 Dec 2017, 12:35

| |
|---|
| “ comments below **(in BOLD)**<br>As discussed short-medium term the following 3 main enhancements need to be implemented; - FCA against relationships defined with the model ***Using FCA functionality to show existing relationships defined with my object page (stereotypes, types, subtypes), the maps, the matices and the models. (but ensuring that the FCA lines are sorted and jump lanes principles are applied). The Button should be called: “Existing Relationships” (the other button on relationships that exist should be called “possible Relationships”*** - FCA meta-model using objects and relationships, displaying boxes **Using FCA functionality to show meta-model using objects and relationships, but adding boxes around the objects, as well as ensuring that the boxes, lines are sorted and jump lanes principles are applied. The Button should be called: “Meta Model view”** - FCA architecture view showing the relationships defined within domain channels - hierarchical view **Using FCA functionality using objects and relationships and render them in a layered architecture view (Enterprise layers and sublayers) The Button should be called: “Architecture view”**<br>Looking first at the short-medium term goals, I would recommend the following; 1. Adding an 'extra' button to the "MyObjects" view for FCA. **The Button should be called: “Existing Relationships” (the other button on relationships that exist should be called “possible Relationships”** 2. The resulting view (from the FCA button) should use the current GUI interface, thus a new model (type) is generated (and stored) depicting the FCA view **(agreed)** 3. An auto router tool/library is required which allows the user to produce a diagram with all connections 'neatly' display, this should be available on the "Arrange" menu and is thus available to 'other' views. **(agreed)** As I mentioned what I would also like to do for my Phd is to make a high level comparison between the tools which I have already implemented in Protégé and EnterprisePlus - without giving away any secrets. **As this is an academic work and research you are doing, I agree that there must be an independent and in-depth analysis of both systems and functionality. I believe that such a comparing of functionality would truly provide good insight** Of course I will need to fit this work in within my other commitments and I would need to look at the current implementation to ascertain how much work would be required before I begin. **Of course, we could possibly look at basic reporting functionality, so that reports of E+ could be generated automatically and therefore a lot of writing for your PhD could be supported by different reports (just an idea)**” |

Table B.57: Email, re:implementing FCA, from E+, 10 Dec 2017, 15:03

| |
|---|
| “Integrate current JAVA FCA implementation (or convert into PHP) into E+ (Richard) Look at possible Javascript solutions for auto-router and jump-lanes for current design modeling solution, gojs looks interesting (Ulrik + Richard) Implement auto-route solution for FCA into E+ within the various views (Richard)” |

Table B.58: Email, re:implementing FCA, to E+, 27 Dec 2017, 16:32

| |
|---|
| "Please see my comments in BOLD<br>Thank you for your response, it looks like we are quite closely aligned on the extra functionality required, thus I would suggest the following tasks/responsibilities to move forward; Skype call to provide overview of E+ development environment - PHP,MySql etc **(Ulrik)** Integrate current JAVA FCA implementation (or convert into PHP) into E+ (Richard) Look at possible Javascript solutions for auto-router and jump-lanes for current design modeling solution, gojs looks interesting (Ulrik + Richard) Implement auto-route solution for FCA into E+ within the various views (Richard)" |

Table B.59: Email, re:implementing FCA, from E+, 10 Dec 2017, 15:03

# Appendix C

# Data Collection - DSRM Step 4 - Demonstration

This Appendix contains the data collected for DSRM Step 4 - demonstration, which includes the following data:

- **CG Import** details the CGIF input used to demonstrate the artefact CGImport
- **CG Export** details the CGIF output, used to demonstrate the artefact CGexport
- **JESS** details the JESS scripts, used to demonstrate the artefact JESS

## C.1 CG Import

This Section details the CG's in the ISO CL CGIF standard which have been imported using CGimport and the AREA KMS.

Note. A LaTeX macro was developed so that the REA entities and CG syntax of CGIF are colour coded, which enhances the readability for humans, refer to Section 8.4.1.

### C.1.1 SAP transaction - HCM Labour Requisition.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in the Figure 8.34 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)
(subtype Event REA)

/* define the entites */

/* Resources */
[Cash][Recruitment_Instrument][Vacancy][Applications]
[Labor_Type]
(subtype Cash Resource)
(subtype Recruitment_Instrument Resource)
(subtype Vacancy Resource)(subtype Applications Resource)
(subtype Labor_Type Resource)

/* Events */
[Requisition_Request][Advertisment][Application][Hire]
(subtype Requisition_Request Event)
(subtype Advertisment Event)
(subtype Application Event)(subtype Hire Event)

/* Agents */
[Employee][Cost_Center][Applicant]
(subtype Employee Agent)(subtype Cost_Center Agent)
(subtype Applicant Agent)

/* more types */
[Manager][Personel_Organiser]
(subtype Manager Employee)
(subtype Personel_Organiser Employee)

/* define the new relationship-links */
[Link][stockflow][participation][responsibility][reserves]
(subtype stockflow Link)(subtype participation Link)
(subtype responsibility Link)(subtype reserves Link)

/* define the types of the attributes */
[integer][string][first_name][second_name][name][ID][date]
(subtype ID integer)(subtype name string)
(subtype first_name string)
(subtype second_name string)
(subtype date integer)
```

```
/* the attributes themselves */
(attribute REA ID/*the unique id for the REA entity*/)
(attribute Event date)
(attribute Employee second_name)(attribute Employee first_name)

/* now the definition of the REA entites */
[Cash: *1][Recruitment_Instrument: *2][Vacancy: *3]
[Applications: *4][Labor_Type: *5]
[Requisition_Request: *6][Advertisment: *7][Application: *8]
[Hire: *9]
[Cost_Center: *10][Applicant: *11][Manager: *12]
[Personel_Organiser: *13]
/* and their relationships */
(stockflow ?7 ?1)(stockflow ?2 ?7)(participation ?13 ?3)
(participation ?12 ?3)
(stockflow ?4 ?8)(stockflow ?5 ?9)
(reserves ?3 ?5)(participation ?10 ?6)(participation ?12 ?6)
(participation ?13 ?6)
(participation ?13 ?7)(participation ?13 ?8)
(participation ?13 ?9)
(participation ?11 ?8)(responsibility ?12 ?10)
```

### C.1.2 SAP transaction - Goods Receipt.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in the Figure 8.36 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the entites */

/* Resources */
[ProductionOrder][Material]
(subtype ProductionOrder Resource)(subtype Material Resource)

/* Events */
[GoodsReceipt]
[UpdateOfMaterialMaster]
[UpdateOfInventoryStockValue]
[UpdateOfProductionOrderStatus]
(subtype GoodsReceipt Event)
(subtype UpdateOfMaterialMaster Event)
(subtype UpdateOfInventoryStockValue Event)
```

```
(subtype UpdateOfProductionOrderStatus Event)

/* Agents */
[GoodsReceiver][PlantAndStorageArea]
(subtype GoodsReceiver Agent)
(subtype PlantAndStorageArea Agent)

/* define the new relationship-links */
[Link][stockflow_in][stockflow_out][participation]
(subtype stockflow_in Link)(subtype stockflow_out Link)
(subtype participation Link)

/* now the definition of the REA entites */
[ProductionOrder: *1][Material: *2][GoodsReceipt: *3]
[UpdateOfMaterialMaster: *4][UpdateOfInventoryStockValue: *5]
[GoodsReceiver: *6][PlantAndStorageArea: *7]
[UpdateOfProductionOrderStatus: *8]
/* and their relationships */
(stockflow_out ?1 ?2)(stockflow ?4 ?2)(stockflow ?5 ?2)
(participation ?4 ?3)(participation ?5 ?3)(participation ?7 ?3)
(participation ?6 ?3)(participation ?8 ?3)
```

### C.1.3 SAP transaction - Create Purchase Order/Purchase Requisition.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in the Figure 8.39 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the entites */
/* Resources */
[OutlineAgreement][Material][Quotation][Cash][PotentialVendor]
(subtype OutlineAgreement Resource)
(subtype Material Resource)
(subtype Cash Resource)
(subtype PotentialVendor Resource)
(subtype Quotation Resource)

/* Events */
[PurchaseRequisition]
[CreatePurchaseOrder]
```

```
[RequestForQuotation]
[CreateVendor]
(subtype PurchaseRequisition Event)
(subtype CreatePurchaseOrder Event)
(subtype RequestForQuotation Event)
(subtype CreateVendor Event)

/* Agents */
[PurchasingOrganisation][ChosenVendor]
(subtype PurchasingOrganisation Agent)
(subtype ChosenVendor Agent)

/* define the new relationship-links */
[Link][stockflow_in][stockflow_out][participation]
(subtype stockflow_in Link)(subtype stockflow_out Link)
(subtype participation Link)

/* now the definition of the REA entites */
[OutlineAgreement: *1][Material: *2][Quotation: *3]
[Cash: *4][PotentialVendor: *5]
[PurchaseRequisition: *6]
[CreatePurchaseOrder: *7]
[RequestForQuotation: *8]
[CreateVendor: *9]
[PurchasingOrganisation: *10]
[ChosenVendor: *11]

/* and their relationships */
(stockflow_in ?2 ?10)
(participation ?10 ?6)
(participation ?10 ?1)
(stockflow_out ?2 ?11)
(participation ?1 ?11)
(participation ?3 ?11)
(participation ?11 ?7)
(stockflow_in ?4 ?11)
(stockflow_out ?4 ?10)
(participation ?10 ?8)
(participation ?8 ?5)
(participation ?5 ?3)
(participation ?10 ?9)
(participation ?5 ?9)
```

### C.1.4 ATM Withdrawal.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in the Figure 8.27 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the entites */

/* Resources */
[Cash]
(subtype Cash Resource)

/* Events */
[ATM_Withdrawl]
(subtype ATM_Withdrawl Event)

/* Agents */
[Customer][Institution_A]
(subtype Customer Agent)(subtype Institution_A Agent)

/* define the new relationship-links */
[Link][instigates][pay_out][stockflow_out]
[receipt][request][response]
(subtype instigates Link)(subtype pay_out Link)
(subtype stockflow_out Link)(subtype receipt Link)
(subtype request Link)(subtype response Link)

/* now the definition of the REA entites */
[Customer: *1][ATM_Withdrawl: *2][Cash: *3][Institution_A: *4]
/* and their relationships */
(instigates ?1 ?2)(pay_out ?2 ?1)
(receipt ?2 ?3)(stockflow_out ?3 ?2)
(request ?2 ?4)(response ?4 ?2)
```

### C.1.5 x0100/x0110 - Authorisation message flow.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in the Figure 8.29 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Transaction]
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the base types of the attributes */
[integer][string][first_name][second_name]
```

```
[name][ID][date_time][time]
[date]
(subtype ID integer)(subtype name string)
(subtype first_name string)
(subtype second_name string)
(subtype date integer)(subtype date_time string)
(subtype time string)

[Customer]
(subtype Customer Agent)
/*Field 2*/ [Primary_account_number]
(subtype Primary_account_number integer)

/* define the entites */
/* Resources */
[Amount_transaction]/*Field 4*/
(subtype Amount_transaction Resource)

/* Events */
[X100_Request]
(subtype X100_Request Event)
/*Field 3*/ [Processing_code]
/*Field 7*/ [Transmission_date_time]
/*Field 11*/ [STAN]
[Time_local]/*Field 12 hhmmss*/
[Date_local]/*Field 13 MMDD*/
/*Field 37*/ [Retrieval_reference_number]
/*Field 49*/ [Currency_code]
(subtype Processing_code string)
(subtype Transmission_date_time string)
(subtype STAN string)
(subtype Time_local string)
(subtype Date_local string)
(subtype Retrieval_reference_number string)
(subtype Currency_code integer)
(attribute X100_Request Processing_code)
(attribute X100_Request Transmission_date_time)
(attribute X100_Request STAN)
(attribute X100_Request Time_local)
(attribute X100_Request Date_local)
(attribute X100_Request Retrieval_reference_number)
(attribute X100_Request Currency_code)

[X110_Response]
(subtype X110_Response Event)
/*Field 39*/ [Response_code]
(subtype Response_code integer)
(attribute X110_Response Response_code)
(attribute X110_Response Retrieval_reference_number)
```

```
/* Agents */
[POS_merchant]
(subtype POS_merchant Agent)
/*Field 22*/ [POS_entry_mode]
/*Field 41*/ [Card_acceptor_terminal_identification]
/*Field 42*/ [Card_acceptor_identification_code]
/*Field 43*/ [Card_acceptor_name_location]
(subtype POS_entry_mode string)
(subtype Card_acceptor_terminal_identification string)
(subtype Card_acceptor_identification_code string)
(subtype Card_acceptor_name_location string)
(attribute POS_merchant POS_entry_mode)
(attribute POS_merchant Card_acceptor_terminal_identification)
(attribute POS_merchant Card_acceptor_identification_code)
(attribute POS_merchant Card_acceptor_name_location)

[Customer]
(subtype Customer Agent)
(attribute Customer Primary_account_number)

/* define the new relationship-links */
[Link][participation][part][subject][source][destination]
(subtype participation Link)
(subtype part Link)
(subtype subject Link)
(subtype destination Link)
(subtype source Link)

/* the attributes themselves */

/*the unique id for the REA db entity*/
(attribute REA ID/*the unique id for the REA entity*/)

[X100_Request: *a]
[X110_Response: *b]
[Transaction: *t]
[Amount_transaction: *req]
[Amount_transaction: *res]
(part *t *a)(part *t *b)
(subject *a *req)
(subject *b *res)
[POS_merchant: *m]
[Customer: *c]
(source *req *c)
(source *res *m)
(destination *req *m)
(destination *res *c)
```

### C.1.6 x0100/x0101 + x0200/x0210 - Authorisation message flow.CGIF

The CGs in CGIF format detailed below provide the input to CGimport which enables the MV in Figure 8.33 to be demonstrated in the AREA KMS.

```
/*first define the standard REA entities*/
[Transaction]
[Resource][Event][Agent][REA]

/* and their Types */
(subtype Resource REA)(subtype Agent REA)(subtype Event REA)

/* define the base types of the attributes */
[integer][string][first_name][second_name]
[name][ID][date_time][time]
[date]
(subtype ID integer)(subtype name string)
(subtype first_name string)
(subtype second_name string)
(subtype date integer)(subtype date_time string)
(subtype time string)

[Acquirer]
(subtype Acquirer Agent)

[Issuer]
(subtype Issuer Agent)

/* define the entites */
/* Resources */
[Amount_transaction]/*Field 4*/
(subtype Amount_transaction Resource)

/* Events */
[X100_Request]
(subtype X100_Request Event)
/*Field 3*/ [Processing_code]
/*Field 7*/ [Transmission_date_time]
/*Field 11*/ [STAN]
[Time_local]/*Field 12 hhmmss*/
[Date_local]/*Field 13 MMDD*/
/*Field 37*/ [Retrieval_reference_number]
/*Field 49*/ [Currency_code]
(subtype Processing_code string)
(subtype Transmission_date_time string)
(subtype STAN string)
(subtype Time_local string)
```

```
(subtype Date_local string)
(subtype Retrieval_reference_number string)
(subtype Currency_code integer)
(attribute X100_Request Processing_code)
(attribute X100_Request Transmission_date_time)
(attribute X100_Request STAN)
(attribute X100_Request Time_local)
(attribute X100_Request Date_local)
(attribute X100_Request Retrieval_reference_number)
(attribute X100_Request Currency_code)



[X110_Response]
(subtype X110_Response Event)
/*Field 39*/ [Response_code]
(subtype Response_code integer)
(attribute X110_Response Response_code)
(attribute X110_Response Retrieval_reference_number)

/* Agents */
[POS_merchant]
(subtype POS_merchant Agent)
/*Field 22*/ [POS_entry_mode]
/*Field 41*/ [Card_acceptor_terminal_identification]
/*Field 42*/ [Card_acceptor_identification_code]
/*Field 43*/ [Card_acceptor_name_location]
(subtype POS_entry_mode string)
(subtype Card_acceptor_terminal_identification string)
(subtype Card_acceptor_identification_code string)
(subtype Card_acceptor_name_location string)
(attribute POS_merchant POS_entry_mode)
(attribute POS_merchant Card_acceptor_terminal_identification)
(attribute POS_merchant Card_acceptor_identification_code)
(attribute POS_merchant Card_acceptor_name_location)

/*Field 2*/ [Primary_account_number]
(subtype Primary_account_number integer)

[Customer]
(subtype Customer Agent)
(attribute Customer Primary_account_number)

/* define the new relationship-links */
[Link][participation][part][subject][source][destination]
(subtype participation Link)
(subtype part Link)
(subtype subject Link)
(subtype destination Link)
(subtype source Link)
```

```
/* the attributes themselves */

/*the unique id for the REA db entity*/
(attribute REA ID/*the unique id for the REA entity*/)

[X100_Request: *a]
[X110_Response: *b]
[Transaction: *t]
[Amount_transaction: *req_100]
[Amount_transaction: *res_110]
(part *t *a)(part *t *b)
(subject *a *req_100)
(subject *b *res_110)
[POS_merchant: *m]
[Acquirer: *acq]
[Issuer: *iss]
(source *req_100 *m)
(source *res_110 *acq)
(destination *req_100 *acq)
(destination *res_110 *m)


/* issuer part */
[X200_Request]
(subtype X200_Request Event)
(attribute X200_Request Processing_code)
(attribute X200_Request Transmission_date_time)
(attribute X200_Request STAN)
(attribute X200_Request Time_local)
(attribute X200_Request Date_local)
(attribute X200_Request Retrieval_reference_number)
(attribute X200_Request Currency_code)

[X210_Response]
(subtype X210_Response Event)
(attribute X210_Response Response_code)
(attribute X210_Response Retrieval_reference_number)

[X200_Request: *x]
[X210_Response: *y]
[Amount_transaction: *req_200]
[Amount_transaction: *res_210]

(part *acq *x)(part *acq *y)
(subject *x *req_200)
(subject *y *res_210)

(source *req_200 *acq)
(source *res_210 *iss)
```

```
(destination *req_200 *iss)
(destination *res_210 *acq)

[AcquiredCustomer]
(subtype AcquiredCustomer Agent)
(attribute AcquiredCustomer Primary_account_number)
[AcquiredCustomer: *acq_c]

(participation *acq_c *x)
(participation *acq_c *y)
```

## C.2 CG Export

This Section provides breif details CG's in the ISO CL CGIF standard which have been exported using CGexport and the AREA KMS.

Note. a LaTeX macro was developed so that the REA entities and CG syntax of CGIF are colour coded, which enhances the readability for humans.

### C.2.1 The Transaction Model (TM) Graph - REA

```
[Resource: *1] [Agent: *2] [Resource: *d] [Resource: *c]
[Outside: *2] [Inside: *1] [Event: *0]
[New Agent: *3] [Event: *b] [Transaction: *t] [Event: *a]
(is_a *b ?0) (destination *d *1) (is_a ?1 ?1) (subject *b *d)
(is_a *c ?1) (source *c *1) (source *d *2) (destination ?3 *c)
(destination *c *2) (part *t *b) (part *t *a) (part *c *c)
(is_a *d ?1) (is_a ?0 ?0) (subject *a *c)
(is_a *a ?0) (is_a ?3 ?2)
```

## C.3 JESS

### C.3.1 Portfolio Management - PortfolioManag.CGIF

```
/* define some types */
[Date][Creation_Date][Trade_Date][Portfolio]
[integer][value]
/* define the subtypes */
(subtype Creation_Date Date)(subtype Trade_Date Date)
(subtype value integer)
```

```
/* define some attributes */
(attribute Portfolio value)
/* define the referents */
[Order: *1][Agent: *2][Transaction: *3]
[Cash_Movement: *4][Trade_Date: *5]
[Creation_Date: *6][Dollar: *7][Portfolio: *8]
[Regular_Portfolio: *9]
[Gold_Portfolio: *10][Platinum_Portfolio: *11]
[TAV: *12][Position: *13][Cash_Asset: 10pct]
[Asset: *14][Held_time: legt30days][Issuer: *15]
[Client: *16][Investment_Firm: TRA_Inc][Dollar: lt100k]
[Dollar: 100k_to_lt1m]
[Dollar: Gt1m][TAV: *17][TAV: *18][TAV: *19]
/* define relations */
(placer ?1 ?2)(part ?3 ?1)(part ?3 ?4)
(point_in_time ?3 ?5)(greater_than *6 *5)
(event_subject ?4 ?7)(characteristic ?8 ?6)
(can_be ?8 ?9)(can_be ?8 ?10)(can_be ?8 ?11)
(market_value ?8 ?12)(consists ?8 ?13)(sum ?13 ?12)
(greater_than ?12 10pct)
(measure ?12 ?7)(holder ?14 ?13)(event_subject ?1 ?14)
(characteristic ?14 legt30days)(source ?14 ?15)
(destination ?7 ?15)(owner ?14 ?16)
(destination ?14 TRA_Inc)(source ?7 TRA_Inc)
(delegate TRA_Inc ?16)(market_value ?9 ?17)
(market_value ?10 ?18)(market_value ?11 ?19)
(measure ?17 lt100k)(measure ?18 100k_to_lt1m)
(measure ?19 Gt1m)
```

### C.3.2 Portfolio Management - JESS Script

```
(mapclass Portfolio)
(facts)
(defrule platinum_portfolio (object (is-a Portfolio)
(Preferred_name ?n)
(value ?v&:(>= ?v 1000000))  )  =>
(printout t "The portfolio" ?n ", is a Platinum portfolio" crlf))
(defrule gold_portfolio (object (is-a Portfolio)
(Preferred_name ?n)
(value ?v&:(<= ?v 1000000) &&  value ?v&:(>= ?v 100000))  )
=>
(printout t "The portfolio" ?n ", is a Gold portfolio" crlf))
(defrule regular_portfolio (object (is-a Portfolio)
(Preferred_name ?n)
(value ?v&:(<= ?v 100000))  )  =>
(printout t "The portfolio" ?n ", is a Regular portfolio" crlf))
(run)
```

# Appendix D

# Data Collection - DSRM Step 5 - Evaluation

This Appendix contains part of the data collected for DSRM Step 5 - Evaluation, which includes the following data:

- **EVAL Step 1** Validation of research justification, detailed below in Section D.1
- **EVAL Step 5** Expert interview, detailed below in Section D.2
- **EVAL Step 6** Field experiment, participant observation, detailed below in Section D.3

Other DSRM Evaluation research data can be found as follows:

- **EVAL Step 2** Formal analysis of usefulness of pre-existing artefacts, methods and protocols, details as part of the AR process, refer to Section 7.2
- **EVAL Step 3** Artefacts of the AREA KMS. Determination of the effectiveness of the prototypical implementation through evaluating each individual artefact, detailed in Section 9.3.3
- **EVAL Step 4** Determination of the effectiveness of the prototypical implementation of the AREA KMS through two case studies, detailed in Sections 8.5 and 8.6.

## D.1 EVAL 1: Research Justification and Validation

This Section contains the data extracted from the Students assignments, presented following the problem definition in Table 9.5. Twelve (12) students took part in the MS.c. course and only a subset (2), of the results are presented here.

### D.1.1 Student X

**SAP transaction - MIGO - Goods Receipt** "D.1 below is the final version of the REA diagram. The 'Update Production Order status' event had not been previously considered in the previous versions of the REA diagram, but after further considerations, it seems relevant for the process. The event of updating the general ledger (GL) account was not included in the diagram because "REA rejects the need for any accounting artefacts, including journals, ledgers, and double-entry bookkeeping" (Hall 2015). In order for financial data to cater for multiple users, it has to be stored in a disaggregated form. This means that the required journals or ledgers are generated from the shared database tables and presented to different users of the system using views (Hall 2015)."

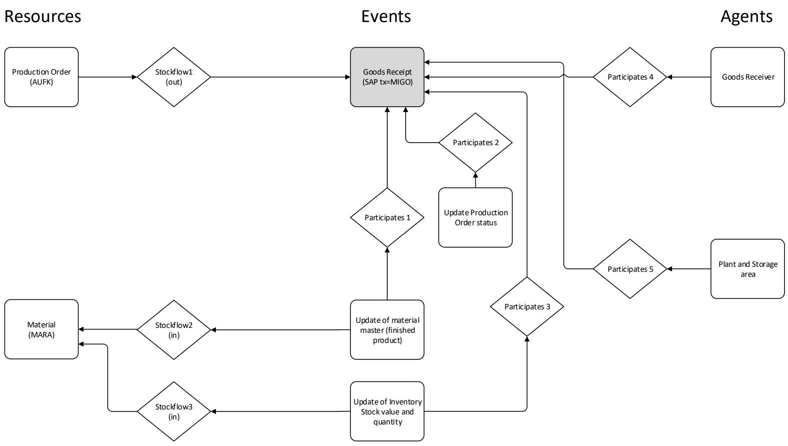


Figure D.1: Student X - REA diagram for SAP Transaction Goods Receipt

**Conclusions** "Analysis of the REA modelling technique was successful and the comparison with the IDEF0 technique gave a clear picture of which technique will be best suited to capture the 'as-is' model for the whole organisation. My recommendation is to use the REA diagram as it provides management with an interesting insight into which value addition activities exist in the organisation. Database developers can also then make use of the REA diagram to model a class diagram. Thus, REA benefits the technical and non-technical users. IDEF0 lacks depth in terms of not showing database tables that store data for the process. IDEF0 would be better suited in a manufacturing processes, but not in capturing the 'as-is' model for the entire organisation."

### D.1.2 Student Y

**SAP transaction - ME21N - "create purchase order"** "Looking at D.2, we have provided a solution using REA that captures the important elements of PO process. Elements of the process cross over organisational boundaries, and we wanted to be sure they were captured in order to prevent the silo effect within the organisation.

In this instance we have captured the two main agents, being the purchaser and chosen vendor. The chosen one being of particular importance as it's required to complete the PO, whether it's an internal or external agent."

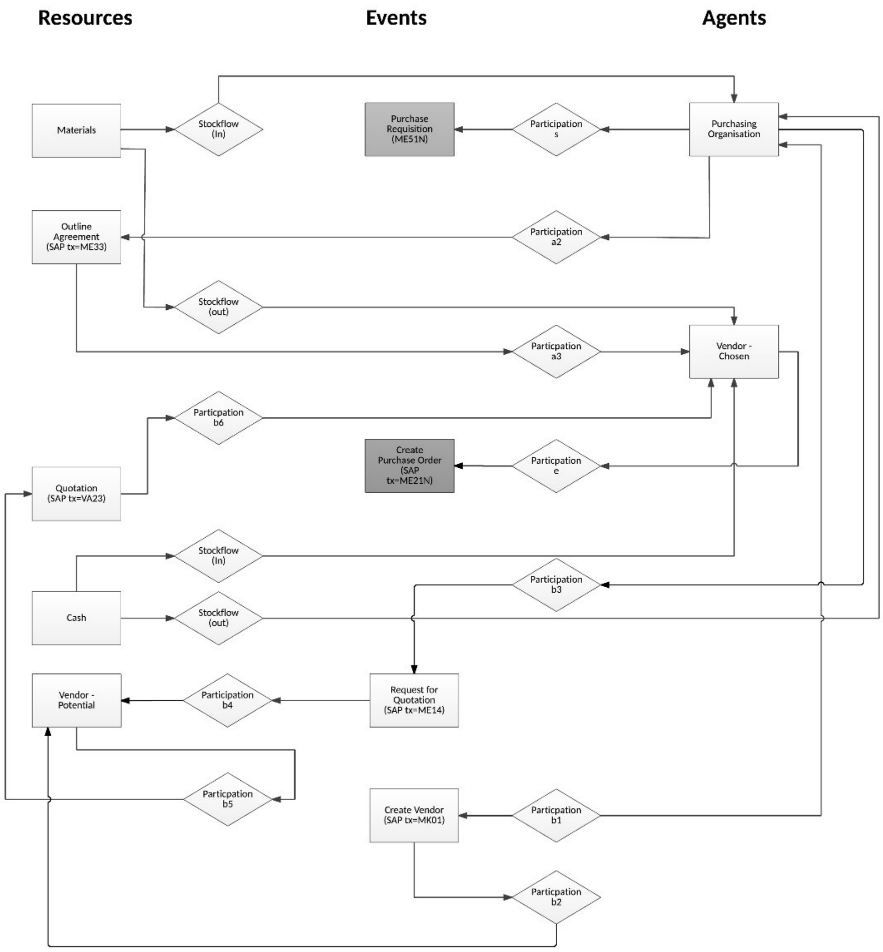


Figure D.2: Student Y - REA diagram for SAP Transaction - Purchase Order/Requisition

**Conclusions** "REA can enable businesses to better map processes as well as the physical database structure. There are multiple free tools available to create REA models that will keep costs low. The simplicity of the idiom also means model could be created in any package and simple models created relatively quickly.

BPMN however, has many different elements to get used to, which means models can take much longer to create depending on the detail.

Although there are certain downside sides to REA, around business logic and even level of detail, these can be over come by minor changes to the REA idiom. These changed mean that it can become a useful tool for mapping future ERP systems.

Based on this analysis we suggest the organisation continue with REA, as their chosen idiom."

## D.2 EVAL 5: Working Solution, Expert Interview

The following codes will be used to code the responses from participants:

1. **ARTE:NOVEL** response address the novelty of the solution
2. **ARTE:FITNESS** response fitness of the solution to solve the problem
3. **ARTE:UNIQUE** response address the uniqueness of the solution
4. **ARTE:USEFUL** response addresses the usefulness of the solution
5. **PART** - participants response or question
6. **INTER** - interviewers question or response

### D.2.1 Expert Interview, Participant A

| |
|---|
| [PART] "The combination of CG and REA is interesting, but how does this fit in with the semantic web and RDFs" [INTER] "RDFs and CGs are very similar, RDFs are based on XML and the ISO standard for the representation of CGs is CGIF, which uses standard text format(example shown)"[ARTE:NOVEL] [PART] "I see, CGIF format is easy to interpret than XML" [PART] "What technology is used Protégé?" [INTER] "JAVA" [PART]: "Is that why the graphics are poor and look somewhat outdated?" [ARTE:FITNESS] [INTER] "Unfortunately yes." [PART]: "Why when importing the CGIF file does the user have to then re-load the Protégé project?" [ARTE:FITNESS] [INTER] "Unfortunately, this is the only way to load in the new project" [PART]: "This could be improved, not very user friendly" [PART]: "I haven't seen this usage of data-driven design previously in EA, usually mostly GUI input is promoted" [ARTE:UNIQUE] [PART]: "Yes, I could see a usage for the AREA KMS with EA, however the (graphical) interface would need improvement" [ARTE:FITNESS][ARTE:USEFUL] [PART]: "The auto routing of the REA entities is also not very user friendly" [ARTE:FITNESS][ARTE:USEFUL] [PART]: "The ability to complete FCA validation on the model during design is an interesting feature" [ARTE:UNIQUE] |

Table D.1: Expert Interview Participant A

## D.3 EVAL 6: Field Experiment, Participant Observation

The following script was provided to the MSc. students on the course: "Architecture for Enterprise Applications" at Sheffield Hallam University. Providing the possibility to evaluate the artefacts of the solution in what could be called a field experiment.

# Exercise Script for 03 – Model Automation (Protégé)

Here is an exercise to help you get to grips with MV and AD.

## Prerequisites

The root Dropbox of all required files:

https://www.dropbox.com/sh/gsbgrasbnank7kb/AABz0v83-rWj5lCWbmpI1ZTja?dl=0 (and is the same link from the BB site)

### CGimport

***Copy over the latest version of CGimport, simply move all the files from; com.fallon.cgimport, to your Protege directory, usually "C:\Program Files (*possibly* x86)\Protege_3.5\plugins\com.fallon.cgimport"

### Jess

Install Jess, move all the files from;Jess/ MoveToLocalJessInstallation
To the directory; "C:\Program Files (x86)\Protege_3.5\plugins\se.liu.ida.JessTab"

## Part 1-"Lecture 14 – MV_MA in Protege - Part 1.PPT"

1. Run CharGer charger40.jar
2. In CharGer open a project file
3. Do a SaveAs CGIF (slide 9) - remember Protégé will **not** understand MV (Peirce logic, deiteration, double negation, ...)
4. Remember where you saved it.
5. Open Protégé
6. Do a CGimport of the file from 3.
7. Show how to "Layout the Graph" (CGimport - how-to - slide 11)
8. Think about the differences between Instances(referents) and Classes(types) in Protégé
9. In a text editor open the books.cgif
10. Add a new book or author etc. (slide 12)
11. Save the file as books1.cgif
12. Go back to Protege, show how easy it is to import books1.cgif
13. Show how to "Layout the Graph" (CGimport - how-to - slide 11)

### Jess

1. Start Protégé and open the file; Projects\TM_MA_to_MV_FT_WITH_TYPES.pprj
2. You should see the Jess-Tab, if not, Start Jess - Part 1 slide 27
3. Look at the Jess\jess_examples file, which shows what should happen

Page 1 of 2

Figure D.3: Model Automation (MA) Exercise - Page 1

4. Copy following line one by one into Jess prompt (press enter after each)

```
(mapclass Portfolio)
(facts)
(defrule platinum_portfolio (object (is-a Portfolio) (Preferred_name ?n)(value
?v&:(>= ?v 1000000))  )  => (printout t "The portfolio" ?n ", is a Platinum
portfolio" crlf))
(defrule gold_portfolio (object (is-a Portfolio) (Preferred_name ?n)(value
?v&:(<= ?v 1000000) &&  value ?v&:(>= ?v 100000))  )  => (printout t "The
portfolio" ?n ", is a Gold portfolio" crlf))
(defrule regular_portfolio (object (is-a Portfolio) (Preferred_name ?n)(value
?v&:(<= ?v 100000))  )  => (printout t "The portfolio" ?n ", is a Regular
portfolio" crlf))
   (run)
```

5. Explain that "mapclass" is required to inform Jess about the Protégé classes
6. Open the Jess tutorial JessTabTutorial.PPT, and briefly explain what is possible, modifying the Ontology from Jess etc.
7. Explain how this allows for Projection

## Part 2 – "Lecture 14 – MV_MA in Protege - Part 2.PPT"

1. Slide 10, show how easy it is to edit CGIF with Notepad++ (if it is installed!)
2. Open the Pizza example from Projects\pizza.pprj and have a look how we defined "attributes", show where these are identified in the CGIF from Graphs\pizza.cgif
3. Explain how we have now turned the trading company example; Graphs\ TM_MA_to_MV_FT.cgif into a working REA pattern Graphs\ REA_TM_MA_to_MV_FT.cgif show them the REA diagram in Protégé Projects\ REA_TM_MA_to_MV_FT.pprj
4. Explain how this leads on to the "Enterprise Database Design".

? Any questions? Use the Forum: Protege Discussion Board.
Also try to answer others' queries yourself - remember the Learning Pyramid from the first session ☺

Page 2 of 2

Figure D.4: Model Automation (MA) Exercise - Page 2

# Appendix E

# Ethics Statement for Students

Sheffield Hallam University

**"The Validity of a Transaction-Oriented Architecture for Enterprise Systems"**

**PARTICIPANT CONSENT FORM**

*Please answer the following questions by ticking the response that applies*

| | | *Yes* | *No* |
|---|---|---|---|
| *1.* | I have read the Information Sheet for this study and have had details of the study explained to me. | ☐ | ☐ |
| *2.* | My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point. | ☐ | ☐ |
| *3.* | I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher. | ☐ | ☐ |
| *4.* | I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet. | ☐ | ☐ |
| *5.* | I wish to participate in the study under the conditions set out in the Information Sheet. | ☐ | ☐ |
| *6.* | I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes. | ☐ | ☐ |

| | | | |
|---|---|---|---|
| **Researcher's Signature:** | | **Date:** | |
| **Researcher's Name (Printed):** | | | |
| **Contact details: email:** | | | |

| | | | |
|---|---|---|---|
| **Participant's Signature:** | | **Date:** | |
| **Participant's Name (Printed):** | | | |
| **Contact details:** | | | |

Figure E.1: Participant Consent Form