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OntoSoS.BPA.ChM: A Semantically-Enriched and Business Process Architecture-driven Framework for Change Management in System of Systems Context

Ahmad A. A. Samhan

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Software Engineering Research Group
Faculty of Environment and Technology
University of the West of England
United Kingdom, Bristol

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ABSTRACT

The interaction and collaboration between the constituent systems in a System of Systems (SoS) context entail more complex and new challenges that face the application of Change Management (ChM) frameworks. Some of these challenges include: (i) the insufficiency of adopting traditional ChM approaches for the emerging SoS context and the need for innovative directions to support ChM application in the SoS context; (ii) the heterogeneous context of SoS resulting from the different ChM standards adopted by the participating constituent systems; (iii) the lack of ChM frameworks that enrich the awareness of the ChM stakeholders of aspects related to the core ChM processes and their interrelationships based on generalised, explicit and formally represented knowledge; (iv) the lack of approaches that represent, align and link between global and local levels of SoS with focus on Business-Information Technology Alignment (BITA); (v) the high dependency of the ChM functional area on other configuration management functional areas in a SoS context to empower ChM stakeholders with knowledge related to change impact analysis and authorities identification.

This research is aimed at addressing the above gaps through using a semantically-enriched Business Process Architecture (BPA)-driven approach in order to improve the effectiveness of the ChM application in a SoS context. In addition, this research adopts the Design Science Research Methodology (DSRM) to develop, demonstrate and evaluate the research artefacts incrementally, leading to the final research framework; namely the OntoSoS.BPA.ChM.

The research framework is composed of three main components developed through multiple DSRM process increments. The ChM component provides a new generalised semantically-enriched BPA-driven model for the ChM functional area. The SoS context view component provides a new generalised semantically-enriched BPA-driven meta-model that can be instantiated for a given SoS arrangement. Finally, the alignment and knowledge retrieval component aligns the ChM component with the SoS view component and provides knowledge retrieval capabilities to retrieve purposeful knowledge from the ChM and SoS components that enriches the awareness of the concerned ChM stakeholders. The OntoSoS.BPA.ChM framework has been demonstrated and evaluated using a representative healthcare case study, in particular, the Cell Therapy and Applied Genomics (CTAG) at King Hussein Cancer Centre (KHCC), Amman, Jordan.

The OntoSoS.BPA.ChM framework has demonstrated its effectiveness in addressing the identified research gaps when applied to the selected representative case study. In particular, (i) a novel approach was used to capture related aspects of the ChM and SoS problem domains using new conceptual models (e.g. BPA models for ChM and BPA-driven models for SoS context) and then introducing an innovative solution (semantically-enriched BPA-driven ChM framework) to support ChM application in a SoS context; (ii) the heterogeneity impact of SoS arrangements on achieving a

common agreement on the different ChM aspects related to managing a change request has been minimised by developing and using a generalised semantically-enriched and object-based BPA-driven model for ChM functional area that aligns between twelve ChM standards and guidelines in the software and systems engineering domains; (iii) the enrichment of ChM stakeholders awareness of different ChM aspects related to ChM processes and the relationships between them has been enabled using knowledge-retrieval capabilities that are based on explicit and formal representations of the related ChM aspects; (iv) a better support of maintaining SoS global-local levels alignment and BITA during ChM application has been facilitated by capturing key related SoS elements and linkages between them using a semantically-enriched and BPA-driven approach; and (iv) compared to traditional ChM frameworks, the OntoSoS.BPA.ChM framework has minimised the dependency of ChM functional area on other separate configuration management functional areas by providing dedicated means that enable more comprehensive traceability of candidate change implications and more effective identification of configuration items and stakeholders related to a change request. In conclusion, the OntoSoS.BPA.ChM framework might be generalised to other healthcare areas, and/or industrial and business domains using more complex case studies.

To My Mother & Father

To (My Mother & Father)-in-law

To My Wife & Children

To My Brothers & Sisters

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' TO ALLAH ALL THE PRAISE AND GLORY '

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ABBREVIATIONS

ANA	Army, Navy and Air Force
BITA	Business-IT Alignment
BPA	Business Process Architecture
BPM	Business Process Model
CC	Configuration Control
CCB	Change Control Board
CEBEs	Candidate Essential Business Entities
ChM	Change Management
CI	Configuration Item
CM	Configuration Management
CMP	Case Management Process
CMS	Configuration Management System
CobiT	Control Objectives for Information and Related Technology
COO	Chief Operating Officer
CP	Case Process
CR	Change Request
CRF	Change Request Form
CSP	Case Strategy Process
CTAG	Cell Therapy and Applied Genomics
CTF	Change Type Form
DAG	Defence Acquisition Guidebook
DoD	Department of Defence
DSR	Design Science Research
DSRM	Design Science Research Methodology
EBE	Essential Business Entity
ECP	Engineering Change Proposal
IS	Information System
IT	Information Technology
ITIL	Information Technology Infrastructure Library
JESS	Java Expert System Shell

KHCC	King Hussein Cancer Center
KPIs	Key Performance Indicators
OWL	Web Ontology Language
OWL-2-RL	OWL-2- Rule Language
OWL-DL	Web Ontology Language - Description Logic
OWL-APIs	Web Ontology Language- Application Programmable Interfaces
PAD	Process Architecture Diagram
Ph.	Phase
RDF	Resource Development Framework
RFC	Request For Change
RFDS	Resource Development Framework Schema
RFV	Request For Variance
RG	Research Gap
RO	Research Objective
RPA	Riva Process Architecture
RQ	Research Question
RQ	Research Question
SoS	System of Systems
SPARQL	Simple Protocol and RDF Query Language
SQWRL	Semantic Query-enhanced Web Rule Language
srBPA	semantic Riva BPA
SWRL	Semantic Web Rule Language
UOW	Unit Of Work
W3C	World Wide Web Consortium
XML	eXtensible Markup Language

CHAPTER 1

INTRODUCTION

In recent decades, organisations have become Information Technology (IT)-enabled and therefore have heavily relied on Information Systems (ISs) to support their business processes and achieve their business targets. Yet, the never-ending development of IT has resulted in increased expectations from service providers, as reflected in greater needs and requirements complexities. These complexities have highlighted shortcomings when traditional engineering approaches are used to meet the new emerging requirements (Gorod, Sauser and Boardman, 2008; INCOSE, 2015). Accordingly, it has been recognised that the complex emergent needs must occasionally be addressed by behaviours that take place at a higher level, above the existing individual monolithic systems. Hence, there has been a clear tendency for ISs to be grouped into large-scale System of Systems (SoS) arrangements, to provide unique capabilities that cannot be provided through a single monolithic IS (Northrop *et al.*, 2006; DANSE Consortium, 2012a).

This section briefly describes the main areas related to this research (i.e. SoS, Configuration Management and Change Management, Business Process Architecture and Semantic-enrichment) and relate these to the overall research aim.

Maier (1998) provided guidelines to classify systems as SoS arrangements. He emphasised that a system requires some of its constituent components (e.g. systems) to be independently operated and managed in order to be considered as a SoS arrangement, regardless of the components complexity or geographic distribution. Operational independence means that dismantling the SoS into its constituent systems would not prevent the useful independent functioning of the constituent systems. Managerial independence means that the constituent systems actually have an operational existence that is independent of the SoS.

Driven by the SoS arrangements' characteristics, dynamic environments and how their constituent systems participate in the arrangements, needs and requirements change during the SoS lifetime, changes to SoS arrangements have become mandatory. These changes, in turn, influence both the SoS arrangement and the participating constituent systems. Consequently, strict emphasis on the need for controlling, managing and tracking changes in a SoS arrangement has become a key priority, and therefore the need for configuration management approaches that take into consideration the challenges posed by the emerging SoS arrangements (Ali and Kidd, 2014).

As presented by Sommerville (2016), configuration management involves four closely related functional areas; Change Management, Version Management, System Building and Release Management. The change management functional area is concerned with managing change requests, change impact analysis, decisions about the requested changes and the coordination of changes implementation and release. The version management functional area is concerned with keeping track of the different developed artefacts' versions and making sure that the changes made by different authorities do not interfere. The system-building functional area is concerned with assembling the systems' components and then creating usable systems. Finally, the release management functional area is concerned with arranging the systems to be released for use and keeping track of the released systems' versions. For this research, the focus will be on investigating the Change Management (ChM) functional area, as it plays the key role in having an effective control and management of changes that affect SoS arrangements.

Applying a ChM framework is vital for any scope of systems, especially for large-scale SoS arrangements. It is used as a means to assure that the development and evolution of the various constituent systems are efficient, cost-effective and under control so that they interoperate efficiently to fulfil the targeted high-level needs (Whitgift, 1991). Nonetheless, there are new, complex and inherent challenges posed by the emergence of SoS arrangements, including overcoming the heterogeneity of participating systems, achieving efficient traceability of implications and authorities related to proposed changes and maintaining global-local levels alignment and business-IT alignment (Northrop *et al.*, 2006; Gorod, Sauser and Boardman, 2008; INCOSE, 2015). Inadequacies were detected when traditional approaches were adopted to address these new challenges (Gorod, Sauser and Boardman, 2008; INCOSE, 2015). Accordingly, addressing challenges facing the application of ChM in a SoS context is a key aim that reduces the gap in the effective application of ChM in the SoS domain (Northrop *et al.*, 2006; Samhan *et al.*, 2016).

This research investigates a novel solution by utilising a semantically-enriched business process architecture-driven approach in order to improve the effectiveness of the ChM application in a SoS context.

The Business-IT Alignment (BITA) involves aligning business goals and needs to the most suitable IT support to ensure the continued survival and enhanced competitive advantages of an organisation. An efficient BITA level requires understanding the main business aspects and how IT can support the business (Luftman and Brier, 1999; Aversano, Grasso and Tortorella, 2013). Developing solutions that utilise business-driven models (i.e. Business Process Architecture and Business Process Models) supports addressing BITA. Dijkman, Vanderfeesten and Reijers (2016, p. 3) define a Business Process Architecture (BPA) as, "An organised overview of business processes that specifies their relations". It represents the overall key business processes that are necessary to conduct business in a defined functional area (Ould, 2005). Using a BPA helps achieve the right division of functional area related activities into core processes, which enables avoiding complex designs or models (Ould, 2005). This, in turn, leads to a clearer understanding of the key business processes amongst stakeholders and improves its support by related IT services (Ould, 2005; Peisl, 2012).

Researchers and practitioners need to understand and share information to work efficiently. Developing ontologies is one of the key semantic approaches to facilitate such understanding by providing explicit and formal representation, knowledge reasoning capabilities and resolving semantic heterogeneities in a SoS context, as will be discussed in Chapter 2. In computer and information sciences, ontology can be seen as an "explicit formal specification of the terms in the domain and relations among them" (Noy and McGuinness, 2001, p. 1). Furthermore, "an ontology defines a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them" (NOY and McGuinness, 2001, p. 1).

Enabling sharing and agreeing ChM knowledge between the various participating stakeholders in a SoS arrangement by providing a generalised semantically-enriched representation of key ChM aspects (ChM processes, relationships, documents and roles, alongside their detected semantic heterogeneities) and key SoS elements (that enable supporting global-local levels alignment and BITA during ChM application) is a viable research direction that supports improving the effectiveness of ChM application in the SoS context.

After the above introduction, the chapter proceeds with the research problem and motivation. Following that, the aim and objectives of the research are identified in Section 1.2, which led to establishing the research proposition and associated questions in Section 1.3. Finally, the chapter is concluded with the thesis roadmap besides the list of means that have been used to communicate the research aim and its related outcomes in Sections 1.4 and 1.5, respectively.

1.1 Research Problem and Motivation

The emergence of SoS arrangements has brought about more complex inherited and new challenges that face the application of traditional software and systems engineering in general, and configuration management/change management in particular. The literature addresses various SoS and ChM related aspects, yet there is a lack of research investigating and supporting the application of ChM in the SoS context. With this regard, the following is a summary of a number of key challenges that motivated this research work. A more detailed discussion can be found in Section 2.7.

First, a number of studies shed light on the insufficiency of applying traditional software and systems engineering approaches, including Configuration Management (CM) and ChM practices, to the context of ultra-large-scale systems and SoS. Accordingly, approaches that introduce innovative solutions are claimed vital to facilitate and enable the application of the traditional approaches in such complex contexts (Cropley, 2004; Northrop *et al.*, 2006; Raygan, 2008; INCOSE, 2015; Sommerville, 2016).

Second, the heterogeneous context of a SoS arrangement resulting from adopting different CM and ChM standards and guidelines by the constituent systems makes reaching a common agreement and shared understanding of CM and ChM terminologies and their interpretations into related procedures challenging to achieve (Raygan, 2008; Bellomo and Smith, 2008).

Third, there is a lack of research investigating, supporting and enriching the awareness of ChM stakeholders of the related ChM aspects found in the literature. Also, a lack of explicit and formal (i.e. machine-readable) representations is evident in modelling ChM processes and their interrelationships. Moreover, no explicit and formal representations linking ChM processes to the related documents and roles needed to carry out these processes have been cited so far. Additionally, no ChM frameworks have been identified that can explicitly and formally consider the dependency relationships of the ChM processes on the domain-specific aspects in traditional or SoS contexts.

Fourth, the linkages between the global and local levels of SoS arrangements have not been explicitly and formally represented or considered during SoS investigations, especially for CM and ChM application. This, in turn, impacts maintaining global-local levels alignment and may lead to the failure of the SoS arrangements.

Additionally, maintaining BITA during ChM application in a SoS context is difficult. One reason is that the existing CM and ChM frameworks consider controlling changes that are limited to IT-related components or assets (AXELOS, 2011; INCOSE, 2015). Furthermore, the existing ChM frameworks lack capturing the relations between the key business elements and supporting IT aspects or recognising related affected business aspects as key elements that need to be under the consideration of ChM.

Fifth, SoS arrangements entail a large number of components and stakeholders. Applying ChM in a SoS context requires correct identification of the key components and related impacted or required stakeholders during the management of the proposed change, which occurs at different levels of the SoS arrangement (Novakouski *et al.*, 2012; MITRE, 2014; INCOSE, 2015). However, existing popular ChM frameworks were criticised for having a high dependency on other separate technical and management frameworks to provide them with sufficient impact analysis from technical and business point of views, which makes their capabilities limited, especially when their application is scaled up into more complex context such as SoS arrangements (Raygan, 2008). Furthermore, inefficient stakeholders identification was flagged out as one of the main challenges for achieving effective communication when applying ChM processes in SoS arrangements (Bellomo and Smith, 2008). The researcher was unable to identify literature with ChM frameworks explicitly and formally capturing the linkages between the Configuration Items (CIs) -the main elements that are required to be under the formal consideration of ChM- and their related stakeholders in traditional or SoS contexts. The frameworks also lack dedicated pre-compiled knowledge that can be used to identify candidate-related parties and impacted CIs, or to be used as benchmarking grounds to validate the implications' feedback regarding a proposed change.

This research, therefore, is motivated to address the identified gaps and challenges using a state-of-the-art approach to build a novel ChM support framework that improves the effectiveness of the ChM application in the SoS context, this framework is named as the OntoSoS.BPA.ChM framework.

1.2 Research Aim and Objectives

This study aims to investigate the implications of using a semantically-enriched BPA-driven approach to improve the effectiveness of ChM application in a SoS context. The following Research Objectives (ROs) have subsequently been identified in light of the research aim and research gap analysis presented in Section 1.1, and further discussed in Chapter 2:

RO1) To reduce the impact of SoS heterogeneity on sharing and agreeing on ChM aspects by providing a generalised, semantically-enriched and BPA-driven model for the ChM functional area.

RO2) To support SoS global-local levels alignment and BITA during the application of ChM through capturing the main related aspects of a SoS and the linkages between them using a semantically-enriched and BPA-driven approach.

RO3) To enable enriching the ChM stakeholders' awareness of ChM and SoS aspects that are related to managing a change request by providing knowledge retrieval capabilities that utilise the knowledge resulting from addressing RO1 and RO2.

RO4) To investigate the effectiveness of the developed ChM framework in improving the application of ChM in a SoS context.

1.3 Research Proposition and Questions

This research proposes that: "**The use of a semantically-enriched and business process architecture-driven approach in driving the development of a change management support framework, improves the effectiveness of change management application in a system of systems context**". In light of this research context, the following aspects related to the above research proposition are further discussed.

First, the proposed research framework (main research artefact) is developed to address identified challenges facing ChM application in the SoS context. Therefore, the scope of this framework is limited to aspects that support the achievement of the established research aim and objectives, which were driven by the identified research gaps.

Second, a focus of this research is to align different ChM standards, practices and guidelines and reduce the impact of SoS heterogeneity by providing a generalised ChM knowledge that can be shared and agreed on amongst the concerned SoS-ChM stakeholders. This is intended by identifying key generalised ChM processes and their interrelationships, the main documents and roles related to handling the application of the identified ChM processes, and the different terminologies used to describe or define the identified ChM processes, documents and roles. In addition, semantically-enriched models to represent all the identified aspects and resolve semantic heterogeneities are intended to be developed. Therefore, a semantically-enriched BPA-driven identification and modelling approach is adopted and utilised.

Third, another intention of this research is to support SoS global-local levels alignment with a focus on BITA during the application of ChM. This requires understanding the main business aspects and how IT can support the business. Accordingly, a semantically-enriched BPA-driven identification and modelling approach is adapted and utilised to capture key SoS related elements (e.g. global-level business services and local-level software services) and the linkages between them (e.g. a local-level software service supports a local-level business presses, which supports a global-level business service).

Fourth, the development of a ChM support framework entails a focus on enriching the ChM stakeholders' awareness of the identified ChM and SoS aspects that are related to managing a change request in a SoS context. Therefore, query-based knowledge retrieval capabilities are developed based on utilising the resulting ChM and SoS knowledge bases.

Fifth, the anticipated research framework aims at improving the effectiveness of the ChM application in a SoS context. In the context of this research, ChM effectiveness improvement is realised by addressing the identified research gaps. In particular, by using a novel approach that enables the SoS-ChM framework to empower the ChM stakeholders with ChM knowledge that can reduce the SoS heterogeneity impact on reaching a shared understanding of and agreement on the main ChM aspects related to managing change requests in a SoS context. In addition, by enabling the ChM framework to empower the ChM stakeholders with knowledge that support maintaining SoS global-local alignment/BITA and support carrying out particular ChM processes (i.e. Change Initiation, Change Validation and Assessment, Authorities Identification) with less dependency on other CM functional areas and SoS authorities and with more comprehensive coverage of CIs and authorities compared to traditional approaches that are not BPA-driven or semantically-enriched. Driven by that, using a real-world case study plays a key role in demonstrating the effectiveness of the research framework in improving ChM application in a SoS context.

In light of the above discussion in relation to the research proposition, Research Questions (RQs) that are aligned with the research aim and objectives have been formulated:

RQ1) How can BPA modelling approaches assist in developing generalised semantically-enriched models for the ChM functional area? (Addressing RO1)

RQ2) What SoS generalised aspects (elements and linkages) can a BPA-driven approach assist in identifying and semantically-enriching to support SoS global-local levels alignment and BITA during ChM application? (Addressing RO2)

RQ3) How can the developed BPA-driven and semantically-enriched ChM and SoS models be utilised to retrieve knowledge that supports SoS-ChM stakeholders, and ChM application in a SoS context? (Addressing RO3)

RQ4) Can the utilisation of the developed OntoSoS.BPA.ChM framework improve the effectiveness of the ChM application in a SoS context? (Addressing RO4)

1.4 Thesis Roadmap and Structure Overview

This thesis consists of eight chapters. Table 1.1 presents an overview of the thesis and highlights how the research objectives and research questions are addressed and answered, respectively. Chapter 1 introduces a summarised background, identifies the research problem and highlights the research motivation. In addition, the chapter states the research aim and objectives and articulates the research proposition and associated research questions. This is followed by Chapter 2, which discusses the research background and literature review. The SoS, CM and ChM domains have been reviewed to reveal the challenges facing CM application in general, and ChM application in the SoS context in particular. Furthermore, the literature's existing related work are presented and reviewed to analyse the research gaps. This also includes reviewing BPA modelling methods and the semantic representation of knowledge using ontologies to support the proposition of the research solution.

Chapter 3 provides an overview of research design and discusses the adoption of the Design Science Research Methodology (DSRM) for the increment development of the main research framework, which is proposed to address the research gaps identified in Chapter 2. Additionally, the research evaluation framework adopted to verify, validate and reveal the effectiveness of the proposed framework is explained. Finally, the selected case study and the basis for selection are discussed.

Having presented the research framework and the design science research process adopted for the framework development and evolution, Chapter 4 provides a detailed discussion of the first-DSRM-increment, in which a set of ChM standards, practices and guidelines are aligned by developing generalised BPA models for the ChM functional area. The developed ChM-BPA is then demonstrated using the selected case study and evaluated by BPA and ChM domain experts. To semantically enrich and extend the developed ChM-BPA models, the second-DSRM-increment is carried out in Chapter 5. Accordingly, an ontology-based component for the semantic-enrichment of BPA-driven models is adapted and then demonstrated through the instantiation of the developed ChM-BPA models. Furthermore, the resulting semantically-enriched BPA models for ChM are extended by linking identified ChM processes with associated BPA-driven ChM-documents and roles. Moreover, the related parts of the adopted evaluation framework are used to verify and validate the resulting models' elements with the support of domain experts. Carrying out the first and second DSRM-increments in Chapters 4 and 5 leads to developing the first main framework component (the ChM component), which contributes to addressing the first identified research objective and answering the first research question.

Chapter 6 details the third-DSRM-increment, which focuses on supporting SoS global-local levels alignment and BITA during the application of ChM in a SoS context by developing generalised semantically-enriched BPA-driven meta-model that represents related elements within the SoS context. Additionally, guidelines to instantiate the developed meta-model for a given SoS arrangement are introduced. Following that, the selected representative case study is used to demonstrate the developed meta-model. Finally, the related parts of the adopted evaluation framework are used to verify and validate the resulting model's elements with the support of domain experts. Carrying out the third-DSRM-increment in Chapter 6 leads to developing the second main framework component (the SoS context view component), which contributes to addressing the second identified research objective and answering the second research question.

Chapter 7 reviews the details of the fourth-DSRM-increment, which focuses on enriching the SoS-ChM stakeholders' awareness of the different represented ChM and SoS elements related to managing a change request by developing query-based knowledge retrieval capabilities. Furthermore, the artefacts developed to achieve the fourth-DSRM-increment's objectives are demonstrated using the selected CTAG-KHCC case study. Following that, parts of the adopted evaluation framework are conducted to verify and validate the developed artefacts and then to inform the effectiveness of the OntoSoS.BPA.ChM framework. Carrying out the fourth-DSRM-increment in Chapter 7 leads to developing the third and last main framework component (the alignment and knowledge retrieval component) and also informing the effectiveness of the whole research framework, which contributes to addressing the third and fourth identified research objectives and answering the third and fourth research questions. Finally, **Chapter 8** concludes with presenting the research contributions. In addition, the chapter concludes with answering the research questions and gaps, leading to answering the research proposition. Moreover, the chapter highlights the research limitations and proposes future research directions.

1.5 RESEARCH COMMUNICATION

The DSRM adopted for this research (Peffers *et al.*, 2007) emphasises communicating the research findings and deliverables to researchers and other relevant audiences. The present thesis is the main means used to communicate the research outcomes. In addition, Table 1.2 presents a list of further methods used.

Table 1. 1: Thesis Roadmap.

Chapter ID	Chapter 1	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8
Chapter Aim	Introduction	Background & Literature Review	Research Design	Generalised ChM-BPA Models	Semantically-Enriched Extended ChM-BPA Model	Generalised Semantically-Enriched BPA-Driven SoS Context View Model	Query-based Knowledge Retrieval Capabilities & Framework Effectiveness	Conclusions & Future Research Directions
Chapter Main Sections	Problem Statement	Background	Overview of Research Design	1st-DSRM-Increment's Design & Development Phase	2nd-DSRM-Increment's Design & Development Phase	3rd-DSRM-Increment's Design & Development Phase	4th-DSRM-Increment's Design & Development Phase	Summary of the Research Contributions
	Motivation	Gap Analysis for the CM and ChM in SoS context	The Adopted Research Design & Methodology	1st-DSRM-Increment's Demonstration Phase	2nd-DSRM-Increment's Demonstration Phase	3rd-DSRM-Increment's Demonstration Phase	4th-DSRM-Increment's Demonstration Phase	Bottom-Up Approach to answer the RQs and Hypothesis
	Research Aim & Objectives		The Research Framework	1st-DSRM-Increment's The Evaluation & Evolution Phase	2nd-DSRM-Increment's Evaluation & Evolution Phase	3rd-DSRM-Increment's Evaluation & Evolution Phase	4th-DSRM-Increment's Evaluation & Evolution Phase	Research Limitations
	Research Hypothesis & Questions		The Evaluation Framework					Future Research Directions
			The Selection of the Case Study					
Chapter Alignment with the Identified Research Objectives				**Research Objective 1**	**Research Objective 1**	**Research Objective 2**	**Research Objectives 3 and 4**	**Conclusion of Addressing the ROs**
Chapter Alignment with the Identified Research Questions				**Research Question 1**	**Research Question 1**	**Research Question 2**	**Research Questions 3 and 4**	**Conclusion of Answering the RQs**

Table 1. 2: Overview of means of research communication.

ID	Communication Means
1	Samhan, A., Kossmann, M., Odeh, M., Sa, J. 2016. OntoSoS.CM: A Business Process Architecture Driven and Semantically-Enriched Change Management Framework for Systems of Systems Engineering, IEEE International Symposium on Systems Engineering (ISSE), Edinburgh, UK, 3-5 October 2016.
2	Workshops for stakeholders at the "King Hussein Cancer Centre (KHCC)/Jordan", in July 2016 and August 2017. This was part of initiating and conducting a case study namely "A KHCC Change Management Framework in System of Systems Context".
3	Workshops for stakeholders at AIRBUS/Bristol in August 2016 and October 2017. This was part of proposing a case study namely "An Airbus Avionics Change Management framework in Systems of Systems context".
4	A Seminar at the ASHLEY project public forum. October 2016. "http://www.ashleyproject.eu".
5	A Seminar at the Software Engineering Research Group (SERG) Monthly Seminar, UWE. Bristol, UK. November 2016.
6	A Seminar at the Software Engineering Research Group (SERG) Monthly Seminar, UWE. Bristol, UK. April 2018.
7	Samhan, A., Odeh, M., Kossmann, M., Tbakhi, A. 2018. Business Process Architecture-driven Change Management Applied to a Cancer Care Organization in a System of Systems Context, 1st International Conference on Cancer Care Informatics (CCI), Amman, Jordan, 19-21 November 2018.
8	Samhan, A., Odeh, M., Green, S., Kossmann, M., Tbakhi, A. 2018. OntoSoS.BPA.ChM: A Business Process Architecture-driven and Semantically-Enriched Change Management Framework Applied in System of Systems Context, PhD Consortium, 1st International Conference on Cancer Care Informatics (CCI), Amman, Jordan, 19-21 November 2018.
9	A book chapter that discusses the detailed development of the generalised BPA models for Change management, [Expected 2020/2021].
10	Kossmann M, Samhan A, Odeh M, Qaddoumi E, Tbakhi A, Watts S. Extending the scope of configuration management for the development and life cycle support of systems of systems—An ontology-driven framework applied to the Enceladus Submarine Exploration Lander. Systems Engineering. 2020;1-26. https://doi.org/10.1002/sys.21532
11	Samhan, A., Odeh, M., Kossmann, M. Tbakhi, A., Green, S. [Expected 2020]. A Semantically enriched Business-IT Alignment-driven view for SoS Context – Applied to Cell Therapy and Applied Genomics (CTAG). The 2nd International Conference on Cancer Care Informatics (CCI), 2020.
12	Samhan, A., Odeh, M., Kossmann, M. Tbakhi, A., Green, S. [Expected 2020/2021]. Business Process Architecture-driven and Semantically enriched Change Management Framework in SoS Context – The Cell Therapy and Applied Genomics. Journal Paper, INCOSE, Systems Engineering Journal, 2020/2021.
13	Contributing to the INCOSE Configuration Management Chapter by Joining the INCOSE Configuration Management Work Group. [Agreed with the steering committee for 2020/2021].

CHAPTER 2

RESEARCH BACKGROUND AND LITERATURE REVIEW

2.1 INTRODUCTION

This research considers different domains, as it has an aim and objectives that address or use aspects from the domains of system of systems, configuration management and change management, business process architecture and models, and semantic-representation. Broadly speaking, problems associated with applying configuration and change management in the system of systems context provided the genesis for the research problem. In addition, the solution space was driven by aspects related to the business process architecture and models, and semantic-representation domains. Therefore, this chapter presents a background to these research domains and provides a research gap analysis, which paves the way for deriving the research problem and proposing the related solution.

2.2 SYSTEM OF SYSTEMS

The complexity of stakeholders' requirements has risen in parallel with the ceaseless evolution of IT (e.g. the need to produce more intelligent and safer aircrafts). This has resulted in shortcomings when applying traditional software and systems engineering approaches to meet the new needs (Gorod, Sauser and Boardman, 2008). Accordingly, engineers have recognised that these emerging needs should be addressed by integrating existing individual ISs into systems arrangements that provide unique capabilities, which cannot be provided by a single monolithic IS. Systems have consequently evolved into System of Systems (SoS) arrangements (Northrop *et al.*, 2006; DANSE Consortium, 2012a).

While the concept 'System' is uncontroversial, the literature indicates that a consensus on a definition for the 'SoS' concept is elusive. Generally, the concept 'System' has been seen as a set of components or subsystems, with an interrelated structure of relationships, working together as a unified whole to accomplish defined goals (INCOSE, 2015; ISO/IEC/IEEE, 2015). Nonetheless, Boardman *et al.* (2006) presented in their report more than 40 definitions for SoS, elicited from a combination of academic literature, conferences and other recognised published documents. This report showed that as there are different purposes under consideration, various SoS definitions were adopted to support these purposes. Furthermore, Gandhi, Gorod and Sauser (2012) emphasised that there is still no single, widely accepted definition for a SoS despite the substantial work conducted in the field.

Preliminary ideas related to SoS can be traced back to Boulding's paper on General Systems Theory (Boulding, 1956). Boulding used the term 'system of systems' to describe an arrangement of theoretical systems in a hierarchy of complexity that is greater than the summation of the system's parts (Gorod *et al.*, 2014; Nielsen *et al.*, 2015). During the following two decades, ideas related to systems that are comprised of systems were highlighted in various pieces of research (Berry, 1964; Ackoff, 1971; Jacob, 1976). Nevertheless, compared to the agreed definitions of traditional monolithic systems, the early initiatives that defined a SoS. did not provide distinctive definitions which could be used to distinguish SoS arrangements from traditional monolithic systems. For example, the definitions introduced by Manthorpe (1996), Kotov (1997), and Popper *et al.* (2004) for a SoS can also be applied to today's complex monolithic systems.

In 1998, Maier postulated five essential characteristics of a SoS arrangement in response to the broad incremental recognition of the SoS concept that was not accompanied by a consensus definition. A list of Maier's characteristics, together with brief descriptions of each, is provided in Table 2.1 (Maier, 1998; Sage and Cuppan, 2001).

Table 2. 1: Maier's characteristics for a SoS arrangement (Maier, 1998; Sage and Cuppan, 2001).

#	Maier's Characteristic	Brief Description
1	Operational independence of the constituent systems	▪ Some or all the constituent systems that participate in the SoS arrangement can usefully operate independently, where each has its own independent purpose(s) to fulfil.
2	Managerial independence of the constituent systems	▪ Some or all the constituent systems that participate in the SoS arrangement are managed (acquired, governed, and operated) independently. This allows the respective system owners to develop their systems autonomously in accordance with their respective needs.
3	Evolutionary development of the SoS arrangement	▪ The SoS arrangement is formed gradually; it is not fully developed from the first instance. The SoS capabilities and purposes can be subject to continuous change: they can be added to, disposed of, and modified with experience and need.
4	The emergent behaviour of the SoS arrangement	▪ The SoS arrangement performs behaviours that arise from the dynamic interactions and relationships of the constituent components. This is done to realise objectives that the constituent systems, acting alone, could not meet.
5	Geographic distribution nature of the constituent systems	▪ In many cases, some or all the constituent systems are geographically dispersed. In the SoS arrangement, the interactions between the participating systems are limited to exchanging information rather than exchanging considerable amounts of mass or energy.

Based on Maier (1998), Several constituent parts of a system should be independent, both managerially and operationally, for it to be recognised as a SoS arrangement. Hence, any system that does not manifest these two characteristics is not considered a SoS arrangement, regardless of its complexity or the geographic distribution of the participating constituent systems. This has led to proposing the following SoS definition "A system-of-systems is an assemblage of components which individually may be regarded as systems, and which possesses two additional properties: Operational Independence of the Components…[and]…Managerial Independence of the Components" (Maier, 1998, p. 271). Conversely, from the perspective of software engineering, Sommerville (2016) viewed the essential distinction between SoS and traditional systems as pertaining principally to managerial independence. He claimed that for one to consider a system as a SoS arrangement, it should entail two or more constituent elements that are independently managed. This implies, of course, that there is no single manager directs all the constitute systems of the SoS arrangement.

Building on Maier's work, various definitions of a SoS were proposed. For example, INCOSE (2015, p. 8) introduced a SoS as a system-of-interest, "whose elements are managerially and/or operationally independent systems. These interoperating and/or integrated collections of constituent systems usually produce results unachievable by the individual systems alone". Furthermore, in the Defence Acquisition Guidebook (DAG), a SoS is described as, 'a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities' (DoD, 2019, Sec. 3.2).

An example of a SoS arrangement is the 'Emergency Control System' (Nielsen *et al.*, 2015), where successful management of an emergency results from the interactions between a number of different services, each provided by different independent systems. For example, the '999' emergency service in the UK starts when the call is directed to the emergency operators that reside in a local telephone company or related 'Operator Assistance Centres'. Subsequently, the operator either transfers the call or collaborates in the emergency response with one or more discrete participants, e.g. police, fire brigade, ambulance service, etc.

Generally, a taxonomy is seen as a "scheme that partitions a body of knowledge and defines the relationships among the pieces"(ISO/IEC/IEEE, 2019b, p. 2). A range of differing system types is addressed by the definitions of 'SoS arrangement' within the literature. For example, definitions comprise SoS arrangements that are owned by an individual organisation but whose constituent systems are managed by different parts of the same organisation. They also include SoS arrangements whose constituent systems are acquired and managed independently by different organisations (Sommerville, 2016). Based on the degree of the managerial and operational independence of the constituent systems, ISO/IEC/IEEE (2019) introduces four types of a SoS arrangement: directed, acknowledged, collaborative and virtual. This taxonomy was originally proposed in (Maier, 1998), then extended by (ODUSD(A&T)SSE, 2008). Table 2.2 presents the aforementioned SoS arrangement types.

Table 2. 2: SoS arrangements classifications.

#	SoS Type	Brief Description
1	Directed	▪ The SoS arrangement is developed with specific purposes in mind. It is centrally managed by a controlling authority and the constituent systems retain their capability to operate independently. Nonetheless, their typical operational mode is subordinated to the SoS-level purpose. ▪ In this type of SoS, the constituent systems can be managed independently by different parts of the organisation, but there is an ultimate governing authority within the organisation that owns the SoS arrangement and defines purposes, sets priorities and resolves conflicts for the SoS arrangement and the participating constituent systems. ▪ An example of a Directed SoS is a, "military command and control system that integrates information from airborne and ground-based systems" (Sommerville, 2016, p. 588).
2	Acknowledged	▪ The SoS has its own dedicated resources and manager, as well as clearly defined objectives. In addition, the constituent systems maintain their independent existence (ownership, purposes, funds, development and evolution, etc.). ▪ The change and evolution aspects of the SoS arrangement are carried out based on collaboration between the SoS arrangement authority and the constituent-system authorities. ▪ An example of an Acknowledged SoS is a DoD's ballistic missile defence system (Madni and Sievers, 2016).
3	Collaborative	▪ The constituent systems interact voluntarily to achieve recognised SoS purposes. Here, there is no dominant authority and the constituent systems jointly (e.g. by setting up a voluntary governance body) decide how to interoperate and adhere to agreed standards and purposes. ▪ An example of a Collaborative SoS is the 'Internet', where the, "Internet Engineering Task Force works out standards but has no power to enforce them. The central players collectively decide how to provide or deny service, thereby providing some means of enforcing and maintaining standards" (BKCASE Editorial Board, 2019, p. 87).
4	Virtual	▪ The various constituent systems may have no agreed overall purpose, as there are no formal objectives for the SoS arrangement and, indeed, no central management. ▪ The participant systems can join and leave the SoS arrangement dynamically. Here, the constituent systems cooperate to perform their purposes when the owners comprehend the benefit that they will get from joining the SoS arrangement. ▪ An example of a Virtual SoS is an, "automated high-speed algorithmic trading system. These systems from different companies automatically buy and sell stock from each other with trades taking place in fractions of a second" (Sommerville, 2016, p. 588).

Having such characteristics and types for SoS arrangements makes them more complex and dynamic than conventional systems (Sommerville, 2016), which has led to introducing more complex challenges that face systems engineers during the development or management of such arrangements. Chen and Clothier (2003), Maier (2005), Northrop *et al.* (2006), DANSE Consortium (2012), Klein, Cohen and Kazman (2013), Dahmann (2014) and BKCASE Editorial Board (2019) have all pointed out a number of general challenges and limitations posed by the different characteristics, classifications or dynamic environments of ultra-large-scale systems and SoS arrangements. Figure 2.1 provides examples of the aforementioned challenges.

In light of these factors, a number of studies (Cropley, 2004; Northrop *et al.*, 2006; Gorod, Sauser and Boardman, 2008; Raygan, 2008; INCOSE, 2015; Sommerville, 2016) emphasised the fact that using traditional software and systems engineering approaches to address the emergent challenges in a SoS context is no longer sufficient. Practitioners, therefore, should investigate and introduce new innovative approaches to adapt or supersede the traditional ones. For instance, Northrop *et al.* (2006) emphasised that addressing knowledge gaps that appear in systems engineering knowledge domain when dealing with the demands of newly emerged systems like SoS arrangements needs more than just an incremental extension of the traditional and current existing approaches. It needs innovative approaches, ranging from capturing problem space by new conceptual models to introducing revolutionary solution-oriented approaches.

2.3 Configuration Management and Change Management

Until the 1950s, the developed systems were small-scale and did not include a high-level of complexity. Therefore, changes could be handled by individuals or a close-knit team. Nonetheless, systems inevitably became more advanced and came to comprise higher levels of complexity. These included, for example being more complex in structure, capabilities, stakeholders' involvement, dynamism, integration and interoperability. Thus, it became impractical to apply changes to systems without having a formal domain that enables the maintenance of control over such systems. This imperative gave rise to Configuration Management (CM) and, even more specifically, to Change Management (ChM).

In 1953, the need for a general discipline for ChM was emphasised and presented by the 'Army, Navy, and Air Force' (ANA) Bulletin No. 390, followed by Bulletin No. 391A. These documents outlined an 'Engineering Change Proposal' methodology that furnished a formal framework for ChM, aligned with the armed forces' products. Nonetheless, in 1963, the former two bulletins were combined in ANA Bulletin No. 445, which was in turn displaced by MIL-STD-480 as a more exhaustive framework for configuration control [ChM] (Brouse, 2008). Subsequently, and until the present day, CM processes have been addressed by the production of assorted military and commercial standards and/or frameworks.

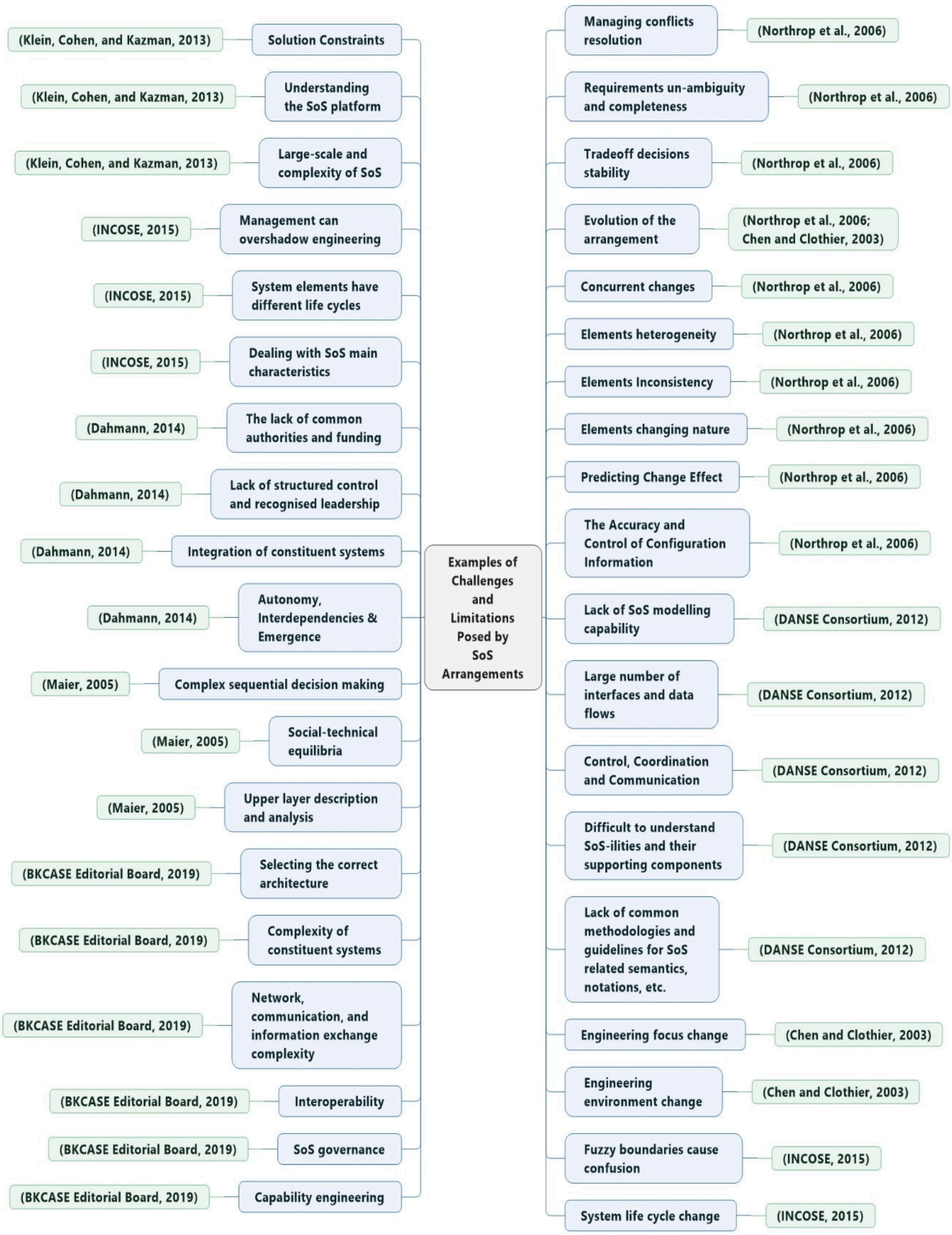


Figure 2. 1: Examples of challenges and limitations posed by the emergence of SoS arrangements.

The DoD defines CM as: "A process for establishing and maintaining consistency of a product's performance, functional and physical attributes with its requirements, design and operational information throughout its life" (DoD, 2001, p. 1-3). Conversely, Sommerville (2016, p. 716) defines CM as: "The process of managing the changes to an evolving software product".

The fact that different bodies deploy different terminologies to indicate similar concepts is a complicating factor in CM implementation (Sommerville, 2016). Still, where the key general principles and concepts of CM have not significantly changed, their adoption into implementation processes and procedures varies with regards to different industries and domains (Ali and Kidd, 2014). For example, according to DoD (2001) and INCOSE (2015) studies, the main elements of CM are: configuration identification, configuration control, configuration status accounting and configuration audits. On the other hand, according to the EIA-649-B (SAE International, 2011) categorisation, the elements of CM are: CM planning and management, configuration identification, configuration ChM, configuration status accounting and configuration verification and audit. Another example of CM activities was introduced by Sommerville (2016) for software CM activities, and these included: change management, version management, system building and release management.

In today's large-scale systems, many factors make change inevitable, e.g. requirements change to adopt newly emerging technology, fixing discovered bugs and matching competitors' offerings, just to name a few (Northrop *et al.*, 2006). The effective management and control of system evolution, and the prioritisation of the most critical and cost-effective changes, is the proper province of CM and (especially) ChM processes (Leon, 2015). In the literature, ChM has been referred to by different terms, such as Configuration Control (CC) (INCOSE, 2015), Configuration Change Management (SAE International, 2011), Change Control (SAE International, 2011), Enterprise Change Management (SAE International, 2011) or simply Change Management (Sommerville, 2016).

ChM can be viewed as, "The CM function that ensures changes to and variances from a configuration baseline are properly identified, recorded, evaluated, approved or disapproved, and incorporated and verified as appropriate" (SAE International, 2011, p. 4), or as "A process to record, check, analyze, estimate and implement proposed changes to a software system" (Sommerville, 2016, p. 759). In general, the focus of the ChM process is on tracking and managing software-change requests, undertaking change-impact analysis, making decisions about proposed changes and tracking those components that are changed (Sommerville, 2016).

Literature affords many practices, frameworks and models for CM, including ChM. One of the popular abstract models for the ChM process (also adopted by this research) is the software ChM process model that appears in Sommerville (2016). Figure 2.2 illustrates the main activities of Sommerville's ChM process model, followed by a brief description to provide the reader with a generalised understanding of what ChM is concerned with.

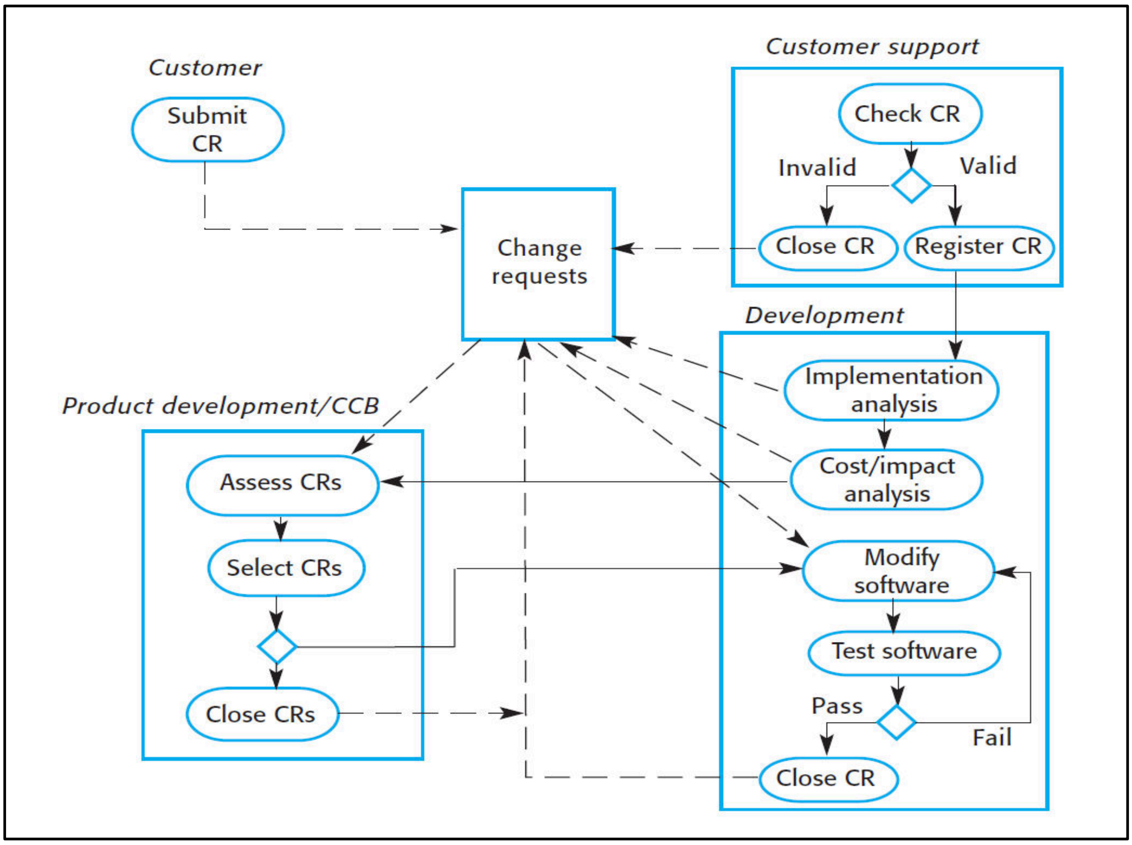


Figure 2. 2: Sommerville's ChM process model, (Sommerville, 2016).

Acknowledgment: Software Engineering, 10th G. Ed., Ian Sommerville, Pearson Education Ltd.

As indicated in Figure 2.2, the ChM process starts when a customer completes and submits a Change Request (CR) using a CR form. Subsequently, the validity of the CR will be evaluated: if it is found to be invalid, it will be closed, and the reason for closure duly noted. Conversely, if the CR is valid, it will be logged in and then passed to the development group for technical-change impact analysis in order to identify all the components that will be affected by the CR, and to estimate the cost of changes to all related components. Later, the CR (aggregated with various feedbacks) will be passed to the Change Control Board (CCB) or 'Product Development Group' to examine the impact of the requested change from an economic, strategic and organisational point of view. Subsequently, the CR will be approved or rejected, largely according to whether it is deemed cost-effective from a business perspective. If the requested change is accepted, it will be passed to the development team to be implemented.

In general, a variety of barriers must be surmounted when implementing CM and ChM. Indeed, a number of studies have highlighted challenges and limitations that traditional CM and ChM approaches face when applied to conventional systems, including complex systems (Larsson and Crnkovic, 1999; Estublier, 2000; Bendix, 2003; Sun and Couch, 2008; Gorod, Sauser and Boardman, 2008; Ying, Lijun and Wei, 2009; Fauzi *et al.*, 2010; PTC, 2011; Dahmann *et al.*, 2011; Lindkvist, Stasis and Whyte, 2013; Xu, Malisetty and Round, 2013; Ali and Kidd, 2014; Leon, 2015; BKCASE Editorial Board, 2019).

Nonetheless, with the recent emergence of SoS, the application of CM and ChM in this new environment has entailed both new challenges and more complex versions of older ones (Raygan, 2008; Bellomo and Smith, 2008). Consequently, a strict emphasis on the need for controlling, managing and tracking changes in a SoS context has become a key priority. Hence, it is necessary for CM and ChM to make due allowance for the SoS context. However, in different studies and guidelines (Northrop *et al.*, 2006; Raygan, 2008; Bellomo and Smith, 2008; INCOSE, 2015) the authors concluded that the use of traditional CM practices is no longer effective when applied to complex systems such as SoS arrangements. This is essentially due to the new and inherited difficulties that the engineering of such systems entails. The authors provided various, concrete examples from real-world practice to illustrate their case.

Surveying the literature, one finds the number of studies that focus on addressing CM and ChM application in SoS is limited. Furthermore, the investigated studies focused on providing general strategies, directions or guidelines rather than on providing practical solutions. Table 2.3 shows the main studies found in the literature related to CM in a SoS context and provides a brief outline of each study.

Table 2. 3: Research studies related to CM in SoS context.

Study	Brief Description
Cropley (2004)	▪ Emphasised the importance of considering knowledge management approaches that focus on the identification of information exchange aspects to support ChM in SoS arrangements. The study introduced a general strategy to consider when developing a knowledge repository to support ChM in complex systems and SoS arrangements. This was guided by answering the Who, What, When, Where and How questions applied to a class of warships in the Royal Australian Navy. ▪ The strategy remains theoretical and abstract, limited in its application to identifying related information by answering the 5W questions.
Raygan (2008)	▪ Provided generic directions to support adapting CM frameworks for SoS arrangements. It highlighted the insufficiency of using the Information Technology Infrastructure Library (ITIL) and Control Objectives for IT (CobiT) frameworks CM processes for application in SoS contexts without adaptation. Consequently, a proposal to integrate and align IEEE professional standards with the CM processes of ITIL and CobiT frameworks was introduced. ▪ Within the cited frameworks, the study remained preoccupied with generic guidance for the direction of CM processes and for terminological alignment. It did not provide a concrete framework or models to take into consideration how to achieve this alignment, the processes of the ChM or the elements of SoS arrangements.

Table 2.3: Research studies related to CM in SoS context, "Continued".

Study	Brief Description
Bellomo and Smith (2008)	▪ Introduced a number of principles and supporting attributes for an effective SoS CM, which was presented as a SoS CM Framework. The introduced principles and attributes were addressed in a real-life scenario to illustrate how they could be used to increase the probability of success when initiating a SoS CM strategy. ▪ This study also remained focused on the provision of abstract principles to be accommodated in the adaptation of CM for SoS contexts.
D'Souza, Kossmann and Watts (2016)	▪ Emphasised the significance of aligning CM with SoS engineering lifecycle. This study provided a perspective on the potential of CM for facilitating systems engineering within SoS arrangements and/or complex systems. ▪ It is limited to providing recommendations that highlight the importance of CM in SoS contexts without proposing a framework that supports or enables the application of CM or ChM in an SoS context.

2.4 Ontology For Knowledge Representation

The word 'Ontology' is derived from the Greek word 'οντολογία' or 'ontologia', which combines the word 'Onto', meaning 'being', and the word 'logia', meaning 'study'. Hence, ontology, as seen from a philosophical perspective, is the science of studying beings, "is the science of what is, of the kinds and structures of objects, properties, events, processes and relations in every area of reality" (Smith, 2002, p. 1). Philosophical ontology focuses on the particular utilisation of words as descriptors of entities; it illuminates the words that belong to entities and those that do not (Floridi, 2004). Although the origin of the word 'Ontology' is from the philosophical domain, ontology has become a popular technical field and research topic in Computer Science, Information Science, Software Engineering and other related disciplines.

Within software engineering and related fields, Gruber has provided one of the most widely recognised and frequently adapted definitions of ontology (Gruber, 1993, p. 1). It is presented as, "an explicit specification of a conceptualisation'. Conceptualisation is, in turn, referred to as, "an abstract, simplified view of the world" (*ibid.*), wherein things or concepts are defined. On the other hand, specification is referred to as a "formal and declarative representation" (Gruber, 1993, p. 2), wherein things or concepts and the relationships between them are formally and declaratively represented using a machine-readable language.

Generally, an ontology is used to semantically enrich a domain of interest by identifying common vocabulary for practitioners in a particular domain who want to share knowledge and obtain a common understanding. This includes using machine-interpretable language to represent the concepts identified in the domain under consideration, as well as the relationships between them (Noy and Mcguinness, 2001). In addition, ontologies may also be deployed to define and reason the properties of the domains under investigation (Ranka *et al.*, 2010). Therefore, ontologies have recently been used in a variety of current disciplines: Artificial

Intelligence, Software Engineering, Semantic Web, Biomedical Informatics, Library Science, Information Architecture, Ecommerce Content Standard and many other fields, in terms of knowledge representation of the domain or part of it (Claramunt, Levashkin and Bertolotto, 2011).

Classes, properties and axioms should typically form the basis of any ontology. An ontology, together with the set of all individuals represented for a domain-of-interest, is called a knowledge-base (Noy and Mcguinness, 2001). Table 2.4 presents these constituents and provide a brief description for each one based on Noy and Mcguinness (2001) and Taye (2010).

Table 2. 4: Ontologies main constituents based on Noy and Mcguinness (2001) and Taye (2010).

Component	Brief Description
A Class	▪ Is the focus of most ontologies. ▪ Usually represents an abstract category for a group of objects that share common properties. ▪ Is represented in a hierarchical structure (super-class and sub-class hierarchy).
A Property	▪ Also known as a role or sometimes as a relation. ▪ Can be used to express attributes and features of each class and related individuals, including expressing relations between the represented classes or between their related individuals.
An Axiom	▪ Also known as a facet, rule or role restriction. ▪ Is used to say what is true in the domain. ▪ Enables verification of the consistency of a developed ontology. ▪ Generally expressed using logic-based languages.
An Individual	▪ Represents a specific case or object of a defined class in an ontology.

Various scholars have proposed different formal languages for the formation of ontologies, which are themselves, after all, a formal medium of representation. Gašević, Djurić and Devedžić (2009) categorised ontology representation languages based on the emergence of the eXtensible Markup Language (XML). The languages that appeared before XML were classified as pre-XML languages, whereas the languages that appeared after XML (and are based on the XML language) were classified as XML-based or Web-based languages.

The Semantic Web is an evolutionary extension of the traditional web, in which data meanings are identified and represented using machine-processable languages (Berners-Lee, Hendler and Lassila, 2001; Antoniou *et al.*, 2012). Ontologies are considered a key component of Semantic Web technologies, and the Semantic Web uses XML-based languages to represent data that are to be processed across the web and used for the anticipated purposes. However, these technologies used for the semantic web are considered universal, meaning that, they are not limited to be used in the web context only. They are also suitable for use in many other domains, such as knowledge representation in SoS contexts (Axelsson, 2019). A more detailed discussion of languages used for ontology representation can be found in Gašević, Djurić and Devedžić (2009). The most popularly used languages are Resource Development Framework (RDF)

(McBride, 2004), RDF Schema (RDFS) (Brickley and Guha, 2014) and Web Ontology Language (OWL) (Smith, Welty and McGuinness, 2004; W3C OWL Working Group, 2012).

RDF uses the syntax of 3-triples format (subject, predicate, and object) to represent individual objects in an ontology (Soomro, 2016). RDFS can be used to represent information about concepts and the relationships between them (a more abstract level than RDF) (Pan, 2009). Yet, compared to other knowledge representation languages, RDFS does not provide further semantic capabilities (e.g. identifying cardinality restrictions, asymmetric properties or disjoint classes). Therefore, RDFS is considered limited (Munir, Odeh and McClatchey, 2012).

OWL is currently considered the most popular ontology representation language, which provides more vocabulary than RDF and RDFS to define and describe concepts, related properties, relations between concepts, cardinality restrictions, richer properties, etc. (Smith, Welty and McGuinness, 2004). Consequently, among languages with the capacity for knowledge representation, OWL is viewed as the most expressive. Moreover, OWL also comprises three subsidiary languages with expressive potential. Namely, these are OWL-Lite, which supports users who require a simple classification hierarchy and constraint capabilities; OWL Description Logic (OWL-DL), which supports users who require a higher expressiveness capability than OWL-Lite provides, with amenability to automated reasoning; and OWL-Full, which supports users who favour maximum expressiveness as a higher priority than being amenable to reasoning (Horridge *et al.*, 2011; Antoniou *et al.*, 2012).

Semantic Web Rule Language (SWRL) was formulated in order to render OWL more expressive and to enhance its capacity for modelling increasingly complex knowledge (Orlando *et al.*, 2012). It is an OWL-based rule language that enables users to create rules that facilitate the deployment of more deductive reasoning capabilities than the use of OWL alone. A SWRL rule consists of antecedent (body) and consequent (head). With the support of a semantic reasoner (e.g., Pellet), once it is checked and the antecedent part is found true, the consequent part is executed (Horrocks *et al.*, 2004). Below, there is an example of a simple SWRL rule that tells the system that if there are three persons (x, y, and z), where (x) has (y) as his/her parent and (y) has a brother (z), then (z) is considered as an uncle of (x).

Person (?x) ^ Person (?y) ^ Person (?z) ^ hasParent(?x, ?y) ^ hasBrother(?y, ?z) → hasUncle(?x, ?z)

Moreover, an ontology may be challenged (queried) in a variety of ways in order to retrieve or extract knowledge. The most popular of these are the Simple Protocol and RDF Query Language (SPARQL) (Prud'hommeaux and Seaborne, 2008), OWL-DL Query (Motik, Sattler and Studer, 2004), and Semantic Query-enhanced Web Rule Language (SQWRL) (O'Connor and Das, 2009). It should be noted that SPARQL is viable only in the context of RDF serialisation and is not comprehensively compatible with OWL ontologies. OWL-DL Query and SQWRL support the querying of OWL ontologies. Nonetheless, in comparison with SQWRL, the query capacity of

OWL-DL is somewhat limited. Below is an example of a simple SQWRL statement that tells the system to retrieve the count of persons in an ontology with age greater than 18.

Person (?p) ^ has Age (?p, ?age) ^ swrlb:greaterThan (?age, 18)→ sqwrl:count (?p)

In order to design and develop a new ontology or manage existing ontologies, developers have formulated ontology-development environments and tools that provide varying capabilities. These tools also deploy various, existing ontological languages to support the management of ontologies. Protégé (Musen, 2015) is considered the dominant free, open-source ontology development aid and editor, and is also a knowledge-management system. It supports XML, RDF(S) and OWL. It is a Java-based tool that enables a variety of plugins to be developed and integrated with Protégé to extend its capabilities. A more detailed discussion of tools used for ontology management can be found in Youn and McLeod (2006) and Slimani (2015).

The literature shows a number of reasons that encouraged researchers and practitioners, and therefore this research, to use semantic web ontologies:

(1) Ontologies facilitate reaching a common and shared understanding of a domain-of-interest that can be communicated between people or application systems. This applies especially to applications or people within diffuse or heterogeneous contexts. This is done by capturing and representing a domain knowledge and creating explicit semantics in a generic way. Thus, ontologies play a key role in enabling semantic interoperability, improving semantics and reducing complexity across organisations (Daga et al., 2005; Rebstock, Fengel and Paulheim, 2008; Taye, 2010; Yang, Cormican and Yu, 2019).

(2) Ontologies can be considered as a means of representing real-world semantics using formal semantics and of providing models of the real-world aspects that express reality as recognised by human beings (Fensel, 2001; Yang, Cormican and Yu, 2019).

(3) Ontologies provide semantic-enrichment of models that, in turn, provide conceptual and syntactic representations of aspects related to a domain-of-interest (e.g. Business Process Architecture Models) (Yousef, 2010; Axelsson, 2019). Furthermore, using ontologies to semantically enrich such models enables defining and constraining the semantics related to the identified concepts. This is achieved by the deployment of axioms that facilitate the automatic discovery of formal errors alongside the capability of inferring and classifying new knowledge (Yousef, 2010; Odeh, 2015).

(4) Ontologies provide a means to reuse knowledge, separate domain knowledge from the operational knowledge, make domain assumptions explicit and analyse, support, and enhance domain knowledge (Noy and Mcguinness, 2001; Jarrar, Demey and Meersman, 2003; Yang, Cormican and Yu, 2019).

(5) Ontologies facilitate the provision of models that are non-dependent on technical details. They also support dynamic reasoning about specific individuals, facilitate a more effective way to

represent knowledge (e.g. management, discovery, and retrieval), and most importantly, enable the provision of generic solutions (Hammad, 2018).

(6) Ontologies provide a means of resolving semantic heterogeneity detected in a domain knowledge (Kossmann, 2010; Yang, Cormican and Yu, 2019). This can be addressed when representing different terminologies that refer to the similar concept in the same ontology. Furthermore, it can be addressed when reusing and merging ontologies that use different terminologies to refer to the same concept under consideration (Kogut and Heflin, 2003).

Driven by the aforementioned motives of using ontologies, in this research, ontology-based frameworks that enable knowledge-driven ChM in a SoS context are anticipated to add value to the anticipated SoS-ChM adoption for a number of reasons:

(1) Ontologies can be used to enable identifying a generalised body of knowledge for the ChM functional area. The ChM body of knowledge is anticipated to align between different ChM standards and practices in the domains of Systems and Software Engineering by providing generalised, explicit, semantic and formal representation of ChM aspects and by resolving any detected semantic heterogeneity, leading to support semantic interoperability.

(2) Ontologies can be used to semantically capture and represent SoS context-related aspects (i.e. BPA-driven Global and Local levels elements). This, in turn, provides semantic enrichment of any given SoS context that is under the consideration of the ChM framework. In addition, it provides SoS stakeholders with a means to share, understand and agree on common knowledge about the arrangement that they participate in, especially within a heterogeneous context.

(3) Using ontologies makes the anticipated research framework independent of specific technical or platform requirements, which, alongside the other factors, increases the probability of providing a generic solution.

(4) Using ontologies to create ChM and SoS knowledge bases enables storing them in a machine-readable format. This, in turn, support dynamic reasoning of knowledge, which facilitates semantic queries and ChM knowledge retrieval, automatic semantic inferencing, consistency checking, taxonomy re-calculations, and forward and backward traceability for change impact analysis, in a given SoS arrangement.

Recently, within differing domains, ontologies have frequently been exploited in aid of systems-engineering applications (Yang, Cormican and Yu, 2019). In the SoS domain, the surveyed literature showed a number of studies (Ferreira and Tejeda, 2014; Madni and Sievers, 2014; He *et al.*, 2014; Benali, Ben Saoud and Ben Ahmed, 2014; Dogan *et al.*, 2014; Ormrod, Turnbull and O'Sullivan, 2016; Langford and Langford, 2017; Abdalla, 2017) that used ontologies to address different SoS-related issues. Nonetheless, the studies lacked addressing the use of ontologies from the perspective of ChM or CM in a SoS context, although they did recognise its significance in terms of knowledge representation within a heterogeneous SoS domain.

On the other hand, when one surveys the literature in relation to research conducted using ontologies in the CM and ChM domain, no explicit ChM coverage of the processes or their application in the SoS domain appears to have been investigated. However, limited research had been carried out on specific parts of the CM and its supporting tools. For example, (Arantes, Falbo and Guizzardi, 2007; Calhau and De Almeida Falbo, 2012) studies presented ontologies to facilitate software CM tools integration and operability. Other research studies (Zeller and Snelting, 1997; Ambrosio *et al.*, 2004; Dong, Yang and Su, 2011; De Almeida Monte-Mor and Da Cunha, 2014) investigated ontologies for semantic artefacts versioning and re-use, product configuration and maintenance of semantic documentation, but not in the context of SoS arrangements.

2.5 Business Process Architecture and Business Process Models

To improve the effectiveness and efficiency of organisations, many authors recommend eliciting, identifying and modelling the most important business processes. Designed models are then used as a base for engineering and to re-engineer the served and the serving systems (Harmon, 2003; Ould, 2005). Modelling Business Process Architecture (BPA) and its related Business Process Models (BPMs) are predominant views that are used to enable a common understanding of an organisation's processes, their related activities and the relationships between them (Ould, 2005; Yousef, 2010). A BPA is defined as "an organised overview of business processes that specifies their relations, which can be accompanied with guidelines that determine how these processes must be organised" (Dijkman, Vanderfeesten and Reijers, 2016, p. 3). It represents the overall key business processes that are necessary to conduct business in a defined functional area (Ould, 2005). Using a BPA helps achieve the right division of functional area related activities into core processes, which enables avoiding complex designs or models (Ould, 2005). This, in turn, leads to a clearer understanding of the key business processes amongst stakeholders (Ould, 2005). Conversely, a BPM can be perceived as an organised overview that captures the activities within a business process and the relationships between them (Ahmad, 2015; Odeh, 2015). Using business process-driven models facilitates translation into technical and executable templates (Peisl, 2012).

Although it is vital to represent the detailed activities of organisation's business processes, it is more vital to represent the business processes at a higher abstraction level to identify the relationships between them prior to modelling the detailed activities (Harmon, 2003). Beeson, Green and Kamm (2013) emphasised that piecemeal approaches that focus on directly modelling processes in detail before modelling BPA will not produce a coherent set of streamlined processes that are needed to meet the organisation's strategic objectives. It is therefore recommended that a BPA is developed first, in order to enable an easier understanding of and a common agreement on core business processes.

A BPA-driven framework was adopted in this research to address the research aim and objectives and to answer the research questions. Working at the BPA level provides this research with a level of abstraction that allows a sufficient and easier shared understanding of the considered ChM and SoS aspects without having to use unnecessarily detailed data. Furthermore, it enables this research to maintain its generality and applicability to an audience of SoS stakeholders at varying management levels or within varying industries. Hence, the scope of this research in relation to representing the ChM aspects does not extend to entail the detailed application of ChM activities or procedures (e.g. detailed impact analysis or change planning and building) or to the creation of BPMs for the identified ChM processes. On the other hand, a business-driven SoS context model that includes BPA and BPMs was adopted to provide comprehensive generic traceability of the main SoS context elements that need to be considered by ChM shareholders.

A number of studies investigated BPA modelling approaches and provided classifications for them. Malinova, Leopold and Mendling (2013) classified BPA modelling approaches used in practice into two main categories. The first category contains decomposition-based BPA approaches, and the second category contains service-oriented-based BPA approaches. The study shows that the decomposition-based approach was used by more organisations considered by the study and that organisations' type and structure play a significant role in how their BPAs are designed.

Furthermore, BPA modelling approaches were classified into methodological and non-methodological approaches by Yousef (2010). Non-methodological approaches are based on using general principles or 'a set of guidelines' to model an organisation's BPA. However, non-methodological approaches do not offer a systematic means to model a BPA. On the other hand, methodological BPA modelling approaches are based on specific criteria to model a BPA. Hence, using a BPA approach from this category is favoured over non-methodological approaches. Given the diversity of the methodological BPA modelling approaches, Dijkman, Vanderfeesten and Reijers (2011, 2016) investigated and reviewed 48 existing approaches and guidelines to create a BPA. They grouped the reviewed approaches into five different classes. Table 2.5 shows the identified classes and provides a brief description of each class.

Table 2.5: BPA modelling approaches classification by Dijkman, Vanderfeesten and Reijers (2011, 2016).

Classification	Brief Description
Goal-based	▪ A goals structure that consists of business goals and the relationships between them is developed first, after which a BPA is designed based on the established structure.
Action-based	▪ A business actions structure that consists of business actions and the relationships between them is developed first, after which a BPA is designed based on the established structure. ▪ A business action is seen as an activity loop by which a provider carries out work for internal or external customers.

Table 2.5: BPA modelling approaches classification by Dijkman, Vanderfeesten and Reijers (2011, 2016), "Continued".

Classification	Brief Description
Object-based	▪ A business objects model that consists of the main business objects and the relationships between them is designed first, after which a BPA is developed based on the established model. ▪ A business object can be a permanent object, which has a long lifecycle (e.g. client); a case object, which guides the execution of a business process (e.g. order); or other objects.
Function-based	▪ A functions hierarchy (an organisations capabilities hierarchy) that represents the decomposition of business functions into more detailed business functions is developed first, after which a BPA is designed based on the established hierarchy.
Reference-based	▪ An existing BPA (developed using one of the previously mentioned categories) is used again and adapted to design a new BPA. ▪ The most often-used concepts in the investigated reference-model based approaches are business functions and industry segments, while the most often-used relations are generalisation and decomposition.

Martyn Ould's (2005) Riva-based BPA modelling approach has gained worldwide recognition. Riva is classified as an object-based methodological approach, where the BPA is designed by studying business objects that exist in the enterprise as well as their interrelations (Dijkman, Vanderfeesten and Reijers, 2016). Riva is used to derive an organisation's BPA from its Essential Business Entities (EBEs). These contain the most subject matter in an organisation's domain (Beeson, Green and Kamm, 2013). Ould asserts that "a Riva process architecture is an invariant for an organisation that stays in the same business" (2005, p. 171). He views Riva as a blueprint of the overall chunking of interrelated business processes that each of them has a lifetime, which the organisation is interested in managing them.

By using Riva, the key processes and their dynamic interrelationships that define the nature of the organisation are identified. These processes could be run sequentially or concurrently, and each one is derived from the EBEs of an organisation's business domain (Ould, 2005). Ould emphasised that Riva-based BPA is driven by an understanding of what business the organisation is in, rather than its current structure or culture. Therefore, once the architecture is understood, it becomes apparent what is required from the IT systems supporting these processes (Yousef and Odeh, 2014).

Riva is often an attractive approach for many different reasons (Beeson, Green and Kamm, 2009). Firstly, it provides a clear and practical method for developing a process architecture from business entities. Secondly, it facilitates the modelling of the internal structure of each organisational process using role-based business process models. Thirdly, BPA can be rendered as the blueprint for the implementation of business processes which might be partly or fully automated. Fourthly, it includes a bold hypothesis of architectural invariance among businesses of the same type, which makes it possible to validate. Fifthly, BPAs can be transferred between businesses once they have been developed. Riva was chosen to be reused and adapted in this research, based on the above-mentioned reasons and others that are more related to this research (discussed in Section 4.2.1 of **Chapter 4**).

Generally, the Riva-based BPA modelling approach entails a sequence of activities introduced by Ould (2005), which are illustrated in Figure 2.3 alongside their main related outputs. As it is classified as an object-based approach, it starts with designing a business object model that consists of the essential business objects and the relationships between them (called Units of Work (UOWs) Diagram in the context of Riva). Then, BPA models are developed based on the established UOWs Diagram (called First-and-Second-Cut Process Architecture Diagrams (1st-and-2nd PADs) in the context of Riva). A more detailed description of the Riva approach can be found in Section 4.2.

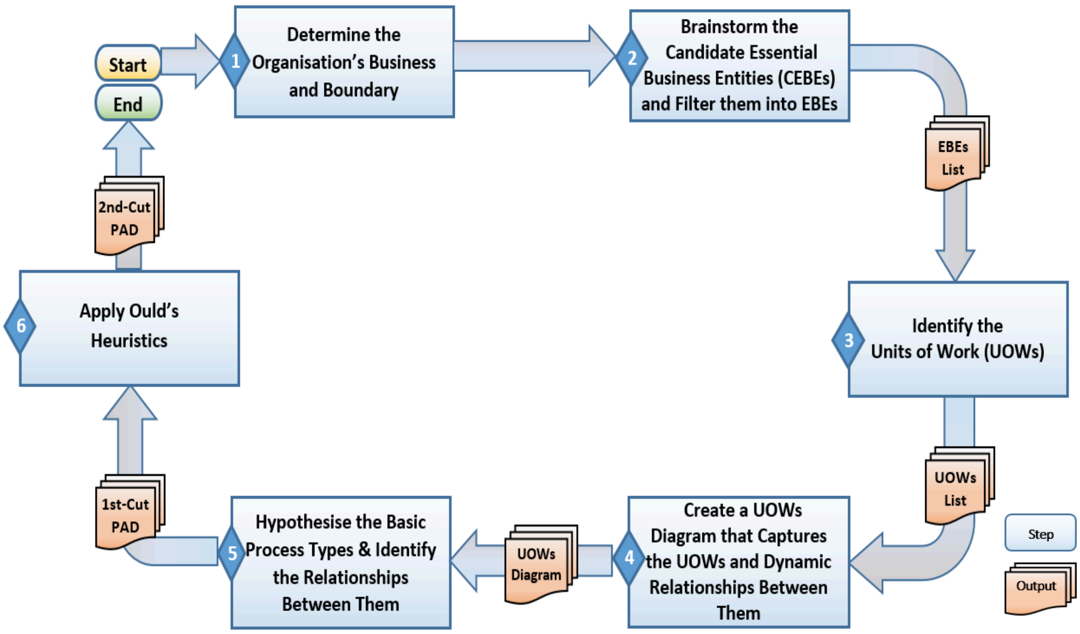


Figure 2.3: Ould's fundamental activities for the Riva-based BPA modelling approach (Ould, 2005).

The Riva-based BPA modelling approach has recently been semantically enriched and formally represented using the semantic Riva BPA ontology (srBPA ontology). The srBPA ontology is proposed by Yousef (2010, p. 51) as "an abstract ontology that conceptualises the Riva BPA elements and sets the relations between them".

The ontology was deployed using a practical case study in an attempt to assess the correctness and usefulness of the developed ontology (Yousef and Odeh, 2014). The assessment showed that the proposed srBPA ontology contributes significantly as a source of business knowledge, as the BPA of an organisation can be semantically extracted and reused. The srBPA consists of a hierarchy of concepts along with its attributes and a set of axioms that are used to generate the UOWs diagram and then derive the Riva process diagrams. It also allows to automatically check if a given BPA diagram derived using the Riva method is consistent. As shown in Table 2.6, the srBPA ontology generally semantically reflects and implements the steps of the

Riva-based approach by applying the relevant srBPA steps. A more detailed discussion of the srBPA ontology and its application to semantically enrich a developed Riva-based BPA can be found in (Yousef, 2010, pp. 65-70) and (Yousef and Odeh, 2014).

Table 2.6: srBPA steps to reflect the Riva-based BPA approach steps.

srBPA Step	Brief Description
1	▪ Agreeing on the boundary of the organisation and brainstorming the organisation's subject matter to identify the EBEs.
2	▪ Classifying the EBEs that have a lifetime, which is handled by, or the responsibility of, members of the organisation as UOWs.
3	▪ Identifying the UOWs diagram that depicts the dynamic relationships between the UOWs.
4	▪ Assuming for each UOW that there will be: o A CP that handles single instances of the UOW. o A CMP for dealing with the flow of instances.
5	▪ Transforming the UOWs diagram into a 1st-Cut-PAD.
6	▪ Applying Ould's heuristics (Ould, 2005, pp. 185-192), to generate a 2nd-Cut-PAD.

The semantic enrichment and representation of the anticipated BPA-driven ChM processes and SoS context models are enabled through the reuse and adaptation of the srBPA ontology in this research. This, in turn, facilitates achieving a shared understanding of the ChM and SoS aspects considered in this research. Furthermore, it supports developing generalised solutions that are independent of specific organisational or technical contexts. Moreover, it enables automating capabilities that are required by this research such as semi or fully automated instantiations, resolving semantic heterogeneity, consistency and classification checks, knowledge reasoning and knowledge retrieval.

2.6 Business-IT Alignment and the BPAOntoSOA Framework

Accomplishing and maintaining alignment between the dynamic environments of business and IT has become challenging (Zhang, Chen and Luo, 2018). The concept of Business-IT Alignment (BITA) was introduced around two decades ago. Since then, research in the BITA domain has been one of the hot topics that align the business goals and needs with the right support of IT to support organisational existence and competitive advantage. Agreeing on a definition of BITA has been difficult (Odeh, 2015). Luftman and Brier (1999, p. 3) highlighted BITA as the concern of "applying Information Technology (IT) in an appropriate and timely way and in harmony with business strategies, goals and needs". Following that, noticeable studies have been conducted in the IT and business domains to develop frameworks, methods, and artefacts that promote the alignment of business strategies, goals and needs alongside their associated processes and operations with their supporting IT-based systems (Aversano, Grasso and Tortorella, 2013). However, BITA remains a persistent issue that needs addressing (Zhang, Chen and Luo, 2018).

In the context of BITA, Luftman and Brier (1999), Silvius (2007), and Aversano, Grasso and Tortorella (2013) have highlighted that achieving an efficient BITA level requires understanding how business can be enabled by IT and understanding how IT can provide support to the business. One predominant way that is evident in the literature and has been adopted to address BITA is the development of solutions that utilise business-driven models (i.e. BPA and BPMs) (Zhang, Chen and Luo, 2018). The benefits of using business-driven models to attain BITA have been pointed out by Malta and Sousa (2016). IBM also emphasised that business-driven models-based approaches facilitate and accelerate achieving BITA (Jensen et al., 2008).

For the concern of this research, applying changes in a conventional organisational context (e.g. technology changes and systems changes) might have a significant effect on business processes and services, which need to be assessed and managed (Ould, 2005; Ahmad, 2015). On the other hand, applying changes to business processes and services might have, in turn, a significant effect on their alignment with the related supporting technical aspects (Ould, 2005; INCOSE, 2015). When scaled up in a complex SoS organisational context, these effects can have more serious and significant impacts that could cause systems and business failures. Therefore, a ChM framework that is aligned with the organisations' strategies and business processes is a key factor in maintaining sustainability (Sekine et al., 2009; INCOSE, 2015; Ahmad, 2015).

This research framework aims to provide the capability of investigating and discovering the implications of a change request that is business-related (e.g. Business Process-related change, Service-related change) on the constituent information systems that serve and support the business. On the other hand, the framework also aims to provide the capability of investigating and discovering the implications of IT-related change requests (constituent software system related changes) on the business elements that are supported by them. A holistic view is, in turn, provided when managing a change request, leading to maintaining a high-level of BITA. For this purpose, the BPAOntoSOA framework (Yousef, 2010), as the only framework available that provides semantic enrichment of the Riva-based BPA models, was investigated and adapted to support this research choice in utilising the Riva-based BPA modelling approach to obtain semantically-enriched models that represent BPA-driven ChM and SoS context aspects. Furthermore, by providing linkages that can be adapted to link the BPA of a SoS arrangement with its related BPMs and identifying the software services that are related to them, the BPAOntoSOA framework supports this research aim in providing knowledge that enables stakeholders to maintain BITA while managing changes in a SoS context.

The generic BPAOntoSOA framework (Yousef, 2010) is a semantically-enriched artefact that utilises a Riva-based BPA to identify candidate software services. Furthermore, it utilises BPMs to derive tasks (capabilities) related to Riva-driven business processes and to link them to their related candidate software services. The BPAOntoSOA framework consists of two layers. The 'BPAOnt Ontology Instantiation layer' is the first layer. This is used to semantically enrich an organisation's BPA and its related BPMs using OWL-DL based ontologies and then link them to each other. The second layer is called the 'Software Service Identification layer', which uses the instantiated BPAOnt ontology that results from carrying out the first layer to identify candidate software services and their related capabilities. The identified candidate software services are presented as Riva Process Architecture Clusters (RPA clusters). Each RPA cluster entails Riva-driven business processes as members. Also, each RPA cluster is linked to capabilities that appear in the BPMs related to the Riva-driven business processes. Table 2.7 illustrates the BPAOntoSOA framework main layers and components and provides the reader with descriptions that help to obtain a general understanding of what the BPAOntoSOA is about. More details about the BPAOntoSOA framework can be found in (Yousef, 2010).

Table 2.7: BPAOntoSOA framework's layers and components, (Yousef, 2010).

Layer	Layer's Component	Description
The BPAOnt Ontology Instantiation Layer		▪ Provides a business-driven knowledge base that represents an organisation's BPA linked to its related BPMs.
	The semantic Riva (srBPA) Ontology Instantiator	▪ Provides a semi-automated means to semantically represent an organisation's Riva-based BPA.
	The semantic BPMN (sBPMN) Ontology Instantiator	▪ Provides an automated means to semantically represent BPMs related to Riva-driven business processes, which are developed using the Business Processes Model and Notation (BPMN) standard. ▪ The sBPMN component is reused from the SUPER project for the deployment of semantic business process management (SUPER 2008, cited in Yousef, 2010).
	The srBPA-sBPMN Ontology Merger	▪ Provides a means to merge and link the ontologies that result from instantiating the previous two sub-components, resulting in deriving the BPAOnt ontology component instantiated for a given organisation. ▪ It links the two ontologies by hypothesising that for each case process/and or case management process that appears in the 2nd-cut-architecture in the Riva-based BPA there is a related business process that is presented by a BPMN-based BPM.

Table 2.7: BPAOntoSOA framework's layers and components, (Yousef, 2010), "Continued".

Layer	Layer's Component	Description
The Software Service Identification Layer		▪ Uses the instantiated BPAOnt ontology related to a given organisation to identify candidate software services and their related tasks. ▪ RPA clusters are used to semantically represent the resulting identified software services.
	The Service Identifier	▪ Based on utilising the second-cut-process architecture of a Riva-based BPA, it applies an algorithmic-based service identification approach. ▪ The approach identifies two types of RPA clusters to represent the anticipated software service; a standalone RPA cluster, which entails only one case process as a member; or an RPA cluster, which entails a set of related case processes and/or case management processes as members. ▪ The identified RPA clusters' members are Riva-driven business processes, but they are well-aligned with service-oriented architecture principles based on a critical understanding and investigation conducted by the owner of the framework.
	The Service Capability Identifier	▪ Applies SWRL-based statements to extract tasks (send, receive and user tasks) identified in the instantiated sBMPN ontology component and link them to the related RPA clusters. This enables the recognition of functional boundaries for the identified software services.

2.7 Research Gap Analysis and Conclusions

This chapter is linked to the first and second stages of the DSRM process adopted for this research (i.e. problem identification and objectives of a solution, respectively), discussed in **Chapter 3**. Therefore, this chapter has provided a review of the notion of the SoS, ChM, ontology, and BPA and BITA related aspects. The chapter has also introduced general challenges posed by the emergence of SoS arrangements and highlighted research work that investigated CM and ChM application in a SoS context.

Having reviewed the literature, various SoS and ChM related aspects were addressed, yet there is a lack of research investigating and supporting the application of ChM in the SoS context. Several limitations and gaps were identified. These gaps revealed the need for and guided the development of the OntoSoS.BPA.ChM framework. The identified gaps are summarised as follows:

(i) More complex inherited and new challenges that face the application of traditional software and systems engineering in general and configuration management and change management, in particular, has been brought about by the emergence of SoS. Investigating these challenges has shed light on the insufficiency of adopting traditional approaches for

SoS engineering. Systems engineering approaches and CM practices (that incorporate ChM practices) are therefore rendered ineffective if they are applied to SoS arrangements without adaptations (Cropley, 2004; Northrop et al., 2006; Gorod, Sauser and Boardman, 2008; Raygan, 2008; INCOSE, 2015; Sommervile, 2016). Yet, not all adaptations can resolve this inefficiency. Incrementally extending traditional and current approaches is insufficient when applied in isolation (Northrop et al., 2006; INCOSE, 2015). Accordingly, approaches that introduce innovative solutions are claimed vital to facilitate and enable the application of the traditional approaches in such complex contexts (Cropley, 2004; Northrop et al., 2006; Raygan, 2008; Bellomo and Smith, 2008; INCOSE, 2015; Sommerville, 2016).

(ii) Investigating the literature shows that the domain of CM (which includes ChM) entails a large number of standards, guidelines and practices. These standards and guidelines use different semantics when describing aspects related to CM in general and ChM in particular. Accordingly, one of the main identified problems of implementing CM principles is that different bodies refer to the same concepts using different terms (Sommerville, 2016).

There are, therefore, concerns over conceptual and terminological heterogeneity used in SoS arrangements as constituent systems might adopt different ChM standards and translations into related processes because of their independence. This heterogeneity creates difficulties in building a consensus to understand the main ChM processes, their scope and the relationships between them within the SoS arrangement. While managing proposed changes within SoS arrangements, adverse impacts on communication and cooperation subsequently occur. Additionally, this issue can create inconsistent ChM applications between different participating parties when SoS arrangements are formed. Bellomo and Smith (2008) and Raygan (2008) consider that the absence of a shared consensus contributed to the failure of given SoS organisations.

(iii) In the literature, there is a lack of research investigating, supporting and enriching the awareness of ChM stakeholders of the ChM aspects related to the generic ChM processes and the relationships between them. This implies there is a lack of explicit and formal conceptualisations depicting ChM processes and their interrelationships. In addition, the literature lacks explicit and formal representations that capture the main ChM documents and roles that are needed during the application of ChM processes. Moreover, the dependency relationships of the ChM processes on the domain-specific aspects in traditional or SoS contexts are not investigated or represented. Such absence of knowledge impacts, understanding, sharing and agreeing on ChM aspects amongst ChM stakeholders, leading to difficulties that face ChM application.

(iv) During ChM and SoS investigations, the linkages between the global and local levels of SoS arrangements are often insufficiently represented and poorly considered. This is particularly true when applying ChM processes. The literature considers these connections and relations from a requirements engineering perspective (i.e. Cavalcante et al., 2015; Alhajhassan, Odeh and Green, 2016) or a quality governance perspective (i.e. Qaddoumi et al., 2017). Insufficient linkages were also identified by Bellomo and Smith (2008) as a key factor in the failure of a large governmental SoS organisation.

Additionally, maintaining BITA is difficult, especially for SoS arrangements. One reason is that the existing CM and ChM frameworks consider controlling changes that are limited to IT-related components or assets (AXELOS, 2011; INCOSE, 2015). Furthermore, the existing ChM frameworks in the literature have not explicitly and formally captured the relations between business and supporting aspects of IT. Moreover, no ChM framework exists with a dedicated means that enable the ChM stakeholders to identify linkages between business aspects and related supporting IT services based on adapting the CI concept to include key business aspects as CIs.

(v) Applying ChM in a SoS context requires the correct identification of the key impacted components [Configuration Items (CIs)] and also the related impacted or required stakeholders during the management of the proposed change. This occurs at different levels of the SoS arrangement (Novakouski et al., 2012; MITRE, 2014; INCOSE, 2015). Existing ChM frameworks predominantly conduct change impact analysis in complex systems by issuing working orders or assessment requests either to necessary parties or all parties. The feedback is then consolidated to create an integrated assessment. Other ChM frameworks request the services of independent formal evaluation authorities to conduct an assessment for proposed changes. Subsequently, existing popular ChM processes such as in ITIL and CobiT frameworks were criticised for having a high dependency on other separate processes to provide them with sufficient impact analysis from technical or business points of views. This makes their capabilities limited, especially when their application is scaled up into more complex context such as SoS arrangements (Raygan, 2008).

Inefficient stakeholder identification was also flagged out as one of the main challenges to achieving effective coordination when applying ChM processes in SoS arrangements. For example, Bellomo and Smith (2008) highlighted that the most often used 'change control boards' communication techniques that are proposed to manage the existence of a large number of stakeholders is the 'broadcast' technique. It is mainly applied by inviting anyone who may be interested to attend the board meetings to assess and provide a decision with regard to a submitted change request. In some reported projects, however, various stakeholders stopped attending the meetings. This was because they believed that few changes were actually relevant to them, leading to them eventually missing important related changes.

The researcher was unable to identify literature with ChM frameworks that formally capture the linkages between the CIs and their related CIs and also between the CIs and their related stakeholders in traditional or SoS contexts. The investigated frameworks also lack dedicated means that can be used to realise the candidate-related parties and impacted CIs on their own. The lack of dedicated means increases the dependency of ChM functional area on other separate CM functional areas and limits having benchmarking grounds to validate the implications' feedback obtained from outside the scope of the ChM processes in relation to a proposed change.

This research, therefore, was motivated to bridge the identified gaps using a state-of-the-art approach to build a novel ChM framework that supports, guides and facilitates the application of ChM in the SoS context, namely the **OntoSoS.BPA.ChM** framework. It aimed to improve the effectiveness of ChM application in the SoS context by providing a generalised semantically-enriched view of key ChM and SoS context aspects supported by knowledge retrieval capabilities that can be utilised to retrieve purposeful knowledge, which can be shared and agreed on between the various participating parties in a SoS arrangement.

Subsequently, several high-level research framework's functional characteristics that were derived from the research gaps were identified to drive the development of the OntoSoS.BPA.ChM framework and its constituent components. Consequently, addressing these identified characteristics for the research framework is anticipated to minimise the identified research gaps. Table 2.8 lists these driven functional characteristics.

Table 2. 8: High-level functional characteristics for driving the development of the research framework in addressing the identified research gaps.

Research Gap	High-Level Functional Characteristic
Research Gap 1	**1.** The framework should use new approaches to capture problem domains related to ChM and SoS.
	2. The framework should provide an innovative solution to support ChM application in SoS context.
Research Gap 2	**3.** The framework should provide generalised models that represent ChM aspects related to ChM processes and their interrelationships.
	4. The framework should capture the different terminologies related to the identified ChM concepts.
	5. The framework should provide a means that enables a shared understanding of and common agreement on the different ChM aspects related to the identified ChM processes in a heterogenetic environment.
Research Gap 3	**6.** The framework should explicitly and formally model generalised aspects related to ChM processes.
	7. The framework should provide dedicated means to enable realising the modelled ChM aspects.
Research Gap 4	**8.** The framework should explicitly and formally model the main elements of an SoS arrangement and the linkages between them driven by global-local levels alignment and BITA perspectives.
	9. The framework should adapt the 'configuration item' concept to further include SoS main business aspects.
Research Gap 5	**10.** The framework should explicitly and formally model the linkages between the SoS-elements and the related stakeholders needed for ChM application.
	11. The framework should provide dedicated means to enable realising the candidate implications and stakeholders related to a change request in both the global and local SoS levels independently of other configuration management functional areas and SoS authorities.

CHAPTER 3

THE RESEARCH DESIGN AND FRAMEWORK

3.1 INTRODUCTION

Having reviewed the state-of-the-art in the fields of ChM, SoS, BPA and knowledge representation through ontologies in Chapter 2, a number of research gaps and research gaps-driven functional characteristics to drive the development of the research framework have been identified (Chapter 2, Section 2.7). Accordingly, this research was motivated to investigate how to respond to the identified research gaps and fulfil the identified characteristics with a novel, BPA-driven and semantically-enriched framework that improves the application of ChM in a SoS context.

After an overview of the research design is presented in Section 3.2, Section 3.3 articulates the research design selected for this work alongside the rationale behind the made research choices. Furthermore, it introduces the proposed new framework, namely the OntoSoS.BPA.ChM framework, aligned with its development phases and evaluation aspects. Following this, the bases for the case study selection are discussed in Section 3.4. Finally, the chapter is summarised in Section 3.5.

3.2 OVERVIEW OF RESEARCH DESIGN APPROACHES

Toledo-Pereyra (2012) and Gorard (2013) have persuasively outlined the importance of adopting a well-considered research design where the research activity sequence, inputs and desired outcomes and how each stage will contribute to the research questions are clarified.

Various philosophical research stances exist, such as Positivism, Interpretivism and Pragmatism (Saunders, Lewis and Thronhill, 2009; Flick, 2015). However, in the context of practical research in Software Engineering and Information Systems (ISs) (which is the context of this research), the 'Design Science Research' (DSR) stance has been widely adopted. This is a problem-solving paradigm that supports pragmatic research facilitating the creation of innovative artefacts to solve real-world problems (Simon, 1996; Hevner *et al.*, 2004; Prat, Comyn-Wattiau and Akoka, 2014). DSR encourages a focus on the IT artefact and prioritises its relevance to real-world problems.

In order to answer questions identified for specific research, a research strategy/methodology needs to be adopted. Bell and Opie (2003) present five main research strategies: experimental research, case studies, surveys, ethnography and action research. Alternatively, the Design Science Research Methodology (DSRM) has been receiving widespread attention as a research methodology for the development of new artefacts in Software Engineering and ISs. It supports the DSR philosophical stance and provides steps towards the development and assessment of innovative solutions to organisational problems (Hevner *et al.*, 2004), such as those in configuration and change management. DSRM adopts an iterative approach for the incremental development of artefacts. It also allows for the utilisation of different research strategies (i.e. case studies, surveys, action research, etc.) alongside supporting quantitative and/or qualitative research methods as needed to address the goals of its increments (Livari and Venable, 2009; Flick, 2015).

In 2004, the popular paper (Hevner *et al.*, 2004) introduced guidelines for the application of DSR in ISs research projects. The paper identified three cycles within DSR in an ISs-related research project: the relevance cycle, which involves defining the application context of the design research that facilitates identifying the problem to be addressed, desired outcome and related acceptance criteria; the rigour cycle, in which the foundational knowledge needed for rigorous research (e.g. methods, expertise and existing artefacts in the domain) is investigated and gathered; and the design cycle, the final and central stage in which the artefacts are designed, developed and evaluated. However, the paper did not propose detailed processes or a model to apply DSR.

3.3 The Design of the Research Framework

This research involves both factual aspects (such as modelling a generalised ChM BPA or identifying the implications of a proposed change), for which a positivist approach is needed, and social aspects (such as taking the views of domain experts into account), which require an interpretive approach. Overall, this research adopts a pragmatic philosophy that adopts integrating aspects from both the positivism and interpretivism research philosophies.

In addition, one of the main research objectives is to develop a new IT artefact that addresses a number of challenges to the application of ChM in a SoS context. Therefore, the 'DSR' philosophical stance has been adopted, which Hevner and Chatterjee (2010, p. 5) define as "a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artefacts, thereby contributing new knowledge to the body of scientific evidence".

Furthermore, the research is divided methodically into stages to ensure that the development and evaluation of the OntoSoS.BPA.ChM framework be completed thoroughly and with a firm grounding in both strong research design and existing knowledge. This involves the creation of constructs (e.g. a ChM ontology), models (e.g. BPA models for ChM processes), methods (e.g. algorithms for knowledge retrieval) and instantiations (e.g. implementation examples of developed constructs, models or methods using a domain-specific case study). Researchers agree that the targeted artefacts of the DSR strategy include these as well as systems (March and Smith, 1995; Hevner *et al.*, 2004; Livari and Venable, 2009). Accordingly, this research adopts the DSRM as it is well suited to an IT context, aligning neatly with the engineering and evaluation of artefacts (such as the systems, models, constructs, and instantiations discussed above) to solve problems in Software Engineering and ISs. Furthermore, the iterative nature of DSRM and its focus on artefacts' 'utility in' and 'relevance to' the application domain contributes to the development of well-constructed artefacts that meet specific needs.

As the design science philosophy and the supporting DSRM focus on the utility and relevance of the developed artefact to the application domain, empirical strategies (e.g. case studies) are required to demonstrate and evaluate the OntoSoS.BPA.ChM framework to assess its utility in and relevance to addressing a real-world business problem. Hammad (2018, p. 52) discussed the increasing popularity of using case studies in Software Engineering because of its "suitability to establish context-related understanding for the phenomenon under investigation". Accordingly, "change management in Cell Therapy and Applied Genomics (CTAG) at the King Hussein Cancer Center (KHCC) in Amman, Jordan" is selected as the case study for this research.

Finally, parts of the planned evaluation criteria are related to the syntax and semantics aspects of the framework and its constituents. Other parts are related to the effectiveness of the framework in addressing the identified challenges and achieving the research objectives, as well as ascertaining the degree to which relevant domain experts found it relative and useful. Consequently, this research involves qualitative data collected by adopting checklist-based walkthroughs designed to be used by their own or through semi-structured interviews and questionnaires.

The framework proposed by (Peffers *et al.*, 2007) for the application of DSRM has become widely accepted as a way of applying DSR in the ISs field. Peffers et al.'s framework was driven by Hevner *et al.*'s (2004) guidelines and synthesised from a number of process elements identified in seven DSR studies in ISs and other disciplines. This makes it consistent with prior DSR literature and ensures that it supports the objectives of ISs research studies. Peffers et al.'s framework is divided into six main phases. Table 3.1 provides a brief description of each phase focus:

Table 3.1: Peffers et al. framework main phases (Peffers et al., 2007).

#	Peffers et al.'s Framework Phase	Brief Description of the Phase Focus
1	**Problem Identification and Motivation**	▪ Focuses on defining the research problem and rationalising the value of the proposed artefactual solution.
2	**Objectives of a Solution**	▪ Focuses on inferring the objectives of the proposed solution from the defined research problem.
3	**Design and Development**	▪ Focuses on creating the artefactual solution. This entails identifying the artefact's anticipated functionality and related structural design aspects and then building the desired artefact.
4	**Demonstration**	▪ Focuses on demonstrating how the developed artefact addresses its objectives in real-world situations.

Table 3.1: Peffers et al. framework main phases (Peffers et al., 2007), "Continued".

#	Peffers et al.'s Framework Phase	Brief Description of the Phase Focus
5	Evaluation	▪ Focuses on assessing how effectively the artefact is designed and supports or facilitates a solution to the identified problem. At the end of this phase, a decision will be taken whether to return to phase three to improve the developed artefact, or to continue to the communication phase and leave further improvement to subsequent projects or future work.
6	Communication	▪ Focuses on communicating the findings and the deliverables of the research to researchers and other relevant audiences.

Accordingly, this research will take the framework proposed by Peffers *et al.* (2007) as a guideline, on the grounds that it provides generic and clear research processes that fit well with the aim, objectives and iterative nature of this research. The adoption of Peffers et al.'s framework enables covering all the activities required to satisfy the identified research activities and objectives. Firstly, carrying out the first DSRM phase enables the researcher to manage the identification of the research problem and motivation and propose a solution for the identified problems. Next, carrying out the second DSRM phase enables the researcher to identify the research objectives to be achieved by the proposed solution in order to address the identified research problems. The iterative nature of DSRM (especially with regard to the application of its third, fourth and fifth phases) enables the identification of increments that support the progressive development of the anticipated research framework including its related artefacts until the research objectives are sufficiently addressed. This also allows the alignment of the individual artefacts developed through identified increments with the individual identified research objectives and with the main research artefact, that is the full OntoSoS.BPA.ChM framework. The last DSRM phase (i.e. communication) enables the researcher to manage to communicate the research findings, contributions and future directions.

Figure 3.1 depicts how Peffers et al.'s model has been adopted for this research. The main phase that aims to develop and mature the OntoSoS.BPA.ChM Framework (Ph. 3) includes four increments. Each increment involves the stages of design, demonstration and evaluation and has an input and an anticipated output. Communication of findings is to occur progressively after the increments have been completed.

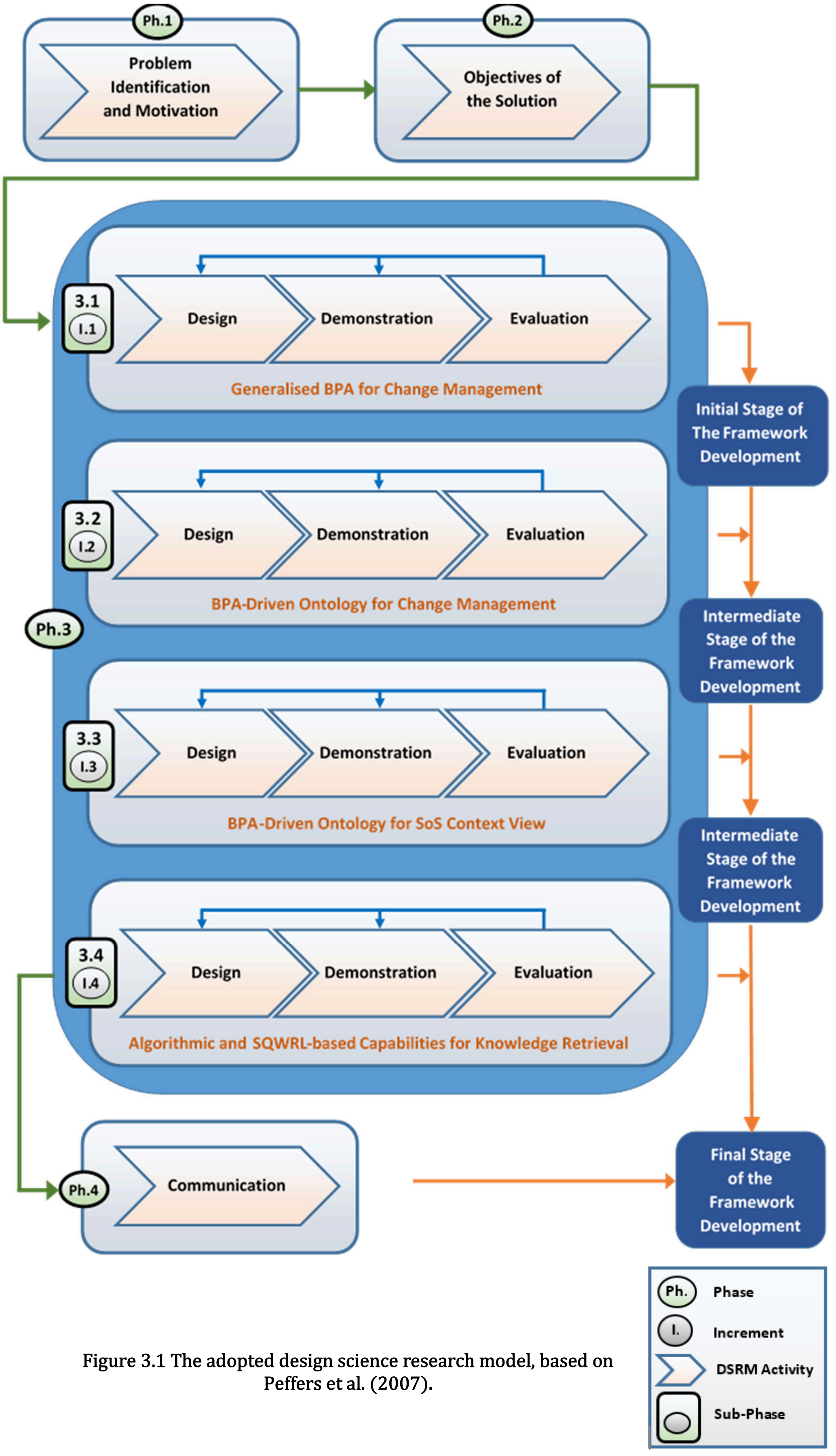


Figure 3.1 The adopted design science research model, based on Peffers et al. (2007).

3.3.1 First Phase: Problem Identification and Motivation

This phase involves the articulation of the research problem, motivation, proposition and related research questions. This was accomplished after conducting a literature review on CM in general, and ChM in particular, with a focus on the challenges facing the application of these disciplines in a SoS context. Existing solutions to the identified challenges were reviewed to identify research gaps to be filled during the design phase. This has also included reviewing BPA modelling methods and semantic representations of knowledge to support the development of the proposed research solution. The outcomes of this phase are presented in Chapter 1 and Chapter 2 of the thesis.

3.3.2 Second Phase: Defining Objectives of the Solution

In this phase, the research gap, problem, questions, proposition and aim that were identified and defined in the previous phase were applied to derive and clarify the stated objectives for the research, culminating in the proposal of novel artefacts to support solutions to the identified problems. The key objective is to improve the application of ChM in a SoS context, informed by BPA and knowledge representation. This is supported by a range of sub-objectives. Existing research and practice in ChM do not offer the solutions proposed here, and hence the significant contribution to the research field. The outcomes of this phase are highlighted in Chapters 1, 2, and 3 of this thesis.

3.3.3 Third Phase: Development and Evolution of the Research Framework

A review of the literature on the state-of-the-art in CM and ChM applied to SoS context shows that an innovative solution that adapts and/or supports the existing solutions is needed to address significant research gaps identified and summarised in Chapter 2. During this phase, the OntoSoS.BPA.ChM framework is proposed and designed, demonstrated and evaluated progressively through four main increments.

The OntoSoS.BPA.ChM framework refers to a ChM framework that is BPA-driven, semantically-enriched and applicable to SoS context. The framework is designed in a layered architecture to support scalability, the separation of concerns, reusability and abstraction (e.g. through the provision of meta-models and models) (Siegel, 2014; Hammad, 2018). The architecture comprises ChM, SoS Context View, and Alignment and Knowledge Retrieval layers. Figure 3.2 presents the OntoSoS.BPA.ChM framework followed by a detailed description of the framework and its relevant DSRM development increments.

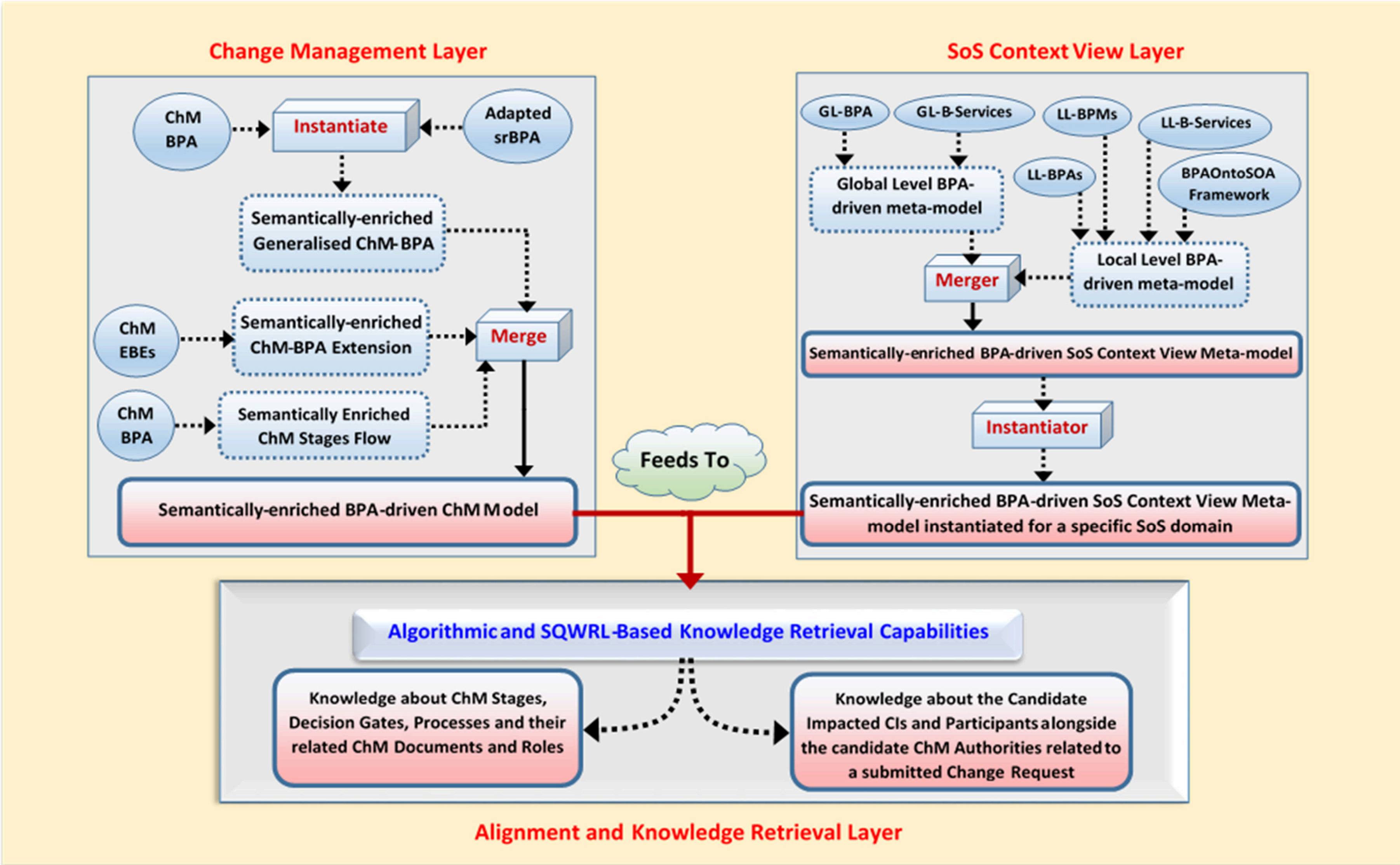


Figure 3.2: Architectural framework design of the OntoSoS.BPA.ChM framework.

3.3.3.1 THE CHANGE MANAGEMENT LAYER – (THROUGH THE FIRST & SECOND INCREMENTS OF THE DSRM MODEL'S THIRD PHASE)

The 'Change Management' layer is the first main component of the OntoSoS.BPA.ChM framework; it is responsible for providing a generic semantically-enriched and BPA-driven ChM model that includes ChM processes, the relationships between them and further related ChM documents (e.g. Change Closure Report) and roles (e.g. Change Assessor), which can be utilised within a specific context. The development of the ChM framework component was carried out through the first and second increments of the DSRM's Third phase. As part of responding to the domain experts' feedback, during the fourth-DSRM-increment, further ChM related artefact (semantically-enriched ChM stages flow model) was developed and linked to the ChM artefacts resulting from the first and second-DSRM-increments.

- **THE FIRST INCREMENT OF THE ADOPTED DSRM'S PROCESS MODEL**

This increment contributes to answering RQ1 and fulfilling Research Gaps (RGs) RG1, RG2 and RG3. Therefore, it focuses on the development, demonstration and evaluation of generalised Riva-based BPA models for ChM functional area in Systems and Software Engineering domains, which capture and propose generic ChM core processes and dynamic relationships between them. The following paragraphs briefly introduce the main DSRM stages of this increment. The detailed development, demonstration and evaluation of generalised BPA models for ChM are discussed in Chapter 4.

(A) First-Increment's Design and Development Stage:

During this stage, the BPA modelling approaches (Dijkman, Vanderfeesten and Reijers, 2016) mentioned earlier in Chapter 2 were revisited and explored. Accordingly, the Riva-based method (Ould, 2005), as an object-based BPA modelling approach, was chosen to model the anticipated ChM-BPA. Generally, the groundings for this selection were mainly based on the suitability of this approach more than others existing to the nature of the research objectives, in addition to the extent to which the BPA models can participate in addressing most or all of the identified research objectives. A more detailed justification for the selection of the Riva-based BPA modelling approach is articulated in Chapter 4. Subsequently, Riva was adapted to design and develop the anticipated generalised ChM-BPA models based on the investigation of existing CM standards and guidelines, particularly in the area of ChM in systems and software engineering domains. This adaptation was achieved partly through the elaboration of the Case Strategy Process (CSP) concept, its relations and the related heuristics within the Riva-Process Architecture Diagrams (Riva-PADs).

(B) First-Increment's Demonstration Stage:

In order to assess the applicability for the developed ChM-BPA in a real-world context, the ChM-BPA models' representation and sufficiency were checked. This was based on assessing the extent to which they suit the needs, represent and cover the real-world ChM practices in a healthcare setting (i.e. the KHCC, Jordan). Accordingly, in this stage combined with the subsequent evaluation stage, the adopted ChM policies for KHCC were checked, and a set of ChM and business modelling experts were asked for their feedback.

(C) First-Increment's Evaluation Stage:

Although there is a broad agreement on the importance of evaluation for DSR, a review of the literature shows that there is a lack of consensus on a comprehensive evaluation framework for general use. The existing literature offers a range of evaluation methods, but these are fragmented throughout the literature, with little guidance available on how to choose among, relate them to the artefacts requiring evaluation or apply them to the success criteria of specific projects. For instance, March and Smith (1995), Hevner *et al.* (2004), Vaishnavi and Kuechler (2004), and Peffers *et al.* (2007) are criticised for providing insufficient guidance with regard to choosing amongst particular evaluation methods and navigating the evaluation criteria related to them (Prat, Comyn-Wattiau and Akoka, 2014; Herselman and Botha, 2015; Venable, Pries-Heje and Baskerville, 2016).

March and Smith (1995) in particular are criticised for the non-generic nature of their proposed criteria; evaluation criteria are highly dependent on the type of artefact being evaluated (Sonnenberg and Brocke, 2012). Pries-Heje, Baskerville and Venable (2008) proposed a 2-by-2 framework to provide guidance for the adoption of evaluation strategies for a DSR project. However, their framework does not systematically consider evaluation criteria, nor does it provide relations between the criteria and suitable evaluation methods to assess them (Herselman and Botha, 2015). Meanwhile, Cleven, Gubler and Hüner (2009) categorised evaluation approaches into twelve dimensions, but with no mention of related evaluation criteria or providing sufficient guidelines on how and why to use particular methods of evaluation (Prat, Comyn-Wattiau and Akoka, 2014).

Sonnenberg and Brocke (2012) listed a number of evaluation criteria, methods and patterns by synthesising Pries-Heje, Baskerville and Venable (2008) and Cleven, Gubler and Hüner (2009). However, they do not explicitly relate specific criteria to specific methods (Prat, Comyn-Wattiau and Akoka, 2014). Prat, Comyn-Wattiau and Akoka (2014, 2015) introduced a hierarchy that links the evaluands with related evaluation criteria. However, their work is limited in that it considers only artefacts classifiable as systems or related dimensions; they do not address evaluation of other artefact types such as constructs, as considered by March and Smith (1995) and Hevner *et al.* (2004).

Venable, Pries-Heje and Baskerville (2012, 2016) proposed an extension of the framework offered by Pries-Heje, Baskerville and Venable (2008). It provides a high abstract view of the aspects of evaluation within DSR (e.g. evaluation purpose, characteristics, kinds of evaluands, etc.) alongside guidelines for the selection of methods. However, this extension still does not explicitly relate specific methods of evaluation to specific evaluation criteria, or criteria to the abstract aspects of the framework.

Juristo and Morant (1998) proposed a common framework for the evaluation of artefacts related to conventional software systems and knowledge-based systems. It is driven by a thorough investigation of the definitions and criteria used for verification, validation and testing of artefacts in both fields. They organised the evaluation of a given artefact into four main categories: (1) Artefact Verification: checking the correctness of an artefact's syntax/structure (i.e. whether the artefact is structurally correct, adheres to the adopted rules and is free of design defects); (2) Artefact Validation: conducting a check of the correctness of semantics (e.g. contents and behaviours) of the artefact; (3) Artefact Usability: checking the applicability of the artefact to a real-world setting; and (4) Artefact Usefulness: checking the positive impact of the artefact on addressing real-world problems or needs.

In addition, their framework has a 'generic nature' (Dobrica and Niemelá, 2002; Khan, 2009), it can be customised to enable the evaluation of a specific artefact (e.g. a conventional software-based solution or a knowledge-based solution) using particular criteria (e.g. consistency, correctness, completeness, redundancy, etc.) with the support of various evaluation techniques (e.g. inspections, walkthroughs, checklists, questionnaire, etc.) (Khan, Ludlow and Caceres, 2013).

Aided by the generic nature of Juristo and Morant's framework, its proposed goals and related criteria are considered independent of the types of evaluand but fit to evaluate them. Furthermore, the framework supports different purposes and scopes of evaluation (e.g. structure checks, content validation, applicability and the artefact's impact on real-world situations). In addition, the categories of evaluation entailed in Juristo and Morant's framework enable researchers to make sure that an artefact's development is correct, complete and consistent (through verification and validation) before assessing its utility and relevance (through externality checks and real-world impact), which is the focus of DSR evaluation. These categories of evaluation can be applied at any point or increment of the research to support methodical and efficient development. Another useful aspect of this framework is that it explicitly links evaluative goals to criteria and assessment techniques, offering guidance as to how evaluation can be most effectively carried out. Finally, the framework has already been successfully adopted and used in other research into ISs and software engineering of a similar nature to this research, e.g. Kossmann (2010); Yousef (2010); and Ahmad (2015).

Based on the above-mentioned characteristics, Juirsto and Morant's (1998) framework was found suitable to the nature of this research. Therefore, it was adopted for the purpose of evaluating the OntoSoS.BPA.ChM framework. The proposed evaluation was carried out incrementally throughout the four adopted DSRM increments. The evaluation aspects adopted to evaluate the developed ChM-BPA component during the First-DSRM-Increment are presented in Table 3.2.

It is important to keep in mind that the purpose of evaluating the OntoSoS.BPA.ChM framework is not mainly to measure quality attributes such as reliability, security, maintainability, etc., but rather to assess to what extent it addresses the identified research objectives and answer the research questions. This involves assessing the extent to which the framework is designed and developed correctly and rigorously; can guide and facilitate the application of ChM processes in a SoS context; and is accepted as a relevant tool to bridge the gap between ChM and SoS.

Table 3.2: The evaluation aspects adopted to evaluate the developed ChM-BPA component during the First-DSRM-Increment.

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="6">(First-DSRM-Increment)

Evaluating the Generalised BPA Models for ChM:

(1) To inform the adherence of the developed generic ChM-BPA models to the adapted Riva-based BPA approach.

(2) To inform the validity of the ChM-BPA models from BPA and ChM points of view.

(3) To inform the validity of the adaptions made to the Riva-based BPA modelling approach.

(4) To inform if the ChM-BPA meets the identified objectives that motivated its development.</td><td colspan="2">Verification</td><td>Type of Assessment</td></tr>
<tr><td>Consistency</td><td>Completeness</td><td rowspan="5">Extensive walkthrough-based questionnaire through semi-structured interviews with domain experts</td></tr>
<tr><td colspan="2">Validation</td></tr>
<tr><td>Correctness</td><td>Completeness</td></tr>
<tr><td colspan="2">Appropriateness</td></tr>
</table>

As the research framework is incrementally developed throughout the adopted DSRM increments, the output of carrying out the First Increment (i.e. Generalised BPA models for ChM) is used as an input to the Second Increment to continue developing the ChM framework component.

➢ The Second Increment of the Adopted DSRM's Process Model

This increment contributes to answering RQ1 and fulfilling RG1, RG2 and RG3. Therefore, it focuses on the development, demonstration and evaluation of a generalised BPA-driven and semantically-enriched model for ChM, which represents the ChM processes modelled by the ChM-

BPA and links them to related ChM documents and roles. For this purpose, two DSRM sub-increments with different concerns were carried out. The following paragraphs briefly introduce the main DSRM stages of this increment related sub-increments. The detailed development, demonstration and evaluation of a generalised semantically-enriched and BPA-driven for ChM are discussed in Chapter 5.

A) First-Sub-Increment's Design and Development Stage:

In this stage, the srBPA ontology component (Yousef and Odeh, 2014) (presented in Chapter 2) was explored and adapted to enable the semantic enrichment of the Riva-based BPA models adapted in the first increment.

(B) First-Sub-Increment's Demonstration Stage:

To demonstrate the adapted srBPA ontology, it was instantiated with ChM-BPA models' elements to assess the extent to which it is applicable for the semantic enrichment of the ChM-BPA model elements. In addition, this enables achieving the semantic enrichment of the developed ChM-BPA models elements.

Software tools used during development and demonstration included the Protégé 3.4.1 ontology development environment (used originally for development of the srBPA ontology), which provided representations written with OWL specification 1.0 using OWL-DL. In addition, ChM and BPA instances were created through SWRL and Java Expert System Shell (JESS)-based rules. JESS is available free if used for academic purposes, but is not compatible with later versions of Protégé, which is why Protégé 3.4.x was used in the initial stages of this research. For the development of a standalone application, which is a potential future direction for this research, OWL-APIs (OWL-Application Programmable Interfaces) can support programming of SWRL statements required for ChM ontology. Therefore, in later increments, development and evaluation of the framework were conducted using OWL 2.0 and Protégé 5.5.

(C) First-Sub-Increment's Evaluation Stage:

The adopted evaluation framework was extended and carried out in this sub-increment for the evaluation of the resulting artefact (that is, an srBPA ontology for ChM adapted for the framework development) to ensure its appropriate development. Table 3.3 shows an abstract view of the adopted evaluation aspects related to this sub-Increment.

(D) Second-Sub-Increment's Design and Development Stage:

This sub-phase aims to create an ontological meta-model (ChM Extension ontology) that semantically represents main ChM documents, roles, processes and the relationships between them. Thereafter, it aims to link the represented concepts with their related ChM processes in the adapted srBPA ontological meta-model.

(E) Second-Sub-Increment's Demonstration Stage:

To assess the applicability of the developed component, the developed ChM extension meta-model was instantiated with related ChM documents and roles. For this purpose, the identified entities for the development of the Riva-based BPA for ChM were revisited, and roles and documents related to main ChM processes were investigated and selected for the development of a semantically-enriched extension model for the ChM-BPA. After that, the developed extension was linked to the adapted srBPA ontology for ChM (Adapted srBPA ontology instantiated with ChM-BPA elements) to form an Integrated BPA-driven ChM ontological model.

(F) Second-Sub-Increment's Evaluation Stage:

The adopted evaluation framework was extended and carried out in this sub-increment for the evaluation of the resulting artefact (that is, an integrated BPA-driven ChM ontology that includes the ChM extension ontology adopted for the framework development linked to the adapted srBPA ontology for ChM) to ensure the validity of its design and utility. Table 3.4 shows an abstract view of the adopted evaluation aspects related to this sub-Increment.

As mentioned previously, carrying out the second increment of the adopted DSRM's model resulted in developing a BPA-driven and semantically-enriched ChM framework component that captures and represents ChM-BPA and enriches it with linkages to identified related ChM artefacts and roles. Furthermore, as the research framework is incrementally developed throughout the adopted DSRM increments, the resulting framework component is used as an input to the 'Fourth Increment' to finalise developing the OntoSoS.BPA.ChM framework.

Table 3.3: The evaluation aspects adopted to evaluate the developed Adapted srBPA component during the Second-DSRM-Increment's First-Sub-Increment.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Second-DSRM-Increment) (First-Sub-Increment) Evaluating the Semantic Enrichment of the ChM-BPA (The Adapted srBPA ontology for ChM): (1) To inform the adherence of the adapted ontological meta-model to the ontology-based representation using OWL-specifications. (2) To further verify the correctness of the Adapted srBPA ontological meta-model by checking the completeness and redundancy aspects of its elements. (3) To inform the validity of the adapted ontological model in representing the developed ChM-BPA elements by checking the correctness, completeness and consistency of the ontological model's elements.	Verification		
	Consistency		Protégé Reasoner
	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness	Completeness	Checklist-based Walkthroughs (By the researcher)
	Consistency		Protégé Reasoner

Table 3.4: The evaluation aspects adopted to evaluate the developed ChM extension component during the Second-DSRM-Increment's Second-Sub- Increment.

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="7">(Second-DSRM-Increment)
(Second-Sub-Increment)

Evaluating the 'Integrated BPA-driven ChM' ontological model
(The Semantic Enrichment of the ChM-BPA linked to the ChM-BPA Extension):

(1) To inform the adherence of the developed semantically-enriched models to the ontology-based representation using OWL-specifications.

(2) To further verify the correctness of the developed semantically-enriched models by checking the completeness and redundancy aspects of their elements.

(3) To inform the validity of the developed ontological-based models in representing the identified ChM-BPA extension elements and linking them to related elements in the ChM-BPA.

(4) To inform if the 'Integrated BPA-driven ChM' component meets the identified objectives that motivated its development.</td><td colspan="2">Verification</td><td></td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td>Completeness</td><td>Redundancy</td><td>Checklist-based Walkthroughs (By the researcher)</td></tr>
<tr><td colspan="2">Validation</td><td></td></tr>
<tr><td>Correctness</td><td>Completeness</td><td>Checklist-based Walkthroughs and Semi-structured interviews (By the researcher and by the domain experts)</td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td colspan="2">Appropriateness</td><td>A Checklist-based Walkthrough by a Semi-structured Interview (By the researcher with support of the domain experts)</td></tr>
</table>

3.3.3.2 The SoS Context View Sub-Layer– (Through The Third Increment of the DSRM model's Third Phase)

The '**SoS Context View**' is the second main component of the OntoSoS.BPA.ChM framework; it is responsible for providing a generic BPA-driven and semantically-enriched meta-model that captures and represents aspects of global and local levels in a SoS context, including the correlations between them, driven by a global and local levels alignment and BITA perspectives. The development of the SoS context view component was carried out through the 'Third Increment' of the DSRM's Third phase.

➢ **The Third Increment of the Adopted DSRM's Process Model**

This increment contributes to answering **RQ2** and fulfilling **RG1** and **RG4.** Therefore, it focuses on the development, demonstration and evaluation of a BPA-driven and semantically-enriched meta-model that captures and represents SoS context aspects considered for this research. This allows key aspects of the business and supporting IT, such as business services, BPA, associated business process models and supporting software services that exist in the SoS operational context to be captured and modelled alongside their interrelationships. The following paragraphs briefly introduce the main DSRM stages of this increment. The detailed development, demonstration and evaluation of the SoS context view component are discussed in **Chapter 6.**

(A) Third-Increment's Design and Development Stage:

This stage aims to identify and define the constituent elements of the SoS context view framework component driven by global-local levels alignment and BITA perspectives, develop related conceptual meta-model, build an abstract SoS context view ontology based on the developed conceptual meta-model and link the developed ontology to related ontologies (e.g. adapted BPA for global level) in order to form an integrated SoS context view ontology that provides the aimed at holistic view.

As discussed in Chapter 2, a SoS is an arrangement of systems that entails two or more independent constituent systems, where integrating the capabilities of the constituent systems enables achieving capabilities or addressing goals at a higher level than could be achieved by the individual constituent systems alone. Therefore, two levels need to be taken into consideration when dealing with a SoS arrangement; the SoS level and the constituent systems level. The SoS level, which in the context of this research is called the **Global-Level** of the arrangement, refers to the high-level system that results from the integration of the capabilities of the constituent systems. This global level has services and processes that are satisfied and supported by integrating the services, processes and capabilities of the constituent systems. Meanwhile, the constituent systems level, which in the context of this research is called the **Local-Level** of the arrangement, refers to the constituent systems that participate in forming the SoS arrangement. At the local-level, each constituent system has its own services, processes and capabilities that may differ from those of the other constituent systems

The interaction of these levels and the constituent systems necessitate the existence of different levels of stakeholders and governing bodies. Those stakeholders and governing bodies must be aware of their systems' roles in the arrangement; an effective collaboration between these participants is crucial to successfully align the work of the global and local levels. Figure 3.3 represents an abstract illustration of this research study's adoption of the global-local levels view of a SoS arrangement in an operational context.

In this research, each constituent system is viewed as an IT-based business enabler that supports the local and global levels. Therefore, this research assumes that if a BPA-driven view could be modelled from a SoS organisational architecture perspective (including the global and local levels of the SoS arrangement and the connections between them), this would facilitate maintaining alignment between global and local levels and business and IT areas, and therefore a more effective application of ChM in a SoS context. The SoS context view, as applied to this research, will be further discussed in Chapter 6.

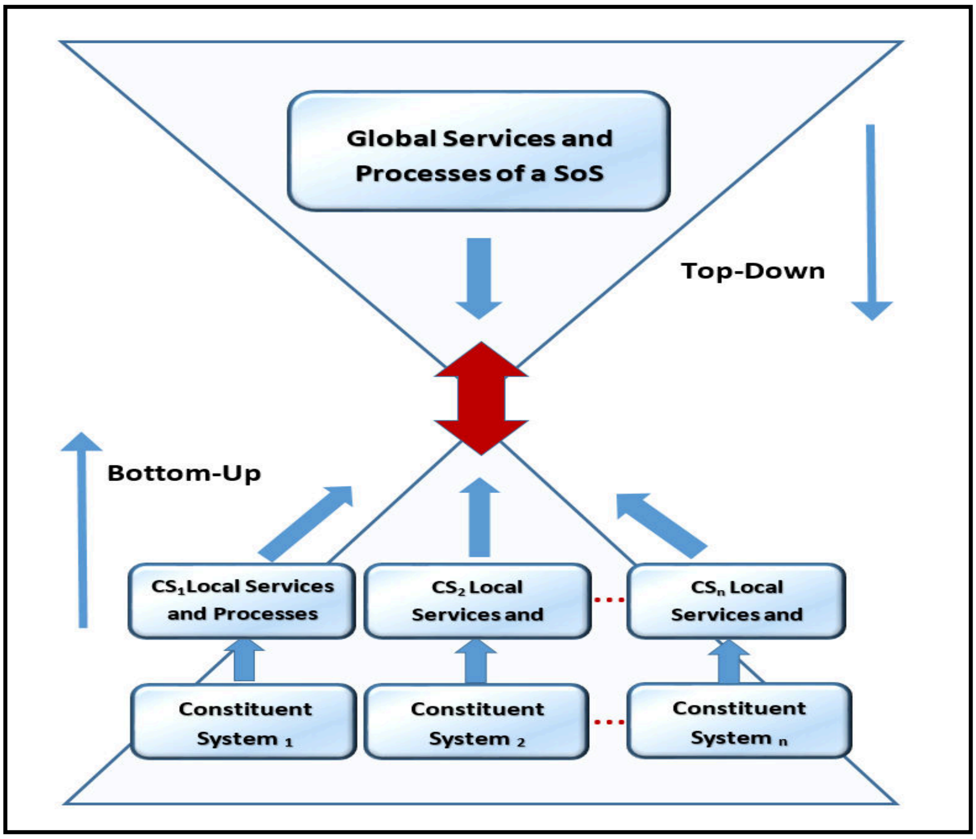


Figure 3.3: An abstract global and local levels view of a SoS arrangement.

(B) Third-Increment's Demonstration Stage:

To demonstrate the developed ontology, it was checked by assessing the extent to which the developed meta-model can be applied to real-world SoS context in a healthcare setting. Subsequently, the CTAG case study within KHCC at Jordan was used to instantiate the developed BPA-driven and semantically enriched SoS context view artefact.

(C) Third-Increment's Evaluation Stage

The adopted evaluation framework was extended and carried out in this increment for the evaluation of the resulting framework component (that is, an Integrated SoS context view ontology constructed for the framework development) to ensure its appropriate development and applicability. Table 3.5 shows an abstract view of the adopted evaluation aspects related to this increment.

As the research framework is progressively developed throughout the adopted DSRM increments, the resulting framework component is used as an input to the fourth increment to finalise developing the OntoSoS.BPA.ChM framework.

Table 3.5: The evaluation aspects adopted to evaluate the developed SoS context view framework component during the Third-DSRM-Increment.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Third-DSRM-Increment) Evaluating the 'Integrated SoS Context View' ontological model (The semantic enrichment of the SoS Context View artefact and its demonstration to CTAG-KHCC): (1) To inform the adherence of the developed semantically-enriched models to the ontology-based representation using OWL-specifications. (2) To further verify the correctness of the developed semantically-enriched models by checking the completeness and redundancy aspects of their elements. (3) To inform the correctness of the developed SoS context view conceptual meta-model from a domain experts' point of view. (4) To inform the validity of the developed ontological-based models in representing the CTAG-KHCC SoS arrangement context. (5) To inform if the 'SoS Context View' component meets the identified objectives that motivated its development.	Verification		
	Consistency		Protégé Reasoner
	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness		A Checklist-based Walkthrough (By the researcher or with support of the domain experts)
	Completeness		Checklist-based Walkthroughs (By the researcher)
	Consistency		Protégé Reasoner
	Appropriateness		A Checklist-based Walkthrough by a Semi-structured Interview (By the researcher with support of the domain experts)

3.3.3.3 The Alignment and Knowledge Retrieval Framework Layer (Through The Fourth Increment of the DSRM model's Third Phase)

The '**Alignment and Knowledge Retrieval**' layer is the third and final main component of the OntoSoS.BPA.ChM framework; it is responsible for providing algorithmic and SQWRL-based capabilities that utilise the ChM and SoS context view components to empower ChM stakeholders with purposeful knowledge that can be used to guide and facilitate the application of ChM in a SoS context. The development of this component is carried out through the 'Fourth Increment' of the DSRM's Third phase.

- **The Fourth Increment of the Adopted DSRM's Process Model**

This increment contributes to answering **RQ3** and **RQ4** and fulfilling **RG1** and **RG5.** It is also the final step towards confirming or rejecting the research proposition identified in **Chapter 1**, to be further explored in **Chapter 8.** Therefore, this increment focuses on the development, demonstration and evaluation of an algorithmic-based knowledge retrieval capabilities that utilise the developed ChM and the SoS context framework components to provide knowledge that can be used to guide and facilitate the application of ChM in a SoS context. The following paragraphs briefly introduce the main DSRM stages of this increment. The detailed development, demonstration and evaluation of the amid at knowledge retrieval framework component are discussed in **Chapter 7**.

(A) Fourth-Increment's Design and Development Stage:

This stage aims at the design and development of the alignment and knowledge retrieval framework component. It starts with investigating aspects that can be used to align between the ChM and SoS framework components and support the research framework aim and objectives. After that, it focuses on developing algorithmic and SQWRL-based knowledge retrieval capabilities that enable retrieving knowledge from the ChM and SoS context view components to enrich the awareness of the ChM stakeholders. A phased approach was adopted to address these objectives methodically.

(B) Fourth-Increment' Demonstration Stage:

To demonstrate the developed framework component, it was checked by assessing the extent to which the developed artefacts can be applied to real-world SoS context in a healthcare setting. Therefore, the already adopted CTAG case study within KHCC at Jordan was used to instantiate the developed knowledge retrieval component and its related developed artefacts. In addition, the demonstration of the developed component paved the way to evaluate it.

(C) Fourth-Increment' Evaluation Stage

The adopted evaluation framework is extended and carried out in this increment for the evaluation of the resulting framework component and its related developed artefacts in order to ensure their appropriate development and practicality. Thereafter, the effectiveness of the OntoSoS.BPA.ChM framework in fulfilling the identified research gaps and therefore improving the application of ChM in a SoS context is assessed. Accordingly, the CTAG-KHCC case study was used for evaluation purposes. Table 3.6 shows an abstract view of the adopted evaluation aspects related to this increment. The evaluation in this stage was conducted through four parts; in the first part, the evaluation was conducted for the ChM related artefacts developed in this increment to support the knowledge retrieval component objectives; in the second part, the evaluation was conducted for the SoS related artefacts developed in this increment to support the knowledge retrieval component objectives; in the third part, the evaluation was conducted for the knowledge retrieval capabilities developed in this increment to support the knowledge retrieval component objectives; finally, in the fourth part, the evaluation was conducted to assess the effectiveness of the overall OntoSoS.BPA.ChM framework.

3.3.4 FOURTH PHASE: COMMUNICATION

The focus of this phase is on the communication and dissemination of the developed and evaluated OntoSoS.BPA.ChM framework, including its constituent artefacts, to the relevant industrial and research communities. The main medium of dissemination is this research thesis. However, conference papers, journal papers, workshops, talks and/or book chapters (in progress) with the well-received findings from the previous phases have contributed to this phase. This process also involved the clarification and acknowledgement of research boundaries and suggestions for the direction of future research. This phase is to be completed by the submission of the final thesis, setting for the viva, and the publication of the thesis in the UWE electronic repository.

Table 3.6: The evaluation aspects adopted to evaluate the developed alignment and knowledge retrieval component during the Fourth-DSRM- Increment.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Fourth-DSRM-Increment) (Part-1) Evaluating the developed ChM stages flow ontological model, the dependency relationships for the BPA-driven ChM Processes and the linkages identified between the newly developed ChM stages and the BPA-driven ChM processes, which were driven by the development of the alignment and knowledge retrieval component: (1) To inform the adherence of the developed semantically-enriched ChM elements to the ontology-based representation using OWL-specifications. (2) To further verify the correctness of the newly developed semantically-enriched ChM elements by checking their completeness and redundancy. (3) To inform the validity of the newly developed semantically-enriched meta-models in representing the identified ChM instances.	Verification		
	Consistency		Protégé Reasoner
	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness	Completeness	Checklist-based Walkthroughs (By the researcher or by domain experts)
	Consistency		Protégé Reasoner
Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Fourth-DSRM-Increment) (Part-2) Evaluating the developed ChM-driven roles which were driven by the development of the alignment and knowledge retrieval component: (1) To inform the adherence of the developed semantically-enriched ChM-driven roles elements to the ontology-based representation using OWL-specifications. (2) To further verify the correctness of the newly developed semantically-enriched ChM-driven roles elements by checking their completeness and redundancy. (3) To inform the validity of the newly developed semantically-enriched ChM-driven roles elements in representing the identified ChM Roles instances.	Verification		
	Consistency		Protégé Reasoner
	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness	Completeness	Checklist-based Walkthroughs (By the researcher or by domain experts)
	Consistency		Protégé Reasoner

Table 3.6: The evaluation aspects adopted to evaluate the developed alignment and knowledge retrieval component during the Fourth-DSRM-Increment, “Continued”.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Fourth-DSRM-Increment) (Part-3) **Evaluating the developed algorithmic and SQWRL –based knowledge retrieval capabilities:** (1) To inform the adherence of the developed SQWRL-based capabilities to the ontology-based representation using OWL and SQWRL specifications. (2) To further verify the correctness of the developed algorithms and their supporting SQWRL-based capabilities by checking their completeness. (3) To inform the validity of the developed algorithms and their supporting SQWRL-based capabilities.	**Verification**		
	Consistency		Protégé Reasoner
	Completeness		Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness	Completeness	Checklist-based Walkthroughs (By the researcher with support of domain experts)
	Consistency		Protégé Reasoner

Objective of Evaluation	Type and Criteria of Evaluation	Evaluation Technique
(Fourth-DSRM-Increment) (Part-4) **Evaluating the Effectiveness of the overall OntoSoS.BPA.ChM Framework:** (1) To inform the appropriateness and novelty of the OntoSoS.BPA.ChM Framework. (2) To inform the induced improvements of using the OntoSoS.BPA.ChM Framework in real-world settings.	**Effectiveness**	
	Fulfilment of the research framework functional characteristics	A Checklist-based Walkthrough By the researcher
	Novelty	A Checklist-based Walkthrough supported by a Semi-structured Interview (By the researcher with the support of domain experts)
	Usefulness	

3.4 Case Study

Evaluating the utility and relevance of an artefact is crucial when adopting the DSRM for the development of innovative IT artefacts (Hevner *et al.*, 2004; Peffers *et al.*, 2007). Case studies are a valuable empirical strategy for evaluating and justifying artefacts in this context (Peffers *et al.*, 2012; Prat, Comyn-Wattiau and Akoka, 2015; Venable, Pries-Heje and Baskerville, 2016). However, it is important to ensure that the chosen case study is representative and sufficient to support a complete demonstration and evaluation of the artefact.

To consider a case study representative, it must be a good model of the context under consideration (in this case, a SoS context) and support aspects of the desired application within that context (in this case, ChM in a SoS context). Furthermore, a representative case study should be able to provide access to representative domain experts and specialists, who should have expertise in and knowledge of the domains under consideration (i.e. BPA, BPM, ChM), or have a high level of comprehension of the real-world context of the case study. Case study participants must be willing and able to interact with the developed artefact and evaluate its applicability and impact. Moreover, a representative case study should provide well-represented, validated and/or accredited data, which can formulate the grounds for demonstration of the artefact in preparation for evaluation (e.g. BPA models, BPMNs, policies and procedures, etc.). On another hand, a sufficient case study should provide adequate data for the artefact to be instantiated and operational in a real-world setting, such that all essential aspects can be assessed. Selecting the right case study is crucial to ensuring that the demonstration and evaluation findings can be generalised to other settings and domains.

3.4.1 The Selection of the Research Case Study

The case study chosen for the demonstration and evaluation of the OntoSoS.BPA.ChM framework and its constituent components is a study of ChM in the CTAG-KHCC. CTAG-KHCC was selected as a representative and sufficient choice based on different factors.

(1) The CTAG operational context represents a good model for the context that is under the consideration of this research, as it is considered as a SoS context. The CTAG-KHCC as a SoS arrangement encompasses two main levels: the CTAG-SoS global-level business area and the CTAG-SoS local-level business area. The local-level business area is comprised of four independent constituent business areas; these are (i) the Flow Cytometry; (ii) the Molecular Diagnostics Immunogenetics; (iii) the Blood and Marrow Transplant; and (iv) Cytogenetic.

The CTAG-SoS arrangement is developed with a specific purpose in mind (i.e. proposing personalised treatments to cancer care patients), which would not be attainable by any of the participating business areas individually. Therefore, the above-mentioned CTAG constituent business areas were integrated in order to provide the CTAG-SoS arrangement with the required capabilities that can serve the CTAG-SoS ultimate purpose. The CTAG-SoS arrangement is centrally managed by a controlling authority. However, the CTAG constituent business areas retain their capability to operate independently, and they are managed by different independent parties of the CTAG-SoS arrangement. Nonetheless, the CTAG constituent business areas' typical operational mode is subordinated to the CTAG-level purpose. Furthermore, the CTAG-SoS has its own dedicated resources and manager, as well as clearly defined objects. In addition, the CTAG constituent business areas maintain their independent purposes, funds, development and evolution, etc. The change and evolution aspects of the CTAG-SoS arrangement are carried out based on collaboration between the CTAG-SoS arrangement authority and the constituent business areas authorities.

Adopting the CTAG-ChM case study provides this research with a relevant and suitable SoS context in which to evaluate the different aspects of the OntoSoS.BPA.ChM framework. This, in turn, conforms to the representativeness criteria to select a case study and contributes to considering the CTAG-KHCC case study as a representative case study.

(2) The CTAG-KHCC setting involves stakeholders and experts in the areas of cell therapy and applied genomics-based cancer care, workflow execution and ChM, who have been willing to participate in this research project by: (i) Evaluating the OntoSoS.BPA.ChM framework and its constituent artefacts; and (ii) Assessing the outcomes of applying the framework in the CTAG-KHCC setting. In addition, the management is willing to provide the researcher with any level of data (general or confidential) needed to conduct the case study throughout all stages of the research. This, in turn, conforms to the representativeness criteria to select a case study and contribute to considering the CTAG-KHCC case study as a representative case study.

(3) The KHCC is the leading cancer care provider in the Middle East region (KHCF, 2018). "KHCC is the only healthcare institution in the Arab world and the sixth in the world to receive disease-specific accreditation from the Joint Commission International (JCI)" (MiddleEastHealthMag, 2016). It is renowned for providing excellent healthcare, being run through efficient business processes, and adopting the highest healthcare standards (KHCC, 2018). In addition, the centre has received many accreditations from leading healthcare and cancer care quality evaluators, both local and international (e.g. the College of American Pathologists [CAP], the Healthcare Accreditation Council [HCAC], and others).

Conducting the case study at such centre ensures that data come from high-quality systems, equipment, and well-trained and knowledgeable staff. Moreover, selecting CTAG-KHCC for the case study supports the possibility of generalising the developed framework to other Cancer Care settings. This, in turn, conforms to the representativeness criteria to select a case study and contributes to considering the CTAG-KHCC case study as a representative case study.

(4) The CTAG-KHCC business-process-architecture models and other related business process models required for the instantiation of the OntoSoS.BPA.ChM Framework in the CTAG-KHCC context are readily available. They have been formally developed, represented and then validated by CTAG-KHCC domain experts and related stakeholders (Tbaishat et al., 2018; Odeh et al., 2018).

The availability of such models provides a solid, relevant and rigorous data to be used for the OntoSoS.BPA.ChM demonstration and evaluation phases during the different development iterations. Accordingly, CTAG-KHCC can provide appropriate real-world scale cases that can feed the OntoSoS.BPA.ChM framework with all the data needed to be fully instantiated and efficiently operational (e.g. CTAG-KHCC BPAs, BPMs, Business Services, Related Roles, supporting SW systems, etc.), enabling the most rigorous possible evaluation of the developed artefact. This, in turn, conforms to the representativeness and sufficiency criteria to select a case study and contributes to considering the CTAG-KHCC case study as a representative and sufficient case study.

(5) Using CTAG-KHCC for the case study also gives the researchers access to a full range of test cases in which to demonstrate the OntoSoS.BPA.ChM framework. Those test cases enabled assessment of the ChM framework when applied to each of the related change types identified for the scope of this research (e.g. service-related change, business process-related changes, etc.). This supports the evaluation of the effectiveness of the ChM framework. Finally, data from CTAG-KHCC's existing ChM framework provides a reference point with which to compare results from the demonstration of the artefact, allowing researchers to place the "artefact against the real world" (Cleven, Gubler and Hüner, 2009). This, in turn, conforms to the sufficiency criteria to select a case study and contributes to considering the CTAG-KHCC case study as a sufficient case study.

3.5 Chapter Summary

This chapter presented an overview of research design and articulated the research design selected for this work alongside the rationale behind the made research choices. Accordingly, the DSRM (Hevner *et al.*, 2004), and in particular Peffers *et al.'s* (2007) framework for conducting research in an ISs setting, was adopted to guide this research through an iterative process to incrementally develop the OntoSoS.BPA.ChM framework. Therefore, four development increments were adopted and devised, where the first increment feeds to the second and fourth increments, and the third increment feeds to the fourth.

Following the presentation of the adopted research design, the framework, namely the OntoSoS.BPA.ChM framework, and its main components have been presented and described. The OntoSoS.BPA.ChM framework (artefact) has three main framework components: the ChM, SoS Context View, and Alignment and Knowledge Retrieval components. Each of these framework components plays a key role in achieving the identified research aim and objectives and guiding the work towards answering the identified research questions and gaps.

The next chapter (Chapter 4) introduces the first increment for the development of the OntoSoS.BPA.ChM. It highlights and discusses the development, demonstration and evaluation stages of generalised Riva-based BPA models for the ChM processes.

CHAPTER 4

BUSINESS PROCESS ARCHITECTURE FOR THE CHANGE MANAGEMENT FUNCTIONAL AREA

4.1 INTRODUCTION

As highlighted in **Chapter 3**, the OntoSoS.BPA.ChM framework consists of three main components (i.e. the ChM, SoS Context View and Knowledge Retrieval framework components), and is gradually developed through four DSRM increments.

The development of the ChM framework component requires developing BPA-driven models to capture and represent the main processes of the ChM functional area and the dynamic relationships between them. It also requires semantically enriching the developed ChM-BPA models, then extending their enrichment by capturing the documents (e.g. Change Request Forms) and roles (e.g. Change Initiator) needed during handling their application. This chapter considers the instantiation of the first-DSRM-increment, which is adopted together with the second-DSRM-increment thereof for the development of the ChM component.

The first-DSRM-increment focuses on developing generalised Riva-based BPA models for the ChM functional area in the domains of Systems and Software Engineering. These models propose and represent generic ChM-related core processes and the dynamic relationships between them, based on existing CM standards, practices and guidelines. The first-DSRM-increment involves three main stages: the design and development stage; the demonstration stage; and the evaluation stage. The design and development stage aims to consider the most suitable approach for developing ChM-BPA. Consequently, the object-based Riva-BPA modelling approach is adapted and ChM-BPA is then modelled. The demonstration stage checks the applicability of the ChM-BPA in a real-world context based on assessing the extent to which it suits the needs, represents and covers the ChM processes adopted in a healthcare setting. The increment concludes with the evaluation stage, in which identified evaluation aspects for the ChM-BPA (e.g. syntax correctness) are applied based on utilising the evaluation framework adopted for this purpose (introduced in Chapter 3). Accordingly, the assessment is carried out at the King Hussein Cancer Center in Amman, Jordan. Based on the evaluation outcomes, the ChM-BPA is revised.

The rest of this chapter is organised as follows. Section 4.2 discusses the design and development aspects of the anticipated ChM-BPA models. Section 4.3 puts the developed ChM-BPA models under the consideration of real-world setting to assess its suitability in covering the ChM practices adopted in the investigated setting (i.e. ChM processes for CTAG-KHCC in Amman, Jordan). The related parts of the adopted evaluation framework applied to evaluate the developed ChM-BPA models are presented in Section 4.4. Section 4.5 summarises the chapter.

4.2 The Design and Development Stage for the ChM-BPA Models

During this stage, existing BPA-modelling classifications and approaches proposed by Dijkman, Vanderfeesten and Reijers (2016) were revisited and explored to select and enact a suitable approach to address the objectives of this research.

4.2.1 The Adoption of a BPA Modelling Approach

The literature on CM and ChM (reviewed in **Chapter 2**) offers a variety of different standards and guidelines incorporating a range of concepts and terminologies. This heterogeneity creates difficulties in building a consensus on key ChM processes, their scope and the relationships between them, especially when the application of ChM is scaled-up to be applied in a SoS context. In addition, the availability of different standards, practices and guidelines leaves a room to a wide range of different adoptions into implementation processes and procedures, which can vary between industries and even between organisations in the same industry. This absence of a clear understanding of and shared consensus on ChM was found to be a major contributor to the insufficiency of applying traditional ChM in a SoS context and therefore the failure of a large governmental SoS organisation (Bellomo and Smith, 2008).

Building on that, this increment focuses on building generalised conceptual models that capture and represent generic ChM core processes and the relationships between them using a BPA modelling approach. Generic BPA-driven models like this enable a clearer comprehension of ChM processes and a shared consensus on them, more effective governance and more efficient application of ChM in a heterogenic context such as SoS. Furthermore, they enable identifying semantic heterogeneities between ChM concepts. Thus, these ChM-BPA models can be considered as a platform for generalising a BPA model for ChM that can be semantically-enriched to resolve conceptual heterogeneities, share and agree on ChM knowledge amongst different ChM stakeholders in a SoS context. Moreover, these models can be adopted by the different levels of a SoS arrangement (i.e. the global and local levels of a SoS) to help in enforcing shared ChM policies and practices amongst them.

While a BPM captures and represents the detailed workflow of activities within a process that is used to achieve a business objective for an organisation (Havey, 2005), a BPA provides a more abstract level of representation that illustrates an overview of the structure of business processes within a business environment and the interrelationships between them (Ould, 2005).

This research focuses primarily on aspects related to ChM and SoS context that guide the work in addressing its aim and objectives and answer the identified research questions. Therefore, the emphasis is on building models that cover the ChM concepts and terminologies related to key generic ChM processes and relationships between them, rather than capturing the detailed activities of each ChM process. Accordingly, BPA modelling is adopted to develop generalised ChM-BPA models based on the investigation of standards and guidelines currently used in different Systems and Software Engineering domains. Hence, the research scope does not extend to the detailed application of ChM activities or procedures (e.g. detailed impact analysis, change planning and building, etc.) or to the creation of BPMs for the identified ChM processes. Working at the BPA level provides this research with an abstraction level that allows sufficient and easier understanding of the considered ChM aspects. Furthermore, it enables this research to maintain its generality and applicability to an audience of SoS stakeholders at varying management levels or varying industries. This research is mainly concerned with ChM and thus does not expand to investigating other functional areas of CM such as version management, system building or release management.

As discussed in Chapter 2, various methodological approaches to BPA modelling exist. They are classified into five main categories based on the way the business processes and the relationships between them are derived: the goal-based, the action-based, the object-based, the function-based and the reference-based approaches (Dijkman, Vanderfeesten and Reijers, 2016).

Current BPA modelling for the goal-based and action-based approaches differentiates between types of goals or actions as well as the type of relations between them (Dijkman, Vanderfeesten and Reijers, 2016). This may lead to different goal-based or action-based structures when using the different related approaches and therefore, to different BPA translations (Dijkman, Vanderfeesten and Reijers, 2016). Development of BPA models using these approaches is therefore seen particularly complex to identify and less stable in providing generic representation compared to the other existing approaches of different classifications (Dijkman, Vanderfeesten and Reijers, 2016). Therefore, using these approaches to model ChM processes and the relationships between them in order to achieve a high level of consensus and shared understanding between the different levels of stakeholders is considered not well-aligned with the objectives of this research. This is because the anticipated stakeholders (the audience of this research) may exist in complex and heterogeneous contexts and have different translations of goals or actions identified for the ChM application within their contexts.

More stable and relatively simple approaches to identifying BPA are those that focus on what a business environment does rather than how it does it. Function-based and object-based approaches are convenient starting points here (Dijkman, Vanderfeesten and Reijers, 2016). Business objects are divided into three classes: permanent objects, case objects and other objects (Dijkman, Vanderfeesten and Reijers, 2016). This classification can entail the identification of business functions. Furthermore, a function-based approach is limited in terms of relation types to the decomposition relation - that is, the decomposition of a business function into its finer business functions. Relation types that can be used to design an object-based structure include relations between permanent objects and case objects, decomposition relations and specialisation relations. Based on that, a BPA that results from applying an object-based BPA modelling approach is found by the researcher to be more comprehensive and convenient for addressing the objectives of this research than a function-based driven BPA. Therefore, this research adopts an object-based approach to BPA modelling, for its greater comprehensiveness and convenience.

In reference-model based approaches, an existing BPA is adapted to design a new BPA. However, approaches found in existing literature tend to focus more on BPMs than BPAs (Dijkman, Vanderfeesten and Reijers, 2016). Furthermore, if a BPA is developed using a reference-model based approach, it is developed as a by-product (Dijkman, Vanderfeesten and Reijers, 2016). The most often-used concepts in the investigated reference-model based approaches are business functions and industry segments, while the most often-used relations are generalisation and decomposition. These are all also covered by function- and object-based approaches, further justifying the selection of an object-based approach in this case.

The Riva-based BPA modelling approach (Ould, 2005) is one of two object-based approaches found in the literature (Dijkman, Vanderfeesten and Reijers, 2016). Based on identifying Essential Business Entities (EBEs) of a specific business nature within a specific business boundary, it is practical, methodological and relatively easy to use (Beeson, Green and Kamm, 2009). Riva-based models have also been semantically enriched by the srBPA ontology (Yousef and Odeh, 2014) and can be semi-automatically instantiated. The other existing object-based approach (Joosten, 2002 cited in Dijkman, Vanderfeesten and Reijers, 2016) proposes a BPA that is mainly driven by the identification of the documents and files in a business environment, and as far as the researcher is aware is not semantically-enriched.

The anticipated model for this research concerns ChM processes driven by the nature of the ChM business, not by documents alone, and also it is required to be semantically-enriched. In addition, a model that takes into consideration processes that resides at the operational (case processes), tactical (case management processes) and strategic (case strategic processes) levels facilitates the identification of ChM business processes related to a particular business management level and increases the awareness of ChM processes by the whole organisational management levels. The Riva-based approach meets these criteria and has accordingly been selected for this research. Further key reasons that contributed to this choice include: (i) the BPA available for the CTAG case study (the case study selected for the demonstration and evaluation stages of this research) is already built using the Riva-based BPA approach (Tbaishat *et al.*, 2018), and (ii) the BITA representation considered for the SoS context in this research adopts the BPAOntoSOA framework (Yousef, 2010), which relies mainly on Riva-based BPA models.

4.2.2 The Riva-based BPA Modelling Approach

Developing Riva-based Process Architecture Diagrams (PADs) involves a sequence of activities introduced by Ould (2005) that are aimed at eliciting, modelling, analysing and designing organisational processes to facilitate its comprehension management and, if necessary, re-engineering. The sequence of activities and related main outputs are shown in Figure 4.1. Furthermore, Table 4.1 offers a brief overview of the main Riva aspects.

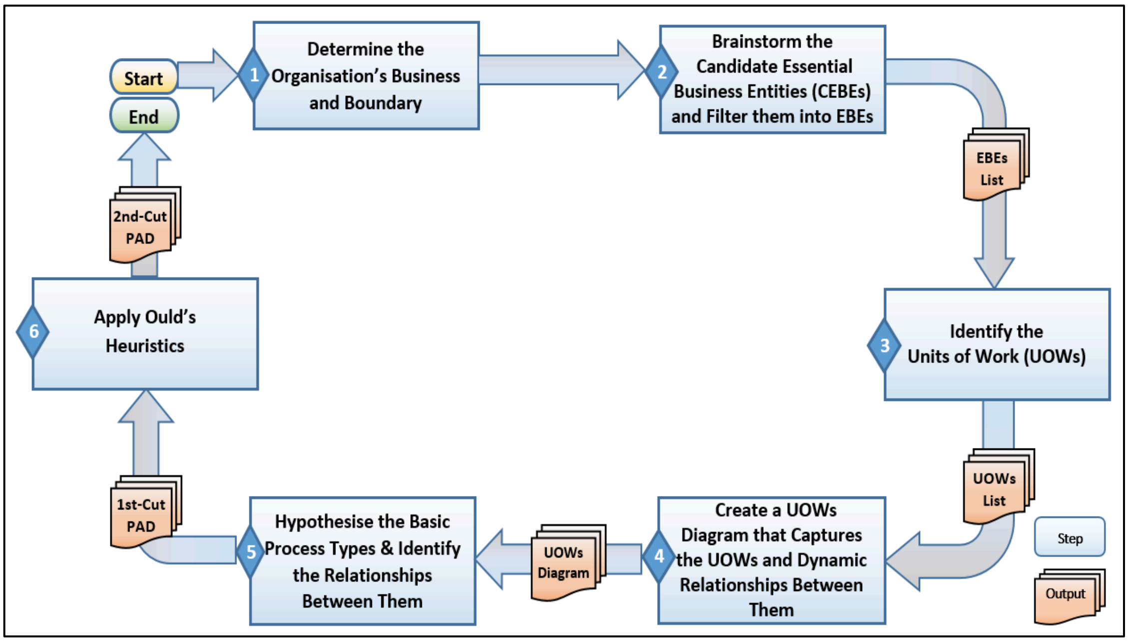


Figure 4. 1: Ould's fundamental activities for the Riva-based BPA modelling approach.

Table 4. 1: A brief description of the main aspects of the Riva-based BPA modelling approach.

Key Riva-based Aspect	Brief Description
Organisation	▪ The word 'Organisation' should be used to indicate "any group we are interested in" (Ould, 2005, p. 6).
Business	▪ The word 'Business' should be used to indicate "what the organisation gets up to" (Ould, 2005, p. 6).
Essential Business Entities (EBEs)	▪ One of the foundational concepts of the Riva approach is that the organisation's process architecture is built based on the EBEs that characterise the organisation's business. ▪ These entities are the subject matter of the organisation's business, i.e. in any business, some objects exist because of the business that the organisation is in.
Design Business Entities (DBEs)	▪ Identified entities which are there only because of the way the organisation has preferred to do its business. ▪ It is recommended to replace DBEs – where applicable – with the EBEs they present or implement (Ould, 2005, pp. 172- 173).
Units of Work (UOWs)	▪ The EBEs that will be depicted in an organisation's process architecture are the ones that an organisation is concerned with during their lifetimes because of the nature of the organisation's business; these are called UOWs (Ould, 2005, p. 176).

Table 4.1: A brief description of the main aspects of the Riva-based BPA modelling approach, "Continued".

Key Riva-based Aspect	Brief Description
UOWs Diagram	▪ A model that depicts the identified UOWs and the dynamic relationships between them.
Dynamic Relationships	▪ A dynamic interaction happens if, during the lifetime of an instance of a UOW (X), instances of another UOW (Y) are required/called for/led to...etc. (Ould, 2005, p. 180).
First-cut Process Architecture Diagram (1st-Cut-PAD)	▪ To model a First-Cut PAD: ▪ Assume that for each identified UOW there are three associated processes; a Case Process (CP); a Case Management Process (CMP); and a Case Strategy Process (CSP) (Ould, 2005, p. 183). ▪ The dynamic relationships between the UOWs shall be examined and translated into two distinct types of relationships and related interactions between the corresponding processes: these are service or task force relationships (Ould, 2005, p. 183).
Second-cut Process Architecture Diagram (2nd-Cut-PAD)	▪ The resulting 1st-Cut-PAD usually shows more than what truly exists. ▪ To model a 2nd-Cut-PAD, an identified set of heuristics shall be applied to reduce the 1st-Cut-PAD into a more close-packed 2nd-Cut-PAD (Ould, 2005, pp. 185-192).

4.2.3 The Riva-based BPA Modelling Approach For Generalised ChM-BPA Models

Having investigated the adopted Riva BPA modelling approach, two limitations were found, which could affect the aim of this research. Firstly, the Riva-based approach relies mainly on carrying out brainstorming sessions with specific stakeholders identified within a specific organisational boundary to elicit the main organising concepts that form the grounds for the BPA model (i.e. EBEs). This process is not well-suited to the creation of a generalised model for ChM-BPA based on using different sources of knowledge. The approach has therefore been adapted to drive the ChM-BPA models based on investigating and using different existing ChM frameworks in Systems and Software Engineering, then validating the resultant models by domain experts. Secondly, the Riva-based approach lacks the representation of the CSP concept and certain aspects related to modelling its relationships with its associated processes (i.e. CP and CMP). Accordingly, notations and heuristics for CSP modelling within the 1st-and-2nd-cut-PADs were proposed.

Following the adaption of the Riva-based BPA approach, the boundary and business of the ChM were identified. Different frameworks for ChM application in Systems and Software Engineering domains were explored and selected. The candidate EBEs for each investigated ChM framework were extracted and refined. For each resulting list of EBEs, filters were applied to identify the related UOWs. The identified UOWs from the different sources were linked together based on their general purpose or goals. A generalised set was selected and proposed to form a consolidated list of ChM-UOWs. A diagram showing these generalised UOWs and the dynamic relationships among them was developed. The various CPs, CMPs and CSPs associated with each proposed UOW were hypothesised, and the relationships between them were investigated and translated into a 1st-cut-PAD. Finally, Ould's heuristics (Ould, 2005) besides an adaption of them to model the proposed CSP elements were applied to produce a more compact 2nd-cut-PAD. By applying this adapted approach, generalised Riva-based BPA models were created and proposed for the ChM functional area. Figure 4.2 depicts the adapted Riva approach for producing a generalised ChM-BPA. Accordingly, the next sub-section discusses the application of the adapted Riva approach to the development of generalised ChM-BPA models.

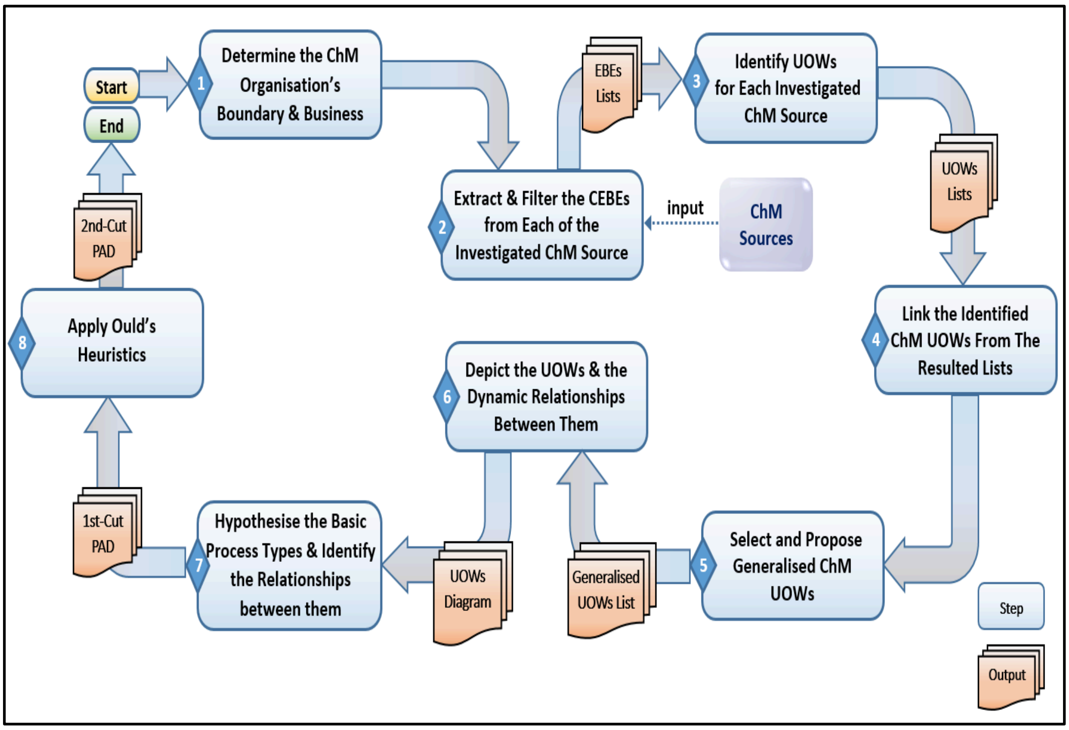


Figure 4. 2: The adapted Riva approach to produce a generalised ChM-BPA.

4.2.3.1 Determining the Organisation's Boundary and Business

The identification of an organisation's boundary and business is the 'base searchlight' that drives the 'scope' of the Riva approach activities and subsequently, their outcomes (Ould, 2005). The approach offers flexibility in identifying a business boundary, which might be a team, department, branch, whole organisation, or any boundary that might be considered as a business environment with a business nature. This flexibility enabled the researcher to identify a generic ChM organisational boundary and business. In this case, the boundary and business identified were: "*The part of an Information Systems-based organisation that is responsible for managing and monitoring a change to an identified configuration item from its proposal until closure*".

4.2.3.2 Extracting and Filtering Related Essential Business Entities

In the original Riva-based BPA modelling approach, this stage would involve brainstorming sessions with stakeholders within the identified boundary to identify a list of related candidate EBEs. That list would then be filtered, and the resulting refined list would form the basis for the development of new BPA models. However, as mentioned earlier, to achieve the generality desired in this research, this activity was adapted. Accordingly, (i) a variety of widely known standards and guidelines in systems and software CM were identified and collected, and the related ChM frameworks were investigated. Different key strings were used to search for the anticipated CM and ChM sources as shown in Figure 4.3; this resulted in the selection of 12 ChM standards and guidelines for the development of generalised ChM-BPA models, as presented in Table 4.2. (ii) Candidate EBEs (CEBEs) were investigated and extracted from each of the selected ChM sources. Questions suggested by Ould (2005) were also adopted and used in the course of this selection can be seen in Table 4.3. (iii) The candidate EBEs lists were filtered using Ould's (2005) recommended filters. Table 4.4 shows parts of the resulting EBEs lists and their sources. The full results are presented in Appendix A.

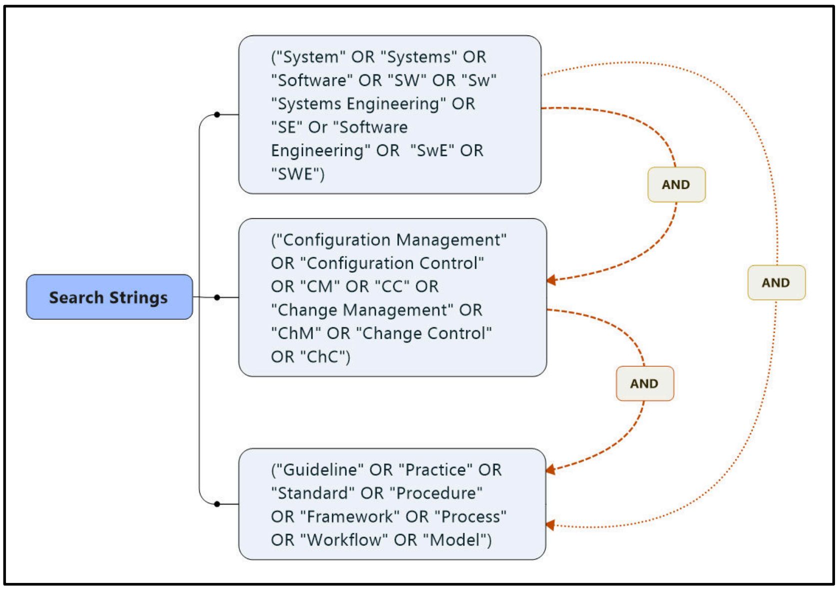


Figure 4. 3: Search strings used to search for related ChM standards and guidelines.

Table 4. 2: Selected CM standards and guidelines.

ID.	Source Name	Citation
1	Information Technology Infrastructure Library (ITIL) Service Transition	(AXELOS, 2011)
2	Software Engineering Book – Ian Sommerville	(Sommerville, 2016)
3	Software Configuration Management Handbook	(Leon, 2015)
4	EIA-649 B: Configuration Management Standard	(SAE International, 2011)
5	Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities	(INCOSE, 2015)
6	BS ISO/IEC/IEEE 15288:2015: Systems and Software Engineering- System Life Cycle Processes	(ISO/IEC/IEEE, 2015)
7	BS ISO 10007:2017: Quality Management Systems – Guidelines for Configuration Management	(ISO, 2017)
8	JSP 886:2015: Defence Logistic Support Chain Manual, Volume 7, Part 8.12 Configuration Management	(MoD, 2015)
9	BS EN 9223-104:2018 Program Management-Configuration Management	(BSI, 2018)
10	IEEE Std. 828:2012 Configuration Management in Systems and Software Engineering	(IEEE Computer Society, 2012)
11	MIL-STD-3046:2013 Department of Defence Interim Standard Practice – Configuration Management	(DoD, 2013)
12	Configuration, Change, and Release Management Policies and Procedures Guide	(Tarrani, 2012)

Table 4. 3: Suggested Ould's questions adopted for this research.

ID.	Suggested Question	Examples of Answers
1	What does Change Management focus on (the Eat and Drink of change management)?	Change Request, Change Record, Configuration Item, Change Approval, Change Plan, Change Schedule, Change Build, Change Test, Change Remediation, etc.
2	What services does the change management offer?	Change Validation, Change Impact Analysis, Change Communication, Change Coordination, Change Categorisation, Change Prioritisation, etc.
3	What things change management cannot get away from?	Owners Approval, Service Level Agreements (SLA), Projected Service Outage (PSO), Outsourced Resources Availability, etc.
4	Who are the external customers of change management?	Change Initiator, User, Manager, Owner, Developer, Help Desk Service, etc.
5	Who are the customers involved in change management?	Change Officer, Change Control Board, Evaluator, Builder, Tester, etc.
6	Are there things a customer can have, want, or do, that might be CEBE for change management?	Change Request Submission, Change Appeal, Business Cases, etc.
7	What things change management deals with in a routinely basis?	Change Form, Change Request, Change Closure, Change Evaluation, Change Update, etc.
8	What things change management would keep information on?	Change History, IDs, Assessments Reports, Authorisation Teams Lists, Dispositions Recommendations, Configuration Items, etc.
9	What are the change types/classifications that change management need to consider?	Major change, Significant change, Minor change, Normal change, Standard change, Urgent change, etc.
10	Who is responsible for achieving the change management goals?	Change officer, Change Manager, Change Advisory Board, Change Evaluator, etc.

4.2.3.3 Identifying Units of Work

This stage began with a review of the lists of EBEs from the previous stage, aimed at identifying UOWs, which are the entities that the ChM business must consider during their lifetimes. Table 4.5 shows part of the resulting lists of UOWs and their sources. The full lists are presented in Appendix A.

Table 4. 4: Parts of the resulting EBEs Lists.

ITIL (AXELOS, 2011)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Proposal	67	An EBE	
Change Creation	69	An EBE	
Change	69	An EBE	
Request for Change (RFC)	69	An EBE	
Change Request (CR)	69	An EBE	
Raising an RFC	69	Not an EBE (a/an)	
Request For Change Submission	71	An EBE	
Change Request Initiator	69	Not an EBE, (Role out of scope)	
Individual, (initiator)	69	Not an EBE, (Role out of scope)	
Organisation (As a request initiator)	69	Not an EBE, (Role out of scope)	
Business Unit, (initiator)	69	Not an EBE, (Role out of scope)	
Problem Management Staff (initiator)	69	Not an EBE, (Role out of scope)	
Major change	69	An EBE	
Change Proposal	69	An EBE	
Change Record	70 65	An EBE	
Change Document	71	An EBE	
Configuration Management System (CMS)	71	An EBE	
CMS Information Update	71	An EBE	
Change Logging	71	An EBE	
RFC Logging	71	An EBE	
Change Documentation (from documenting)	71	An EBE	
Change Recordation	69, 71	An EBE	
SW-Engineering Book (Sommerville, 2016)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
System Stakeholder (AS **Change Requester** in the diagram)	747	Not an EBE, (Role)	
Customer (As a CR initiator)	747	Not an EBE	
System Owner (As a CR initiator)	747	Not an EBE	
System User (As a CR initiator)	747	Not an EBE	
Beta Tester (As a CR initiator)	747	Not an EBE	
Marketing Department (As a CR initiator)	747	Not an EBE	
Developer (As a CR initiator)	747	Not an EBE	
Change Request Submission	747	An EBE	
Change Request (CR)	746/ 747	An EBE	
Bug Report	747	An EBE	
Additional functionality Request	747	An EBE	
Change Request Form (CRF)	747	A DBE	
Electronic CRF	747	A DBE	
CR Validity Check	748	An EBE	
Validity Checker	748	An EBE	
Customer Support (As a CR Validity Checker)	748	An EBE	
Application Support (As a CR Validity Checker)	748	An EBE	

Table 4. 5: Parts of the resulting UOWs Lists.

ITIL (AXELOS, 2011)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Proposal	67	An EBE	Not UOW, (input)
Change Creation	69	An EBE	**A UOW**
Change	69	An EBE	= RFC Submission
Request for Change (RFC)	69	An EBE	= RFC Submission
Change Request (CR)	69	An EBE	= RFC Submission
Raising an RFC	69	Not an EBE (a/an)	Not a UOW
Request For Change Submission	71	An EBE	**A UOW**
Change Request Initiator	69	Not an EBE, (Role out of scope)	Not a UOW
Individual, (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Organisation (As a request initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Business Unit, (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Problem Management Staff (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Major change	69	An EBE	A type of a Change
Change Proposal	69	An EBE	A type of a Change Request
Change Record	70 65	An EBE	Not a UOW, (Output)
Change Document	71	An EBE	= Change Record
Configuration Management System (CMS)	71	An EBE	Not a UOW, (Lifetime)
CMS Information Update	71	An EBE	**A UOW**
Change Logging	71	An EBE	= RFC logging
RFC Logging	71	An EBE	**A UOW**
Change Documentation (from documenting)	71	An EBE	**A UOW**
Change Recordation	69, 71	An EBE	= RFC Documentation
SW-Engineering Book (Sommerville, 2016)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
System Stakeholder (AS **Change Requester** in the diagram)	747	Not an EBE, (Role)	Not a UOW
Customer (As a CR initiator)	747	Not an EBE	Not a UOW
System Owner (As a CR initiator)	747	Not an EBE	Not a UOW
System User (As a CR initiator)	747	Not an EBE	Not a UOW
Beta Tester (As a CR initiator)	747	Not an EBE	Not a UOW
Marketing Department (As a CR initiator)	747	Not an EBE	Not a UOW
Developer (As a CR initiator)	747	Not an EBE	Not a UOW
Change Request Submission	747	An EBE	**A UOW**
Change Request (CR)	746/ 747	An EBE	Output of CR Submission
Bug Report	747	An EBE	= CR
Additional functionality Request	747	An EBE	= CR
Change Request Form (CRF)	747	A DBE	Not a UOW, (output)
Electronic CRF	747	A DBE	A Type of a CRF
CR Validity Check	748	An EBE	**A UOW**
Validity Checker	748	An EBE	Not a UOW, (Role)
Customer Support (As a CR Validity Checker)	748	An EBE	Not a UOW, (Role)
Application Support (As a CR Validity Checker)	748	An EBE	Not a UOW, (Role)

4.2.3.4 Linking the Units Of Work

This stage involved investigating and linking the UOWs from the different lists based on their main general objectives. For example, the 'Request For Change Submission' UOW from the ITIL guidelines (AXELOS, 2011) was linked to the 'Change Proposal' UOW from the ISO 10007 standard (ISO, 2017) and the 'Engineering Change Proposal' UOW from the MIL-STD 3046 standard (DoD, 2013) as they all have the same general objective of initiating a potential change.

Similarly, the ‘Change Building and Testing Authorisation’ UOW from the ITIL guidelines (AXELOS, 2011) was linked to the ‘Change Request Approval’ UOW from the CCRM policies and procedures guide (Tarrani, 2012) and to the ‘Engineering Change Proposal Approval’ UOW from the Systems Engineering Handbook (INCOSE, 2015) as they all work towards the approval or authorisation of a submitted change request.

Table 4.6 shows part of the linked UOWs. The full list is shown in Appendix B. In the Appendix, all the identified UOWs in the previously captured UOWs lists were investigated and linked together within the presented table. Each row of the table represents a series of ChM-UOW terminologies, where they have almost the same general objective for their application. Furthermore, the table partitions the rows into seven ChM stages, with each stage ordered in terms of their ordering in the normal application of ChM, i.e. from Change Request Submission and Initiation through Change Plan and Schedule to Change Closure.

4.2.3.5 Selecting and Proposing a Consolidated List of Generalised UOWs

At this stage, a consolidated list of generalised UOWs was proposed for ChM in systems and software engineering. The names selected are catch-all names that represent the general purpose of the individual UOWs that they represent. Therefore, each of the UOWs identified at earlier stages, in this consolidated list. For example, the Request For Change Submission, Change Request Submission, Request For Change (RFC), Request For Variance (RFV), Change Request Origination, Change Proposal, Change Request and Engineering Change Proposal (ECP) Submission UOWs are all represented by one proposed generalised UOW, that is the Change Request Submission UOW.

Table 4.7 presents the proposed set of generalised ChM-UOWs. The table presents two main columns. The first column entails a number, which indicates the ID of the UOWs row in the table that shows the UOWs linked to each other (as in Table 4.6) that the proposed generalised UOW represents. The second column represents the UOW name proposed for the consolidated UOW. It is worth mentioning that four of the proposed UOWs, coloured in green, were derived from a number of existing UOWs to achieve a specific purpose similar to UOWs already captured in different ChM stages. For example, in the ‘Change Assessment’ stage there was an ‘Integrated Assessment’ UOW; therefore, the researcher proposes an ‘Integrated Plan and Schedule’ UOW to maintain the balance between the Assessment and Planning stages.

Table 4. 6: Selections from the linked UOWs.

#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	RFC Submission	Change Request Submission	RFC Submission	Request for Change	Change Request Preparation & Submission	Change Request	Request for Change	Change Proposal	Change Proposal	Change Request	ECP Submission	Change Request
2			CR Review (For completeness)									
3	Change Creation		Change Initiation	Change Initiation				Change Initiation	Change Initiation	Change Initiation		
4	RFC Logging	CR Logging	Tracking Number Assignment	Change Identification	CR Identification	Change Identification	RFC & RFV Identification	Change Identification	Change Identification		Change Identification	
5	RFC Review	CR Validity Check	Pre-Evaluation Screening								ECP Revision (initial after submission)	
6			Change Classification (Category & Priority, if the CR valid)	Change Classification	Request Priority Validation						Change Classification & Prioritisation (Initial)	
7				Preliminary Change Coordination (for justification & Assessment)								
8				Change Justification Provision							Change Justification	
9				Approval Authority Identification (initial stage)								
10	CMS Information Update		CR Tracking Database Update									
11	Change Documentation Update	CRF Update	CR Files Update	Change Documentation		Change Recordation	RFC & RFV Recordation	Change Documentation	Change Documentation		Change Documentation	Change Documentation

Table 4. 7: Proposed generalised UOWs.

ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW
1	Change Request Submission	2	Change Request Review for Clarity and Completeness	3	Change Initiation	4	Change Logging
5	Change Validation	6	Change Category and Priority Check	7	Change Validation Coordination	8	Change Justification
9	Initial Disposition Authority Identification	10	Configuration Management (CM) System Update	11	Change Documentation Update	12	Change Initiation Feedback to Change Request Imitator
13	Change Closure	14	Change Assessment and Evaluation	15	Change Assessment Coordination with Impacted Parties	16	Impacted Parties' Change Assessment
17	Formal Change Evaluation	18	Integrated Change Assessment	19	Implementation Analysis	20	Impact Assessment
21	Cost Analysis	22	Risk and Benefits-based Assessment	23	Category and Priority Analysis	24	Initial Plan and Schedule Determination
25	Resources Assessment	26	Applicability Analysis	27	Change Assessment and Evaluation Documentation	28	Change Closure
29	Change Disposition	30	Change Disposition Authority Identification	31	Change Integrated Assessment Submission to the Dispositioning Authority	32	Dispositioning Authority Change Disposition
33	Change Appeal	34	Change Closure	35	Change Disposition Feedback to CR Initiator	36	Change Disposition Documentation
37	Change Disposition Dissemination	38	Change Update	39	Authorised Change Plan and Schedule	40	Authorised Change Submission to Planning Authority
41-46	**Authorities' Change Plan and Schedule**	41-46	**Change Integrated Plan and Schedule**	41	Implementation Plan	42	Change Schedule

Table 4.7: Proposed generalised UOWs, "Continued".

ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW	ROW ID	Proposed Representative UOW
43	Verification Plan	**44**	Projected Service Outage Plan	**45**	Remediation Plan	**46**	Release and Deployment Plan
47	Change Plan and Schedule Review	**48-53**	**Authorised Change Build and Test**	**48**	Authorised Change Submission to Build and Test Authorities (Coordination)	**49**	Change Build
50	Change Test	**51**	Change Build and Test Documentation	**52**	Change Build and Test Evaluation Coordination	**53**	Change Build and Test Evaluation
54	Change Build and Test Evaluation Outcomes Submission to Related Change Authorities	**55**	Change Build and Test Evaluation Review for Deployment Authorisation	**56**	Change Remediation	**57-60**	**Change Release and Deployment**
57	Change Deployment Coordination	**58**	Change Deployment	**59**	Change Release	**60**	Status Accounting
61	Change Final Evaluation	**62**	Formal Change Evaluation	**63**	Change Check	**64**	Change Final Evaluation Documentation
65	Stakeholders'' Disposition of Final Evaluation	**66**	Follow-up Action	**67**	Configuration Management System Update	**68**	Change Closure
69	Change Update						

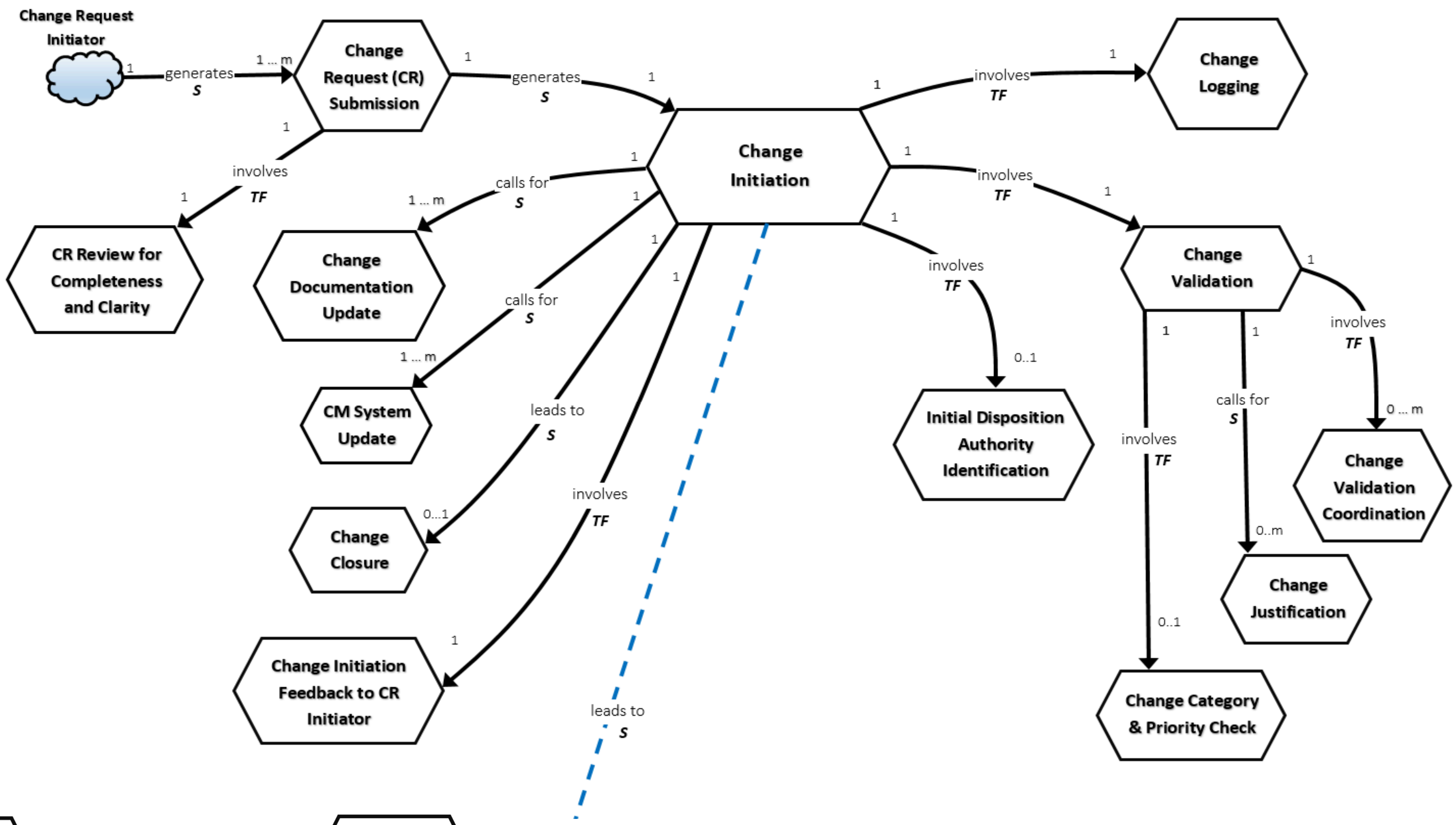
4.2.3.5 Producing a UOWs Diagram

The next important activity in the adapted Riva approach is to model the proposed generalised UOWs and the dynamic relationships between them in a diagram. Dynamic relationships between UOWs occur if, during the lifetime of a case of UOW (X) it generates - (calls for, leads to, needs, activates, requires, involves...) – a case or cases of another UOW (Y). The main aim of the diagram is to present, not a flow of sequenced processes or a hierarchy of processes, but a network of processes that interact in dynamic relationships. Figure 4.4 shows a section of the developed diagram. The full UOWs diagram is presented in Appendix C. It is worth to mention that the UOWs diagram is considered as the foundational model that BPA models are derived from.

4.2.3.5 Producing a First-Cut Process Architecture Diagram

The next step towards a Riva-based ChM-BPA is to model a 1st-cut-PAD from the UOWs diagram. As mentioned in **Section 4.2**, this stage depends on hypothesising three types of processes for each identified UOW: the CP, the CMP and the CSP. Following this, the service and task force relationships are examined and translated as appropriate into a set of relationships between the hypothesised processes.

Having investigated the literature, aspects related to CSP modelling were not represented in any of the Ould's formally published work. Ould stated "we shall generally omit the CSPs from the process architecture unless they are of specific interest for our purpose" (Ould, 2005, p. 184). Similarly, CSP modelling had a limited presence in Ahmad's (2015) work on using an adapted srBPA ontology to semantically derive enterprise information from a Riva-based BPA framework. Ould has made the important point that CPs and CMPs do not cover all types of activities taking place in an organisation (2005, pp. 166-168). CPs present processes at the operational level of the organisation, and CMPs present processes at the tactical level, but other processes taking place at the strategic level of the organisation are not covered by these; this is the role of CSPs. Ould stated, "A CSP has its CP and CMP as subject matter" (Ould, 2005, p. 166). That is, a CSP aims to investigate the following: what internal or external factors may affect a UOW and how they can be dealt with; the changing nature, rates and volumes of a UOW; the performance of a UOW-associated CP and CMP, and their adherence to organisational procedures. In addition, Ould emphasised that "the outcome of the work of a CSP is likely to be changes or instructions to its associated CP and CMP" (2005, p. 167).



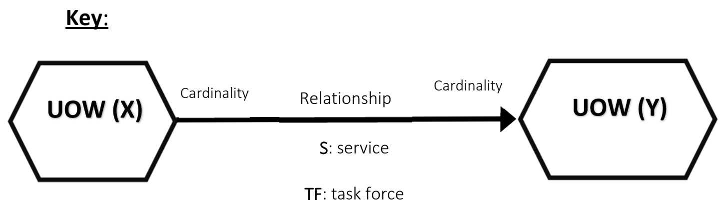


Figure 4. 4: Selection from the developed UOWs diagram.

The CSP concept modelling in Riva-based PADs was extended to serve the needs of this research. Each CSP is associated with a CP and CMP, for which its purpose is to maintain a strategic view. The CSP investigates the internal and external environments of a UOW in order to govern and drive the work of the associated CP and CMP at the operational and tactical management levels, respectively. A CSP, therefore, has a direct effect on middle management processes (the associated CMP) and an indirect effect on operational processes (the associated CP). This research proposes that the CSP serves a supervisory role, governing and directing the CMP and CP to ensure they adhere to a common strategic view. Additions to the 1st-and-2nd-cut-PADs' notations were proposed to reflect this. Figure 4.5 shows an example of the proposed additions to the model, which appear in blue. The proposed additions are the same for both service and task force relationship translations.

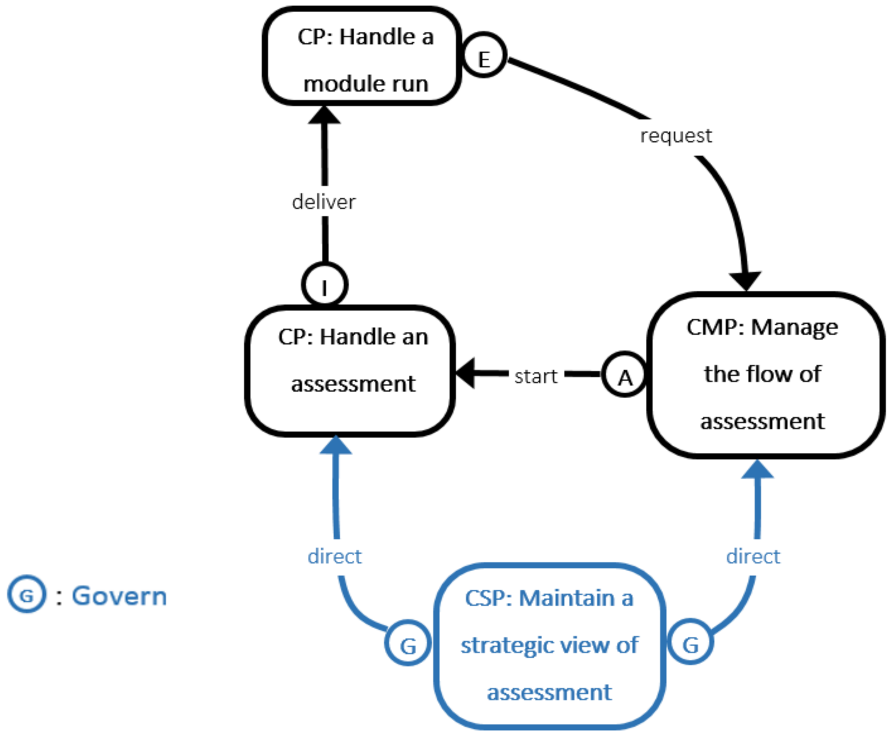


Figure 4. 5: Proposed additions to the 1st-cut-PAD to reflect CSP relationships.

Figure 4.6 shows a section of the 1st-cut-PAD, translated from the UOWs diagram, with proposed additions to include CSP modelling.

4.2.3.6 Producing a Second-Cut Process Architecture Diagram

At this final stage of the Riva-based approach, Ould's heuristics (2005, pp. 185-192) were applied as appropriate to turn the 1st-cut-PAD into a more compact and practical 2nd-cut-PAD. Table 4.8 shows a summary of how Ould's heuristics were applied to the ChM-BPA models and adapted for the proposed CSP concept modelling. Figure 4.7 presents part of the resulting 2nd-cut-PAD.

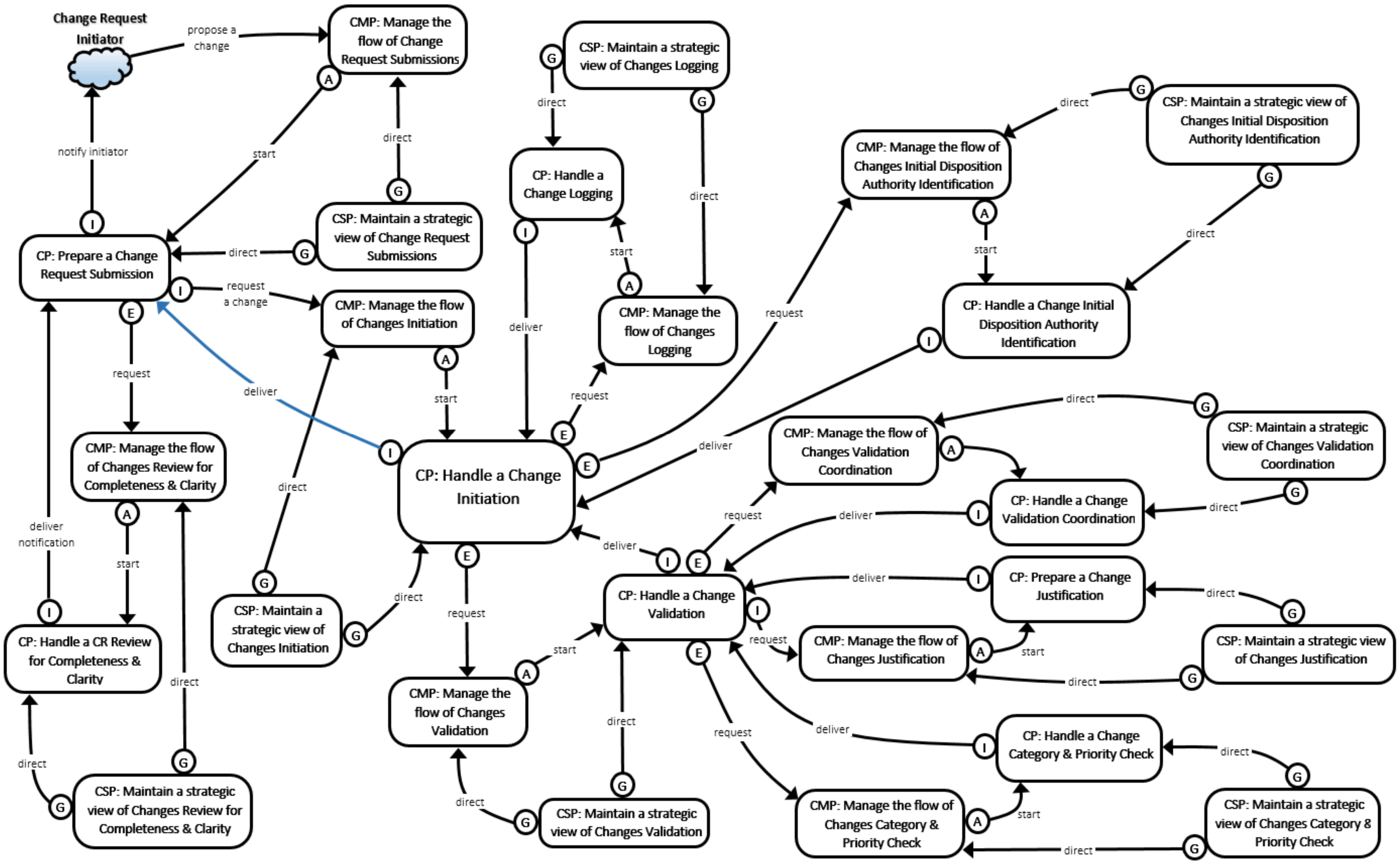


Figure 4. 6: Section of the 1st-cut-PAD.

Table 4. 8: Adaption of Ould's heuristics.

<table>
<tr><th>Ould's Heuristic</th><th>The applicability of the heuristic to the developed ChM-1st-Cut-PAD</th><th>Adaption for CSP concept modelling</th></tr>
<tr><td>(1) Folding a task force CMP into the requesting CP:</td><td>▪ This heuristic was the most applied heuristic to the ChM-1st-Cut-PAD as the model contains a high number of task force relationships.</td><td rowspan="2">▪ For the purpose of this research, when a decision was made to fold any of the CMPs into the requesting CP as a result of applying the first or the second heuristics, the associated CSP is folded as well.

▪ It is assumed that when the CMP role is folded and incorporated into the requesting CP for reasons stated in the first or the second heuristics, the CSP role should also be folded, but here it will be incorporated into the requesting CP's associated CSP.

▪ Therefore, in addition to the original CP and CSP roles, the requesting CP will be in charge of managing, ordering, prioritising, etc. the requested CP's flow of cases. In addition, the CSP associated with the requesting CP will be in charge of maintaining a strategic view of the requested CP and its flow of cases.</td></tr>
<tr><td>(2) Dealing with collections:</td><td>▪ This heuristic was not applied to the developed ChM-1st-Cut-PAD, as none of the remaining proposed UOWs is part of another UOW collection.</td></tr>
<tr><td>(3) Dealing with delivery interactions and delivery chains:</td><td>▪ To maintain the generality of the developed BPA-models, this heuristic was not applied.</td><td>▪ This heuristic does not affect the existence of the CSP concept. Therefore, no adaptation was proposed.</td></tr>
<tr><td>(4) Dealing with 1:1 'generates' relationships:</td><td>▪ Although a good number of the existing relationships have 1:1 cardinality, service relationships were not folded into the requesting CPs in accordance with recommendations about exceptions to this rule and to maintain the generality of the models.</td><td rowspan="2">▪ For the purpose of this research, if a CMP is folded into the requesting CP as a result of applying the fourth or the fifth heuristics, it is recommended to maintain the CSP that is related to the requested CP. In addition, if the 'generate' relationship source is considered an outside-world entity (e.g. Change Initiator), and it has been decided to omit the CMP that corresponds to the requested CP because of applying the fifth introduced heuristic, it is recommended in this research to maintain the CSP that corresponds to the requested CP.</td></tr>
<tr><td>(5) Dealing with empty CMPs:</td><td>▪ For this research, the CMPs remaining after applying heuristics were not assumed to be empty. Hence, they were not removed from the 2nd-Cut-PAD.</td></tr>
</table>

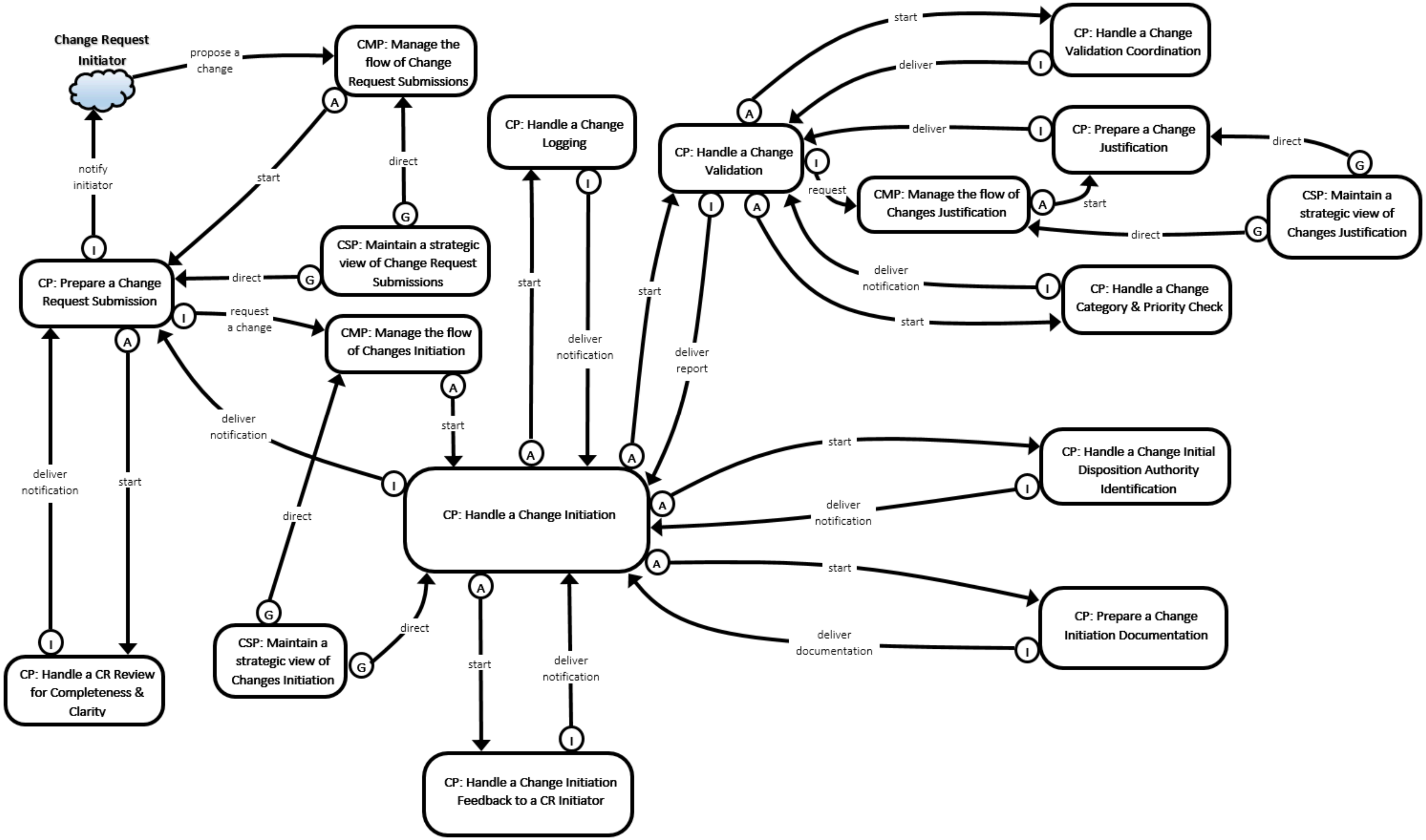


Figure 4. 7: Section of the 2nd-cut-PAD.

4.3 DEMONSTRATION OF THE ChM-BPA MODELS

Generally, this key stage of the DSRM process model (Peffers *et al.*, 2007) focused on demonstrating how the developed artefact addresses its objectives in a real-world context. Accordingly, the generality of the ChM-BPA models was assessed by checking the extent to which they suit the needs of, represent and cover real-world ChM practices in a healthcare setting (the King Hussein Cancer Center, Amman, Jordan). This assessment, combined with the subsequent evaluation stage, involved checking the ChM-BPA models against change processes adopted at CTAG-KHCC. Table 4.9 shows key KHCC processes and how they are covered by ChM-BPA processes.

Table 4. 9: Coverage of the CTAG ChM processes by the proposed ChM processes.

KHCC-ChM Key Process	Corresponding ChM-BPA Process
RFC Submission	Change Request Submission
Change Creation	Change Initiation
RFC Logging	Change Logging
Change Documentation Update	Change Update
Change Assessment & Evaluation	Change Assessment & Evaluation
Impact & Resource Assessment	Resources Assessment
Risk & Benefits-based Assessment	Risk & Benefits-based Assessment
Change Build & Test Authorisation	Change Disposition
Appeal	Change Appeal
Rejected Change Review & Closure	Change Closure
Change Planning & Scheduling	Authorised Change Plan and Schedule
Change Projected Service Outage	Projected Service Outage Plan
Remediation Planning	Remediation Plan
Change Build Coordination	Change Build
Change Remediation	Change Remediation
Test Coordination	Change Test
Change Deployment Authorisation	Change Build and Test Evaluation Review
Change Deployment Coordination	Change Deployment
Change Review	Change Final Evaluation
Change Record Closure	Change Closure

Investigation revealed that all key CTAG-KHCC ChM processes are covered by the proposed ChM-BPA. When this result and the developed ChM-BPA were communicated to CTAG-KHCC stakeholders, they found that the ChM processes presented in the proposed ChM-BPA are more comprehensive than the ones they currently use. In addition, they expressed interest in adopting the ChM processes detailed in the developed ChM-BPA to guide the application of ChM at their organisation.

4.4 EVALUATION OF THE ChM-BPA MODELS

During the previous two DSRM stages, the Riva-based BPA modelling approach was adapted and utilised to develop generalised ChM-BPA models. In this DSRM stage, the evaluation of aspects related to the design and utility of this developed component was carried out.

This stage emphasises the verification and validation of the resulting ChM-BPA models, including the adapted aspects, based on the evaluation framework adopted for this research (discussed in **Chapter 3**). Table 4.10 presents the part of the evaluation framework related to evaluating the ChM-BPA models. The table presents an abstract description of the objectives for evaluation. In addition, the table lists the adopted evaluation types, criteria and techniques. Moreover, Table 4.11 provides a description of the adopted verification and validation criteria.

Table 4. 10: The part of the evaluation framework related to evaluating the ChM-BPA models.

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="6">(First-DSRM-Increment)

Evaluating the Generalised BPA Models for ChM:

(1) To inform the adherence of the developed generic ChM-BPA models to the adapted Riva-based BPA approach.

(2) To inform the validity of the ChM-BPA models from BPA and ChM points of view.

(3) To inform the validity of the adaptions made to the Riva-based BPA modelling approach.

(4) To inform if the ChM-BPA meets the identified objectives that motivated its development.</td><td colspan="2">Verification</td><td>Type of Assessment</td></tr>
<tr><td>Consistency</td><td>Completeness</td><td rowspan="5">Extensive walkthrough-based questionnaire through semi-structured interviews with domain experts</td></tr>
<tr><td colspan="2">Validation</td></tr>
<tr><td>Correctness</td><td>Completeness</td></tr>
<tr><td colspan="2">Appropriateness</td></tr>
</table>

Table 4. 11: Adopted criteria for the verification and validation of the developed ChM-BPA models.

Verification Criteria	Description
Consistency	▪ The resulting ChM-BPA models adhere to the structure and syntax of the Riva-based BPA modelling approach.
Completeness	▪ The ChM-BPA models contains the entire original and adapted Riva-based BPA elements.
Validation Criteria	**Description**
Correctness	▪ The ChM elements captured and represented are correct from ChM and BPA point of views.
Completeness	▪ All the related ChM-BPA elements are captured and presented in the models.
Appropriateness	▪ The ChM-BPA meets the identified objectives that motivated its development.

To ensure the validity and quality of the developed ChM-BPA models through an evaluation process that entails human participation, appropriate subjects/participants should be selected. However, the criteria that are used to select the participants must ensure the selection of knowledgeable and experienced subjects in the ChM and BPA domains alongside the willingness of the participants to take part in the activity. the proposed selection criteria should focus on competencies relating to qualification, position, and professional experience as well. These conditions can form a qualifying set of criteria that can be used to pre-qualify candidate participants, who can then be formally asked to confirm their requirements for participation (Yin, 2014).

Accordingly, the selection of participants in this study was based on the following guidelines:

1) Having sound knowledge and understanding of business process architecture and/or business modelling.
2) Having an understanding of the entire business processes and workflows of the CTAG-SoS arrangement.
3) Having extensive working experience in one or more of the CTAG constituent business areas, with a full understanding of all the processes and roles inside that constituent business area.
4) Having sound knowledge of the CTAG constituent systems, the supported services, different roles, and the linkages of these to the business processes of the organisation.
5) Having experience with the CTAG change management framework.
6) Having knowledge and experience of the current change management frameworks.

Based on applying the above-mentioned criteria, the selected sample size for the study was around ten participants distributed between the CTAG-SoS senior management, CTAG-constituent business areas management members, BPA and BPs modelling engineers, ChM officers and managers, and IT support technical members and managers. The recruiting of these participants was done through the following actions:

1) The chair of the research council with the cooperation of the Chief Operating Officer (COO) at KHCC selected the potential participants for the semi-structured interviews and cases walkthroughs. The selection of these candidate participants is based on one or more of the previously defined selection criteria.
2) Invitations to the candidate participants were sent by the chair of the research council or the COO through the KHCC-CTAG email following their own internal procedure asking them for their willingness to participate in the study. Participants have the right to accept the invitation as volunteers or reject the invitation without making any further clarifications. There is no penalty for rejecting the invitation. If they were willing to participate, invitations were sent to the participants in addition to a summary of the study. Furthermore, each of the participants was provided with an information sheet and consent sheet to be signed at the day of study.

To this end, an extensive walkthrough-based questionnaire was developed for use in semi-structured interviews with experts at KHCC and the CTAG in particular. Figures 4.8 to 4.11 show parts of the questionnaire used. Further segments that show examples of each section of the conducted questionnaire can be found in Appendix D.

Questionnaire

UWE Bristol | University of the West of England

Faculty of Environment and Technology,
Software Engineering Research Group (SERG).

Dear Participants,

This Questionnaire is part of a PhD research work namely **a Semantically-enriched and Business Process Architecture-driven Change Management Framework for Change Management in System of Systems Context.** It aims to verify and validate a generalised "Change Management Business Process Architecture" model developed for the purpose of this research. Participants are asked to answer different questions related to various elements of this model. The provided feedback is highly valuable for the research and will allow to further develop and mature the framework for the next stages of the research.

Please note that to protect the participant's confidentiality, no personal information will be collected that would identify any of the participants, and the results will be used only for scholarly purposes and may only be shared amongst members of the research team.

This questionnaire consists of the following eleven sections:

- The **First Section** includes questions regarding the respondent's background;
- The **Second Section** includes questions regarding the organisational boundaries and business scope for change management;
- The **Third Section** investigates the standards, practices and guidelines used to drive the development of the change management framework;
- The **Fourth Section** investigates the elicited Essential Business Entities (EBEs).
- The **Fifth Section** investigates the validity of the filtered Units Of Work (UOWs).
- The **Sixth Section** includes question to validate the UOWs Diagram's elements.
- The **Seventh Section** includes questions that help to validate the proposed Case Strategy Process translation;
- The **Eighth Section** investigates the proposed application of Ould's heuristics for the selected Case Strategy Process concepts and its translation;
- The **Ninth Section** includes questions to validate the proposed second cut process architecture diagram for change management.

It would be very much appreciated if you could complete the attached questionnaire and return it back to the researcher. Thank you ever so much for your valuable participation in this research. Please do not hesitate to contact the researcher if you have any questions regarding this questionnaire or the research.

Figure 4. 8: Part of the questionnaire used to evaluate the development of the ChM-BPA models.

Q4. To what extent do you agree that the stated standards and guidelines listed **are sufficient** to drive the development of a generalised change management process architecture?

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Figure 4. 9: Part of the questionnaire used to evaluate the development of the ChM-BPA models.

Q1. To what extent do you agree with the following as Consolidated and Generic Change Management Units of Work (UoWs); (i.e. represent the main entities that the change management process needs to manage its lifetimes and adhere to Ould's UOW Filters?

ID	UOW Name	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	Comment
1	Change Request (CR) Submission	☐	☐	☐	☐	☐	
2	CR Review for Completeness and Clarity	☐	☐	☐	☐	☐	
3	Change Initiation	☐	☐	☐	☐	☐	
4	Change Logging	☐	☐	☐	☐	☐	
5	Change Validation	☐	☐	☐	☐	☐	
6	Initial Impacted Partied Identification	☐	☐	☐	☐	☐	
7	Change Validation Coordination	☐	☐	☐	☐	☐	
8	Change Justification	☐	☐	☐	☐	☐	
9	Change Category and Priority Check	☐	☐	☐	☐	☐	
10	Initial Disposition Authority Identification	☐	☐	☐	☐	☐	

Figure 4. 10: Part of the questionnaire used to evaluate the development of the ChM-BPA models.

Q1. To what extent do you agree with the following elements: Name, Type (Service, Task Force) and Cardinality that are related to each 'Generate' relation presented in the above UOW's diagram part?

Relation's ID	Element	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	Comment
G1	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G2	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G3	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G4	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	

Figure 4. 11: Part of the questionnaire used to evaluate the development of the ChM-BPA models.

The conducted evaluation raised a number of key points. Table 4.12 presents a summary of the evaluation results and the concerns that were raised by experts interviewed during the evaluation stage.

Table 4. 12: Summary of the evaluation results and concerns based on feedback from domain experts.

Evaluation Objective	Summary of Results or Concerns	Brief Description of the Results or Raised Concerns
(1) Informing the validity of the adaptation of the Riva-based approach	▪ Experts were in complete agreement with the adaptations made to the Riva-based approach to investigate EBEs and elicit consolidated UOWs. ▪ Experts partially agreed with the proposed modelling aspects for CSP. An updated version of the CSP modelling translations was agreed.	▪ Based on the stated role of the CSP concept (Ould, 2005), it is hypothesised that the CSP governs the associated CMP and CP by directing the associated CMP and guiding the associated CP to ensure adherence to a common strategic view.
(2) Informing the adherence of the ChM-BPA models to the adapted Riva-based approach	▪ Experts agreed that the developed ChM-BPA models adhere to the adapted Riva-based BPA modelling approach.	▪ All necessary elements for developing ChM-BPA models based on adapting the Riva-based BPA modelling approach were found to have been addressed and applied correctly.
(3) Informing the validity of developed ChM-BPA models' elements from ChM and BPA points of view.	▪ Generally, the ChM-model's elements were found valid. However, some concerns were raised in relation to a number of investigated elements.	▪ A number of concerns were raised regarding some elements of the ChM-BPA model, e.g. combining the 'CM System Update' and 'Change Update' UOWs into one UOW to be called 'Change Record', modifying the cardinality of the 'Change Initiation Feedback' to be '1..M', and the need for adding an 'Initial Impacted Parties Identification' UOW.
(4) Informing the generality and practicality of the developed ChM-BPA models	▪ Experts found the developed ChM-BPA models comprehensive and believed they could be successfully adopted for their domain.	▪ Investigation reveals that all key CTAG-KHCC ChM processes are covered by the proposed ChM-BPA. When this result and the developed ChM-BPA were communicated to CTAG-KHCC stakeholders, they found that the ChM processes presented in the proposed ChM-BPA are more comprehensive than the ones they currently use. In addition, they expressed interest in adopting the ChM processes detailed in the developed ChM-BPA to guide the application of ChM at their organisation.

Table 4.12: Summary of the evaluation results and concerns based on feedback from domain experts, "Continued".

Evaluation Objective	Summary of Results or Concerns	Brief Description of the Results or Raised Concerns
(5) Informing if the developed ChM-BPA meets the identified objectives that motivated its development	▪ Experts found that the developed ChM-BPA models address its identified objectives subject to be semantically-enriched and enabling semantic heterogeneity resolution.	▪ The main aim identified for the development of the ChM-BPA models is the development of generalised ChM models that capture key ChM processes and the relationships between them. These developed models can be used to achieve a common understanding of and consensus on the application of ChM amongst different stakeholders at different management levels. Moreover, these developed ChM-BPA models can be adopted by the different levels of an SoS arrangement to enforce shared standardised application of ChM. ▪ Experts agreed that the developed models are partially sufficient to achieve these objectives. This is due to the fact that the developed Riva-based BPA models mainly capture the syntax and structure of the ChM process architecture rather than their semantics. Furthermore, the models did not capture and represent the detected concepts heterogeneity. Therefore, the developed ChM-BPA is considered as a platform that enables the semantic enrichment of the intended ChM aspects.

4.5 Revisiting the ChM-BPA Models

As mentioned in the previous section, a number of aspects have been raised as concerns by the interviewed domains experts at KHCC. Table 4.13 shows the main detailed concerns raised by the experts, which resulted in revisiting the developed models in order to be more consistent, correct and complete from the received BPA and ChM point of views. In relation to that, Figures 4.12 to 4.15 show examples of how the identified concerns were reflected in the adaptation of the Riva-based BPA approach and the modelled generalised ChM-BPA.

Table 4. 13: Main concerns that were raised by the interviewed domains experts and reflected in the developed ChM-BPA models.

#	Description
1	Merging the 'Change Documentation Update' and the 'CM System Update' UOWs into one UOW to be named 'Change Record'.
2	Adding the 'Closure Feedback To Initiator' UOW to be generated and managed by the 'Change Closure' UOW with '1..1' cardinality.
3	Adding the 'Change Initiation Documentation' UOW to be generated and managed by the 'Change Initiation' UOW with '0..M' cardinality.
4	Modifying the cardinality of the 'Change Initiation Feedback to Change Initiator' to be '0..M'.
5	Adding the 'Change Model Selection' UOW to be generated and managed by the 'Change Initiation' UOW with '0..1' cardinality.
6	Modifying the name of the 'Change Validation' UOW to be 'Change Initial Validation'.
7	Adding the 'Change Initial Impacted Parties Identification' UOW to be generated and managed by the 'Change Initial Validation' UOW with '1..1' cardinality.
8	Modifying the name of the 'Change Category & Priority Check' UOW to 'Change Category & Priority Validation'.
9	Merging the 'Change Validation Coordination' and 'Change Justification' into one UOW to be named 'Change Initial Validation By Impacted Parties'.
10	Merging the 'Change Assessment Coordination with Impacted Parties' UOW into the 'Change Assessment & Evaluation' UOW.
11	Adding the 'Impacted Parties List Validation' UOW to be generated and managed by the 'Change Assessment & Evaluation' UOW with '1..1' cardinality.
12	Modifying the name of the 'Applicability Analysis' UOW to 'Applicability Assessment' UOW.
13	Modifying the name of the 'Initial Plan & Schedule Determination' to 'Initial Plan and Schedule'.
14	Adding the 'Change Assessment & Evaluation Feedback to Change Initiator' UOW to be generated and managed by the 'Change Assessment & Evaluation' UOW with '0..M' cardinality.
15	Adding the 'Change Record' UOW to be called by the 'Change Assessment & Evaluation' UOW with '1..M' cardinality.
16	Merging the 'Change Integrated Assessment Submission to Dispositioning Authority' UOW into the 'Change Disposition' UOW.
17	Modifying the name of the 'Change Dispositioning Authority Identification' into 'Change Disposition Authority List Validation'.
18	Adding the 'Change Appeal Feedback to Change Initiator' UOW to be generated and managed by the 'Change Appeal' UOW with '1..1' cardinality.
19	Modifying the cardinality of the 'Change Disposition Documentation' and 'Change Disposition Dissemination' UOWs to be '1..M'.

Table 4.13: Main concerns that were raised by the interviewed domains experts and reflected in the developed ChM-BPA models, "Continued".

#	Description
20	Merging the 'Authorised Change Submission to Planning Authorities' UOW into the 'Authorised Change Plan and Schedule' UOW.
21	Splitting the 'Implementation Plan' UOW into the 'Build Plan' and 'Test Plan' UOWS.
22	Adding the 'Change Planning and Scheduling Authorities Identification' UOW to be generated and managed by the 'Authorised Change Plan & Schedule' UOW with a '0..1' cardinality.
23	Adding the 'Authorised Change Plan & Schedule Documentation' UOW to be generated and managed by the 'Authorised Change Plan and Schedule' UOW with '1..M' cardinality.
24	Modifying the name of the 'Change Plan & Test Review' UOW to 'Change Build & Test Authorisation' UOW.
25	Adding the 'Change Closure' UOW to be called by the 'Authorised Change Plan and Schedule' UOW with a '0..1' cardinality.
26	Adding the 'Change Record' UOW to be called by the 'Authorised Change Plan & Schedule' UOW with '1..M' cardinality.
27	Merging the 'Authorised Change Submission to Related Authorities' UOW into the 'Authorised Change Build & Test' UOW.
28	Splitting the 'Change Implementation' UOW into 'Change Build' and 'Change Test' UOWs with '1..M' cardinalities.
29	Merging the 'Change Build & Test Coordination' UOW into the 'Authorised Change Build & Test' UOW.
30	Adding the 'Change Closure' UOW to be called by the 'Authorised Change Build & Test' UOW with '0..1' cardinality.
31	Adding the 'Change Record' UOW to be called by the 'Authorised Change Build & Test' UOW with '1..M' cardinality.
32	Merging the 'Build & Test Evaluation Outcomes Submission to Related Change Authorities' UOW into the 'Authorised Change Build & Test' UOW.
33	Modifying the name for the 'Build & Test Evaluation Review' UOW to ' Change Release & Deployment Authorisation'
34	Modifying the name of the "Change Build & Test Formal Evaluation' UOW to 'Change Build & Test Evaluation'
35	Merging the 'Change Check' UOW into the "Change Build & Test Evaluation' UOW.
36	Adding the 'Change Record' UOW to be called by the 'Authorised Change Release and Deployment' UOW with '1...M' cardinality.
37	Adding the 'Change Release and Deployment Authorities Identification' UOW to be generated and managed by the 'Authorised Change Release and Deployment' UOW with '1..1' cardinality.
38	Merging the 'Change Deployment Coordination' UOW into the 'Authorised Change Release and Deployment' UOW.
39	Adding the 'Change Release and Deployment Documentation' UOW to be generated and managed by the 'Authorised Change Release and Deployment' UOW with '1..M' cardinality.
40	Modifying the name of the 'Formal Change Evaluation' UOW to 'Final Formal Change Evaluation'.
41	Modifying the name of the 'Change Check' UOW to 'Final Change Check'.
42	Modifying the name of the 'Stakeholders Disposition of Final Evaluation' UOW to 'Authorities Acceptance of Final Evaluation'.
43	Addressing the lack of semantics representation by the Riva-based ChM-BPA models by semantically enriching the developed models (in **Chapter 5**).

Figure 4.12 shows an example of revising the relationship proposed between the 'CSP' concept and the 'CP' concept (the direct relation) to adapt the CSP concept modelling in the Riva-BPA modelling approach. Furthermore, Figure 4.13 shows part of the revisited aspects in the developed ChM-UOWs diagram, where UOWs names were modified, added or merged. In addition, a number of related 'Generate' relations were also modified, added or merged. The

revisited aspects are presented in an orange colour. Moreover, Figures 5.14 and 5.15 present examples of how the raised concerns were reflected into the 1st-and-2nd-cut-PADs of the ChM-BPA models, where the translations and relations related to the revised UOWs diagram elements where revisited.

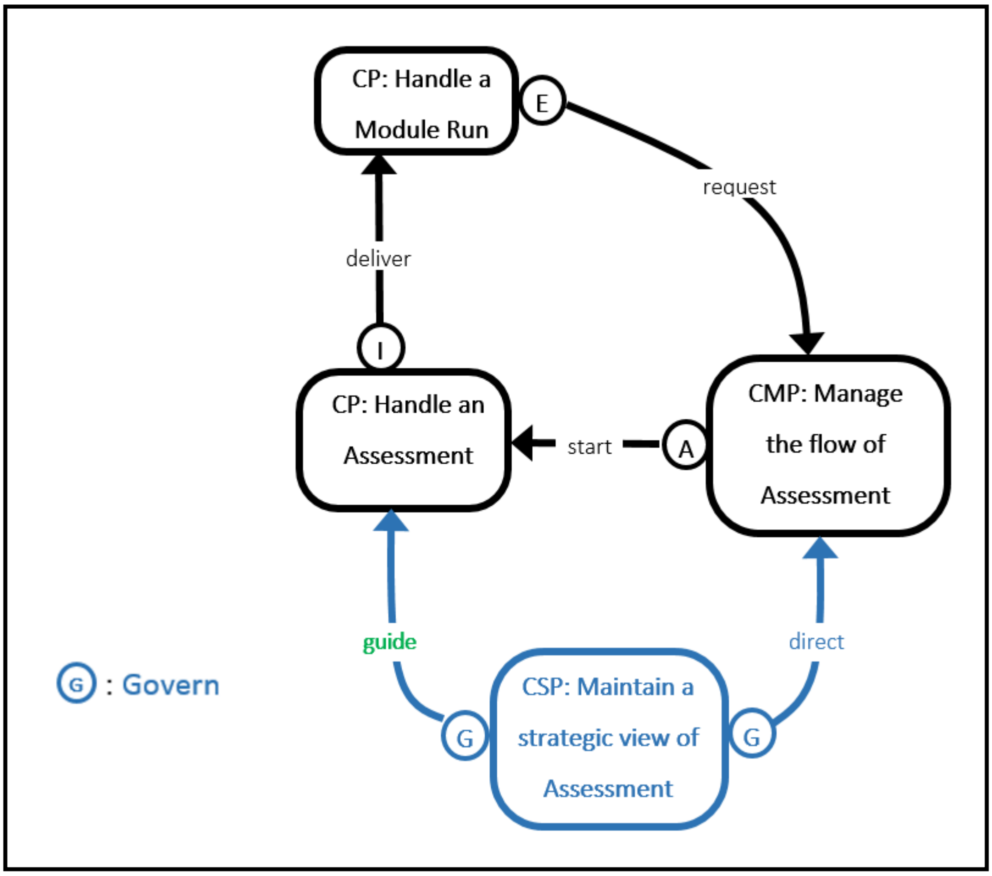


Figure 4. 12: Revisiting the proposed CSP concept representation based on expert feedback, where the revised aspect is in green font colour to reflect point 42 in Table 4.13.

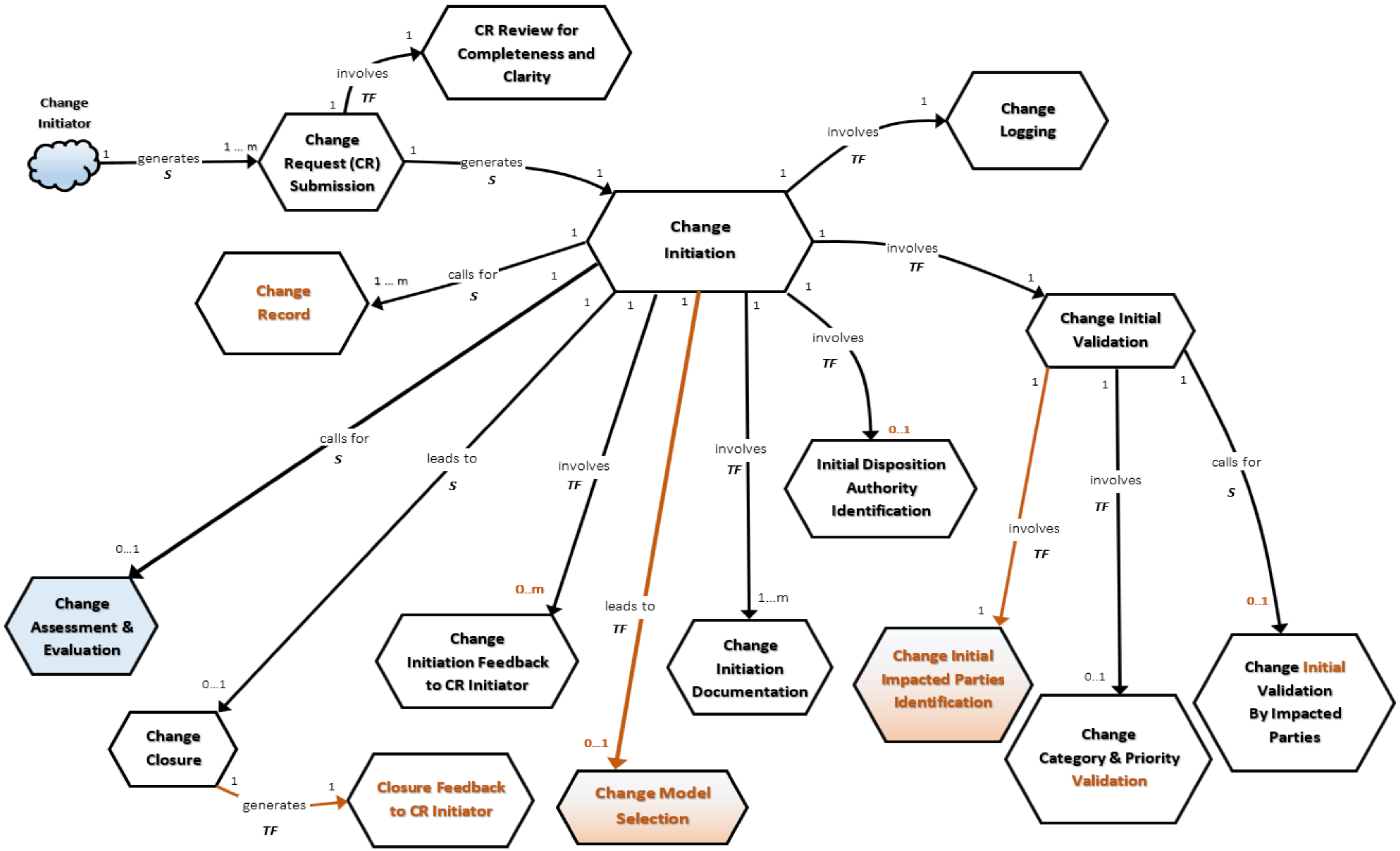


Figure 4. 13: Section of a revised UOWs diagram based on expert feedback, where the revised aspects are in orange colour.

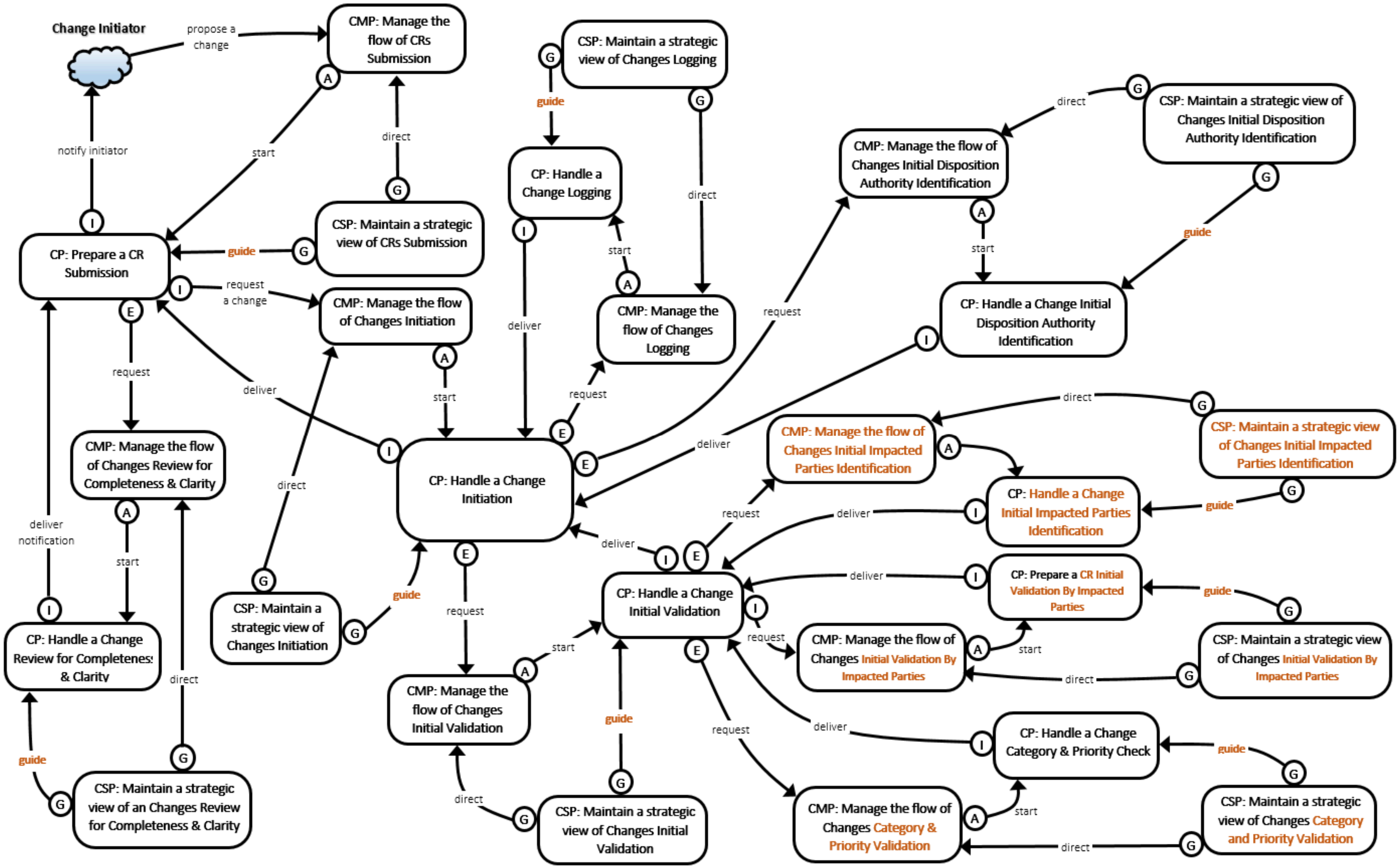


Figure 4. 14: Section of a revised 1st-cut-PAD based on expert feedback, where the revised aspects are in orange colour.

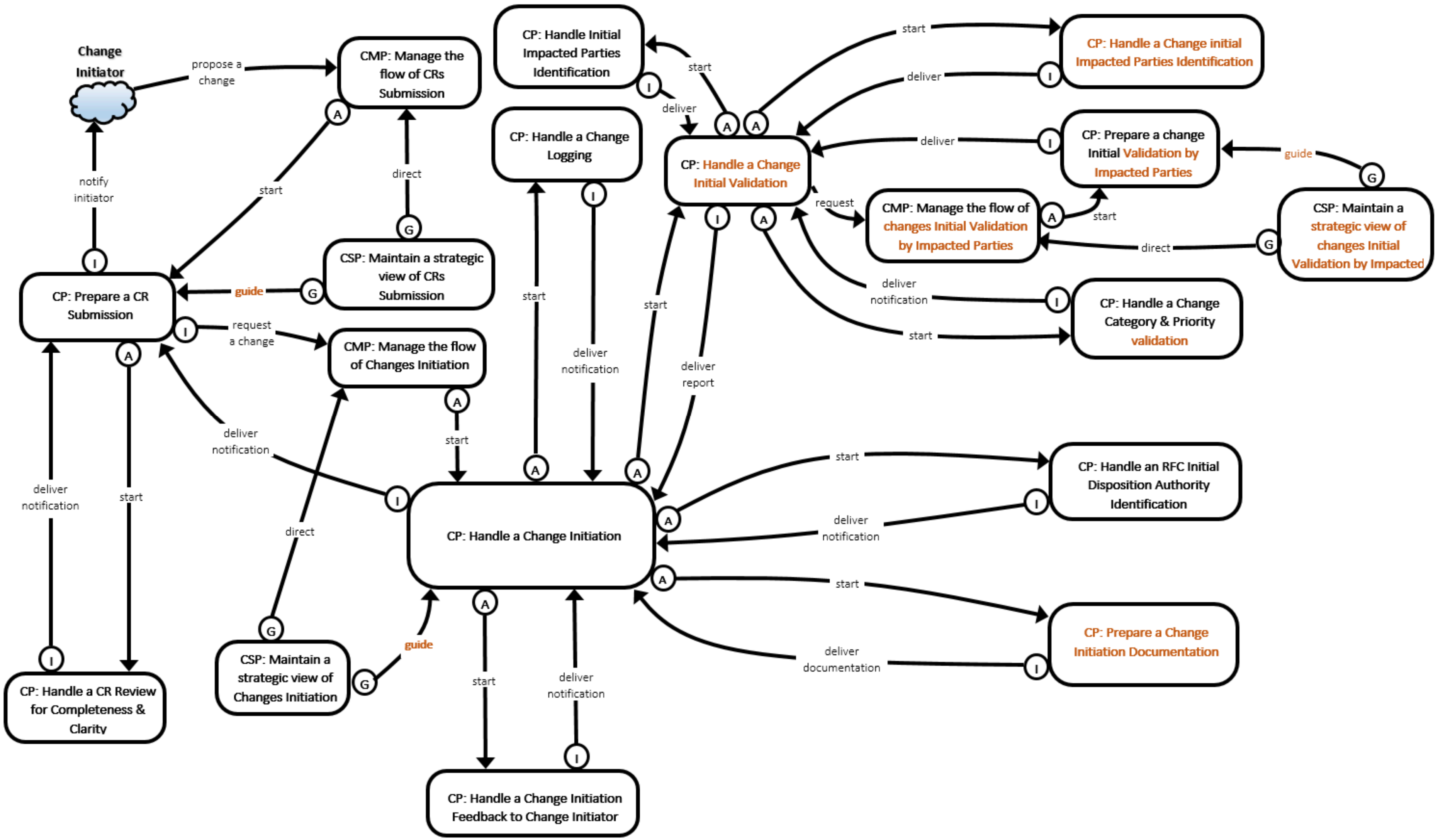


Figure 4. 15: Section of a revised 2nd-cut-PAD based on expert feedback, where the revised aspects are in orange colour.

4.6 Chapter Summary And Discussion

This chapter discusses the first-DSRM-increment adopted for the development of the OntoSoS.BPA.ChM framework, which focused on the development of generalised ChM-BPA models that capture and represent generalised ChM processes and the relationships between them. This involved the DSRM stages of development and design, demonstration and evaluation.

During the design and development stage, the BPA modelling classifications present in the literature (Dijkman, Vanderfeesten and Reijers, 2016) were revisited and explored. Following this, the Riva approach, as an object-based BPA modelling approach (Ould, 2005), was selected for the development of the anticipated models. However, the Riva approach was adapted to address key limitations and make it suitable for this research.

Building on the proposed adaption for the Riva-based BPA modelling approach, the boundary and business of the ChM research scope were identified. Different frameworks for ChM in Systems and Software Engineering domains were explored and selected. Candidate EBEs for each investigated framework were extracted and refined, then filtered to identify UOWs lists. UOWs from different sources were linked together based on their general goals to form a consolidated list of ChM-UOWs. This list was the basis for a diagram showing the UOWs and the relationships between them. The various CPs, CMPs and CSPs associated with each proposed UOW were hypothesised, and the relationships between them were investigated and translated into a 1st-cut-PAD. Finally, Ould's heuristics (2005), and an adaption of them to model CSP elements, were applied to produce a more compact 2nd-cut-PAD. Through this adapted approach, generalised Riva-based BPA models were created and proposed for the ChM framework.

During the demonstration stage, the generality of the ChM-BPA models was assessed by checking the extent to which they suit the needs of, represent and cover real-world ChM practices in a healthcare setting. Accordingly, the models were checked against change processes adopted at the CTAG-KHCC Jordan.

An evaluation was then carried out according to the framework adopted and set out in Chapter 3. This took the form of an extensive walkthrough-based questionnaire focused on assessing different identified criteria, through semi-structured interviews with a set of ChM and business modelling domains experts at KHCC in general and at CTAG-KHCC in particular. Several concerns were raised at this stage, based on which revisions were carried out on the adapted modelling approach and the ChM-BPA models themselves.

The ChM framework component is the first of three main components proposed to form the OntoSoS.BPA.ChM framework. This component was planned to be developed during the first and second increments of the DSRM model. The first increment entailed developing BPA-driven models for the ChM functional area. The second increment involves semantically enriching the developed BPA-driven ChM models and then extending their enrichment. As this chapter introduced the first-DSRM-increment, the next chapter (**Chapter 5**) introduces the second-DSRM-increment.

Using a BPA-driven modelling approach has enabled the provision of a novel conceptual representation of the ChM core processes and the dynamic relationships between them (i.e. ChM-BPA models). In addition, the newly-developed ChM-BPA has resulted in the alignment between twelve existing ChM standards and guidelines, particularly the ones associated with systems and software engineering. Furthermore, it has enabled identifying semantic heterogeneities between concepts of the twelve investigated ChM sources of knowledge for common ChM processes. Thus, the developed ChM-BPA models can be considered as a platform for generalising a BPA model for ChM that can be semantically-enriched to resolve conceptual heterogeneities, share and agree on ChM knowledge amongst different ChM stakeholders in a SoS context. As demonstrated by the conducted case study, the developed ChM-BPA models enabled attaining a clearer and comprehensive understanding of ChM processes amongst stakeholders in general and ChM stakeholders in particular. However, the case study highlighted that the ChM-BPA models are limited to presenting structural aspects more than semantics. Therefore, developing semantically-enriched models based on these developed ChM-BPA models should be the next logical development step. This chapter contributed to answering **RQ1**.Table 4.14 maps between the main research questions and the thesis chapters where they were addressed up to this point.

Table 4. 14: The status of addressing the identified RQs by the main research chapters up to this point.

Research Question	Chapter 4	Chapter 5	Chapter 6	Chapter 7
RQ1	✓			
RQ2				
RQ3				
RQ4				

CHAPTER 5

SEMANTICALLY-ENRICHED BPA-DRIVEN MODELS FOR CHANGE MANAGEMENT

5.1 INTRODUCTION

This chapter continues the development of the ChM framework component by carrying out the second-DSRM-increment. This is done by adapting the srBPA ontology component (Yousef, 2010; Yousef and Odeh, 2014) to develop an ontology-based model that semantically enriches the ChM-BPA elements modelled in Chapter 4 and the heterogeneity detected between the ChM-UOWs (Adapted srBPA ontology for ChM). In addition, an extension to boost the enrichment of the developed 'Adapted srBPA ontology for ChM' is proposed, namely the 'BPA-driven ChM Extension ontology'. The proposed extension entails developing an ontological model that represents the main ChM documents and roles found related to handling the application of the identified Riva-driven ChM processes. Thereafter, the 'BPA-driven ChM Extension ontology' is linked to the 'Adapted srBPA ontology for ChM' in order to form the anticipated 'Integrated BPA-driven ChM' ontological model for the ChM component.

Developing the 'ChM component' within the second-DSRM-increment generally involves three main stages: The Design and Development stage, the Demonstration stage and the Evaluation stage. However, to meet the objectives of this increment, it is anticipated to entail two sub-DSRM-Increments. The 'first-sub-DSRM-increment' focuses on adapting the 'srBPA ontology' and then semantically enriching the ChM-BPA models (developed in Chapter 4). On the other hand, the 'second-sub-DSRM-increment' focusses on the development of the 'BPA-driven ChM Extension ontology' and linking it to the 'Adapted srBPA ontology for ChM' in order to form the anticipated 'Integrated BPA-driven ChM' ontological model.

Having the 'Integrated BPA-driven ChM' ontology provides this research with a more holistic and traceable semantic representation of BPA-driven knowledge that represents the ChM processes, the relationships between them and the generic basic documents and roles related to handling the captured ChM processes. This is anticipated to contribute to addressing the disparities in concepts of ChM used in existing ChM standards and practices. Also, it contributes to enabling the achievement of a shared understanding of and consensus on the ChM processes and relationships between them amongst the various practitioners in the systems and software engineering domains. Moreover, having generic and agreed knowledge about ChM enables its adoption by different business settings, for example, healthcare or industrial settings. Furthermore, it provides the OntoSoS.BPA.ChM framework with a form of ChM knowledge repository. This enables stakeholders to retrieve, share and agree upon knowledge about the ChM processes required to manage changes in general and especially in a heterogenetic context such as a SoS arrangement context. Having such knowledge then plays a key role in meeting the ultimate goal of this research by improving the application of ChM in a SoS context. Accordingly, the fourth-DSRM-increment (**Chapter 7**) describes how ChM knowledge, related to managing a submitted change request in a SoS arrangement, can be retrieved and utilised.

The rest of this chapter is organised as follows. Section 5.2 discusses the semantic enrichment of the ChM-BPA models by conducting the first-sub-DSRM-increment. Section 5.3 discusses the semantic extension of the ChM-BPA models by conducting the second-sub-DSRM-increment. Section 5.4 summarises the chapter.

5.2 The Semantic Enrichment of the ChM-BPA Models: (First-Sub-DSRM-Increment of the Second-DSRM-Increment)

A SoS operational context demands that various stakeholders at all levels communicate and interact in order to manage a submitted change. To efficiently do so, the ChM processes and their interrelationships need to be clearly understood and aligned across the SoS arrangement's organisational boundary. The Riva-based ChM-BPA models (developed in the previous chapter) provide an organised view of the generic ChM processes and the relationships between them, which enables a clear understanding that can be shared amongst the different parties participating in managing a change in a SoS arrangement. However, the developed Riva-based BPA models mainly capture the syntax of the ChM processes architecture rather than their semantics. The lack of semantic expressiveness of the Riva-based ChM-BPA models may contribute to causing a significant problem while managing a change in a semantically heterogenetic context such as a SoS arrangement. This happens especially as the different stakeholders in the global and local levels of a SoS are required to interact or integrate with one another, in a form of wider collaborative ChM business processes application, in order to manage a submitted change request.

To enable the OntoSoS.BPA.ChM framework support for a high-level of ChM semantic interoperability between the SoS participating parties, this research adopted the semantic enrichment of the developed ChM-BPA models. Subsequently, when the formal representation and semantic enrichment of a model is required, the ontology provides a key means. Recall from **Chapter 2** that ontologies provide a formal (machine-readable) representation of real-world entities and the relationships between them, which can be used to achieve a shared understanding of knowledge between practitioners or stakeholders in a domain of interest and can help in resolving semantic heterogeneity (Guarino, Oberle and Staab, 2009; Taye, 2010). Having reviewed the literature, the srBPA ontology (Yousef and Odeh, 2014) was the only ontology found that provides a formal semantic representation for the Riva-based BPA elements. Table 5.1 presents the main four features incorporated into the srBPA ontology.

In addition to that, the srBPA ontology was implemented and introduced using OWL-DL. This was recommended by the World Wide Web Consortium (W3C) group to represent knowledge-domain ontologies (Smith, Welty and McGuinness, 2004). Furthermore, the 'Protégé' version

3.4.1 was used as the ontology development and management tool (Musen, 2015) supported by the JESS capabilities (Crosar and Sleeman, 2006). Moreover, the srBPA ontology semantically reflects and implements the steps of the Riva-based approach by applying the srBPA steps, as shown in Table 2.8 Chapter 2. A reader can obtain a detailed description of the srBPA ontology from Yousef and Odeh (2014).

Table 5. 1: The srBPA main incorporated features, (Yousef and Odeh, 2014).

#	srBPA Entailed Feature
1	▪ A hierarchy of concepts (presented as classes and subclasses) that represent the main elements considered in the Riva-based BPA method, e.g. 'EBE', 'UOW', 'CP', 'CMP', 'Request' and 'Start'.
2	▪ The elements' related attributes (presented as object or data properties), e.g. 'isConsideredUOW', 'belongsTo1stCutDiagram' and 'isActive'.
3	▪ A set of OWL restrictions (or axioms) that govern the relations between the proposed concepts, e.g. 'UOW ∀ BelongsToUoWDiagram only UoW_Diagram'.
4	▪ SWRL-based or JESS-based statements to set constraints representing some Riva rules or to apply Riva rules that cannot be represented without the use of variables, e.g. translating a UOW diagram relation into its related relations in a 1st-Cut PAD.

The first-sub-DSRM-increment for the development of a semantically-enriched ChM-BPA has therefore gone through three DSRM stages. The first was the design and development stage, where the srBPA ontology was adapted to cover the adapted aspects of the Riva-based BPA (e.g. by representing the CSP concept) and to support representing detected semantic heterogeneity. The second was the demonstration stage, where the adapted srBPA ontology was instantiated with the ChM-BPA models' elements. In the final DSRM stage of evaluation, aspects related to the design and the utility of the adapted srBPA ontology (including the semantically-enriched ChM-BPA models) were assessed.

5.2.1 The First Sub-Increment's Design and Development Stage

As mentioned in the previous section, the srBPA ontology (Yousef and Odeh, 2014) semantically represents the elements of the original Riva-based BPA presented by Ould (2005). Accordingly, the developed srBPA ontology lacks the semantic representation of the Riva-based CSP concepts and its translation into the 1st-and-2nd-Cut-PADs. Furthermore, it lacks the representation of different terminologies used for the same UOW.

A form of an srBPA ontology extension was proposed to cover a part of the semantic representation for the CSP concept when it was recently extended for the generic BPAOntoEIA Framework (Ahmad, 2015). This was done by (i) adding the CSP class to the extended srBPA ontology; (ii) adding properties that relate the CSP class with the corresponding UOW, CP and CMP classes; and (iii) adding OWL restrictions to govern the proposed properties. However, as the CSP concept and its effect on the 1st-and-2nd-cut PADs were still under consideration and were being researched, they had limited presence in the BPAOntoEIA Framework. Therefore, the translation of the CSP concepts into the 1st-and-2nd-cut PADs, by linking the CSP concept to the related CP and CMP using Riva relations, was not present in the proposed extended srBPA ontology.

This section continues by introducing how the original srBPA ontology was adapted to be aligned with the adaptation of the Riva-based BPA modelling approach proposed in Chapter 4, resulting in an 'Adapted srBPA ontology'. The main issues raised while investigating the srBPA ontology to produce the Adapted srBPA ontology component are presented in Table 5.2.

Table 5. 2: The key aspects in the development of the Adapted srBPA ontology.

ID	Brief Description of the Issue	Brief Description of the Conducted Adaptation
Issue 1	▪ Addressing the lack of semantic representation of the CSP concept in the srBPA-Step 3.	▪ Adding and updating classes, properties, restrictions, SWRL and JESS-based statements to reflect the proposed adaption related to modelling the CSP concept.
Issue 2	▪ Addressing the Lack of the CSP concept translation into the 1st-Cut-PAD in srBPA-Step 4.	▪ Adding and updating the related JESS rules to include aspects related to the proposed translation of the CSP concept into the 1st-Cut-PAD.
Issue 3	▪ Addressing the Lack of the CSP concept translation into the 2nd -Cut-PAD in srBPA-Step 5.	▪ Adding and updating properties and SWRL-based statements to include aspects related to the translation of the CSP concept into the 2nd-Cut-PAD.
Issue 4	▪ Resolving semantic heterogeneity by semantically enriching the different terminologies captured for the ChM-UOWs.	▪ Adding a new data property to support the semantic enrichment of synonyms detected for the captured UOWs.

Figures 5.1 to 5.3 show examples of the adaptation conducted for the srBPA ontology based on the issues proposed in Table 5.3.

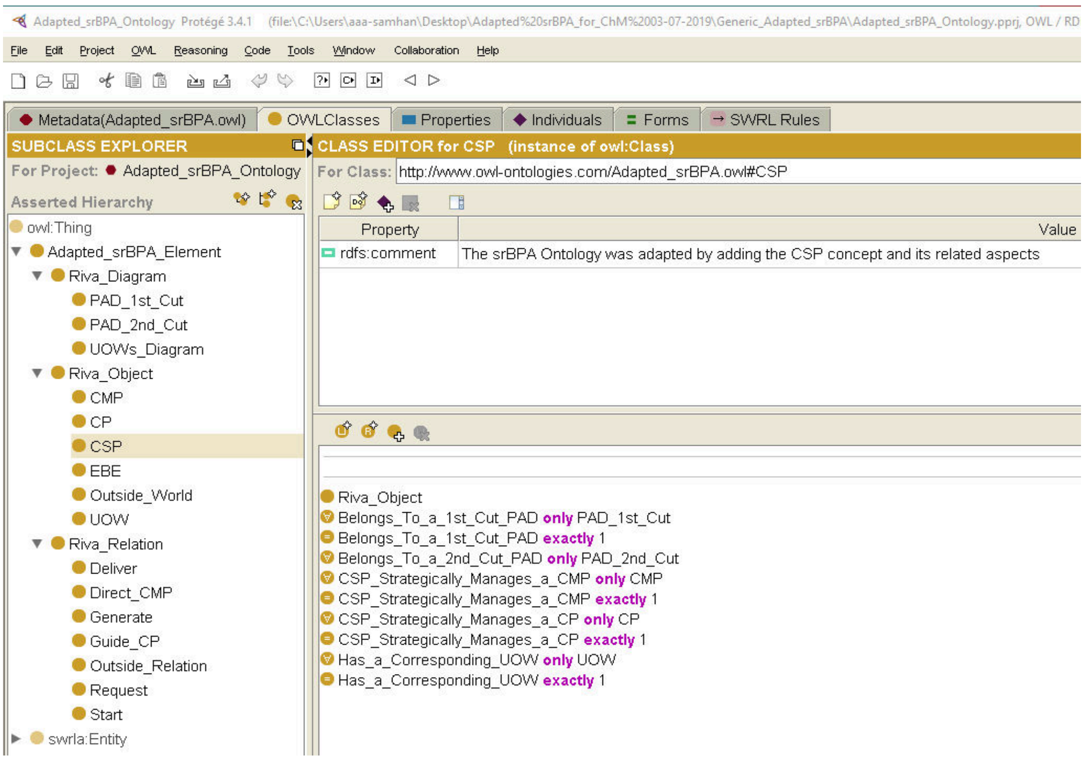


Figure 5. 1: The CSP concept and its related proposed restrictions as part of adapting the srBPA ontology using Protégé (Reflecting Issue #1).

```
(mapclass http://www.owl-ontologies.com/Adapted_srBPA.owl#UOW)
(mapclass http://www.owl-ontologies.com/Adapted_srBPA.owl#CP)
(mapclass http://www.owl-ontologies.com/Adapted_srBPA.owl#CMP)
 (mapclass http://www.owl-ontologies.com/Adapted_srBPA.owl#CSP)

(defrule translate_CSP_riva_relations

(object (is-a http://www.owl-ontologies.com/Adapted_srBPA.owl#CSP) (OBJECT ?acsp)
(http://www.owl-ontologies.com/Adapted_srBPA.owl#Has_a_Corresponding_UOW ?a)
(http://www.owl-ontologies.com/Adapted_srBPA.owl#CSP_Strategically_Manages_a_CP
?acp)  (http://www.owl-
ontologies.com/Adapted_srBPA.owl#CSP_Strategically_Manages_a_CMP  ?acmp) )
=>
 (make-instance (str-cat(instance-name ?a) "_GuideCP") of http://www.owl-
ontologies.com/Adapted_srBPA.owl#Guide_CP (http://www.owl-
ontologies.com/Adapted_srBPA.owl#Has_a_CSP_Source ?acsp) (http://www.owl-
ontologies.com/Adapted_srBPA.owl#Has_a_CP_Destination ?acp))
(make-instance (str-cat(instance-name ?a) "_DirectCMP") of http://www.owl-
ontologies.com/Adapted_srBPA.owl#Direct_CMP (http://www.owl-
ontologies.com/Adapted_srBPA.owl#Has_a_CSP_Source ?acsp) (http://www.owl-
ontologies.com/Adapted_srBPA.owl#Has_a_CMP_Destination ?acmp))  )
```

Figure 5. 2: An example of a JESS rule to create 'CSP' related Riva-relations instances as part of adapting the srBPA ontology using Protégé (Reflecting Issue #2).

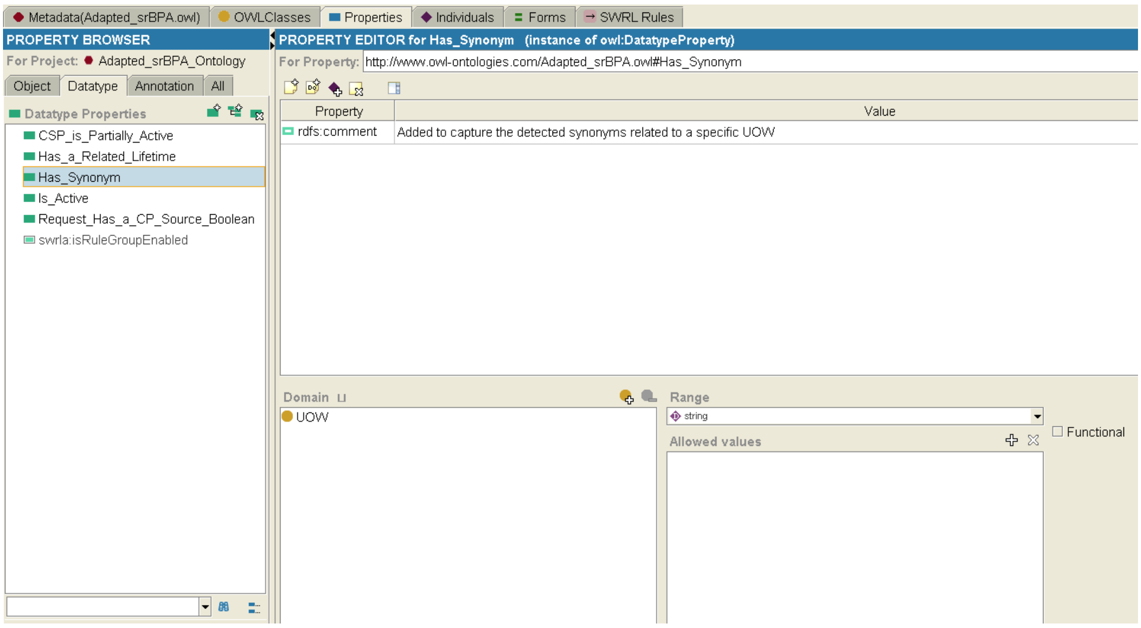


Figure 5. 3: Adding the 'Has_Synonym' property to represent UOWs terminologies as part of adapting the srBPA ontology using Protégé (Reflecting Issue #4).

5.2.2 The First Sub-Increment's Demonstration Stage

During this stage, the Adapted srBPA ontology was instantiated with the elements of the developed generalised ChM-BPA models. This enables using the Adapted srBPA ontology to semantically enrich the developed ChM-BPA models and considering the applicability of the Adapted srBPA ontology to a real-world setting. Accordingly, the srBPA ontology instantiation steps (Yousef, 2010, pp. 65-72) were considered for the instantiation of the srBPA ontology elements. Table 5.3 shows the main steps followed for the instantiation of the Adapted srBPA ontology for the ChM-BPA models whilst taking into consideration the adapted aspects mentioned in the previous section. It shows the steps alongside a brief summary of what was done during the execution of the steps.

Table 5. 3: Overview of the instantiation process of the Adapted srBPA ontology for ChM-BPA.

<table>
<tr><td>Adapted srBPA-Riva instantiation Step</td><td>Step 1:
▪ Instantiating the captured EBE's for ChM-BPA models</td></tr>
<tr><td>Description of the conducted instantiation Step</td><td>▪ Instantiate the ChM-EBE instances based on the EBEs captured in Chapter 4 for the ChM-BPA models.
▪ Because of the large number of the captured EBEs, only the EBEs that were considered later as consolidated UOWs were instantiated in the Adapted srBPA for the ChM-BPA.</td></tr>
<tr><td>Adapted srBPA-Riva instantiation Step</td><td>Step 2:
▪ Instantiating the classified UOWs for ChM-BPA models</td></tr>
<tr><td>Description of the conducted instantiation Step</td><td>▪ Instantiate the property 'Has_a_Related_Liftime' as 'True' for the ChM-EBEs that their lifetimes need to be managed or handled during the ChM application.
▪ Execute the related SWRL-based statement to automaticity create the UOWs instances.
(e.g. EBE (?ebe) ∧ Has_a_Related_Liftime (?ebe, true) → UOW (?ebe))
▪ Instantiate the 'Has_Synonym' property for each created UOW based on the linked UOWs introduced in Chapter 4.</td></tr>
<tr><td>Adapted srBPA-Riva instantiation Step</td><td>Step 3:
▪ Instantiating the UOWs Diagram</td></tr>
<tr><td>Description of the conducted instantiation Step</td><td>▪ Instantiate the UOWs Diagram, Outside_world and Generate_Relation concepts based on the UOWs diagram developed in Chapter 4 for the ChM-BPA.
▪ For each 'Generate' relation instance, insatiate the (Has_a_UOW_Source), and (Has_a_UOW_Destination) properties with the corresponding UOWs.
▪ For each 'Outside_relation' instance, insatiate the (Has_an_Outside_World_Source), (Has_a_UOW_Destination) properties.
▪ Execute the related SWRL-based statements to facilitate the instantiation of the following further related aspects:
  ▪ UOW_Has_a_Generate_Relation.
  ▪ OutsideInstance_hasOutsideRelation.
  ▪ UOW_belongstoUOWsDiagram.
  ▪ OutsideWorldInstance_belongsToUOWDiagram.
  ▪ Generate_belongsToUOWDiagram.
  ▪ OutsideRelation_belongsToUOWDiagram.</td></tr>
<tr><td>Adapted srBPA-Riva instantiation Step</td><td>Step 4:
▪ Instantiating the CP, CMP and CSP instances for each UOW</td></tr>
<tr><td>Description of the conducted instantiation Step</td><td>▪ Execute the related JESS-based statement to create the CP, CMP, and CSP instances for each identified ChM-UOW.
▪ Execute the related SWRL-based statements to facilitate the instantiation of the following further related aspects:
  ▪ UOW_Has_a_Corresponding_CP
  ▪ UOW_Has_a_Corresponding_CMP
  ▪ UOW_Has_a_Corresponding_CSP
  ▪ CP_Has_a_Managing_CMP
  ▪ CP_Has_a_Strategically_Managing_CSP
  ▪ CMP_Has_a_Strategically_Managing_CSP</td></tr>
</table>

Table 5.3: Overview of the instantiation process of the Adapted srBPA ontology for ChM-BPA, "Continued"

Adapted srBPA-Riva instantiation Step	**Step 5:** ▪ Instantiating the 1st-Cut-PAD for the ChM-BPA
Description of the conducted instantiation Step	▪ Execute the related JESS-based statement to create the Start, Guide_CP, Dirtect_CMP, Request and Deliver relations instances. ▪ Execute the related SWRL-based statements to facilitate the instantiation of the following further related aspects: ▪ CP_has_Request ▪ OutsideWorld_Has_Request ▪ CP_has_Start ▪ CMP_has_Start ▪ CP_has_Deliver ▪ CSP_has_GuideCP ▪ CSP_has_DirectCMP ▪ OutsideWorld_Belongs_To_a_1st_Cut_PAD ▪ CP_Belongs_To_a_1st_Cut_PAD ▪ CMP_Belongs_To_a_1st_Cut_PAD ▪ CSP_Belongs_To_a_1st_Cut_PAD ▪ Deliver_Belongs_To_a_1st_Cut_PAD ▪ OutsideRelation_Belongs_To_a_1st_Cut_PAD ▪ Request_Belongs_To_a_1st_Cut_PAD ▪ Start_Belongs_To_a_1st_Cut_PAD ▪ DirectCMP_Belongs_To_a_1st_Cut_PAD ▪ GuideCP_Belongs_To_a_1st_Cut_PAD
Adapted srBPA-Riva instantiation Step	**Step 6:** ▪ Instantiating the 2nd-Cut-PAD for the ChM-BPA
	▪ For each CP, CMP and CSP instance, identify the values for its related 'isActive' property based on the applied Ould's heuristics. ▪ For each CSP instance, identify the values for its related 'CSP_is_Partially_Active' property based on the applied Ould's heuristics. ▪ Execute the related SWRL-based statements to facilitate the instantiation of the 'isActive' property related to the Start, Request, Deliver, Direct_CMP and Guide_CP relations. ▪ Execute the related JESS-based statement to create the modified copies of the 'Start' relations. ▪ Execute the related SWRL-based statements to facilitate the instantiation of the following further related aspects: ▪ CP_has_Modified_Start_Relations ▪ OutsideWorld_Belongs_To_a_2nd_Cut_PAD ▪ CP_Belongs_To_a_2nd_Cut_PAD ▪ CMP_Belongs_To_a_2nd_Cut_PAD ▪ CSP_Belongs_To_a_2nd_Cut_PAD ▪ DeliverRelation_Belongs_To_a_2nd_Cut_PAD ▪ RequestRelation_Belongs_To_a_2nd_Cut_PAD ▪ StartRelation_Belongs_To_a_2nd_Cut_PAD ▪ Direct_CMP_Relation_Belongs_To_a_2nd_Cut_PAD ▪ Guide_CP_Relation_Belongs_To_a_2nd_Cut_PAD

Figures 5.4 and 5.5 show examples of the Adapted srBPA ontology after instantiation for the ChM-BPA.

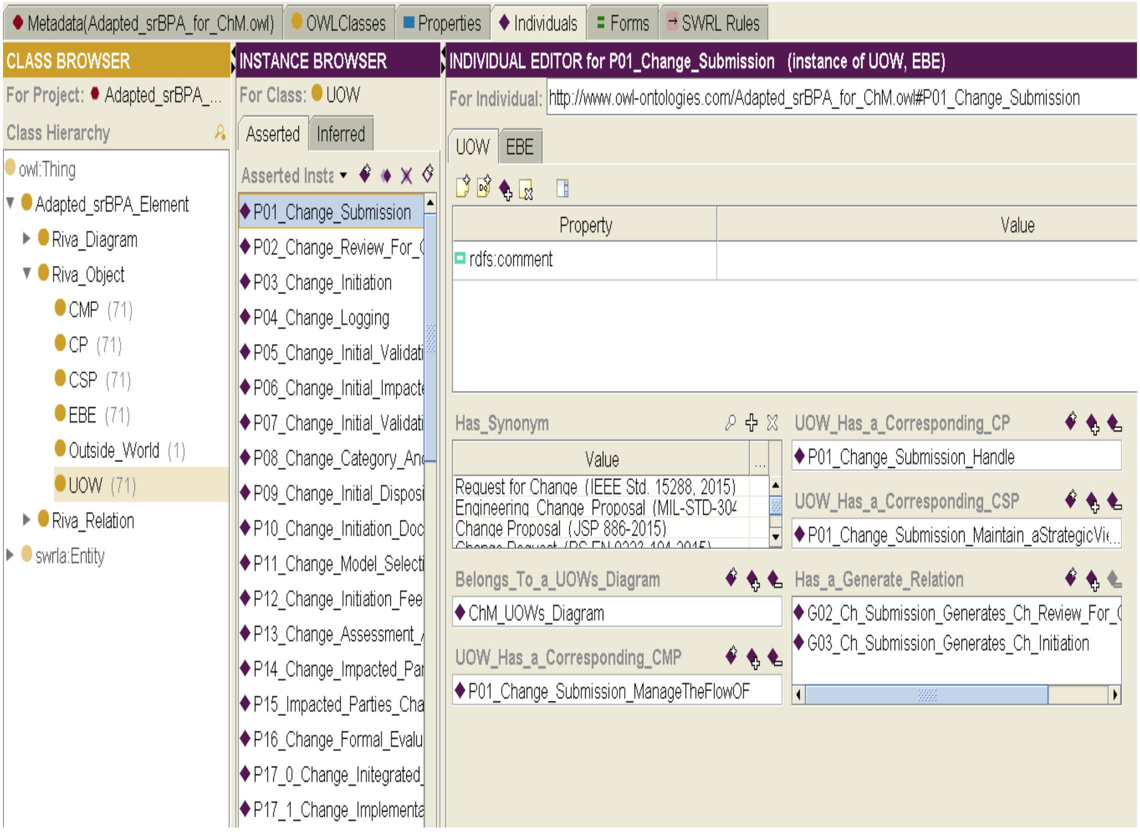


Figure 5. 4: Example of the Adapted srBPA ontology after instantiation for the ChM-BPA using Protégé.

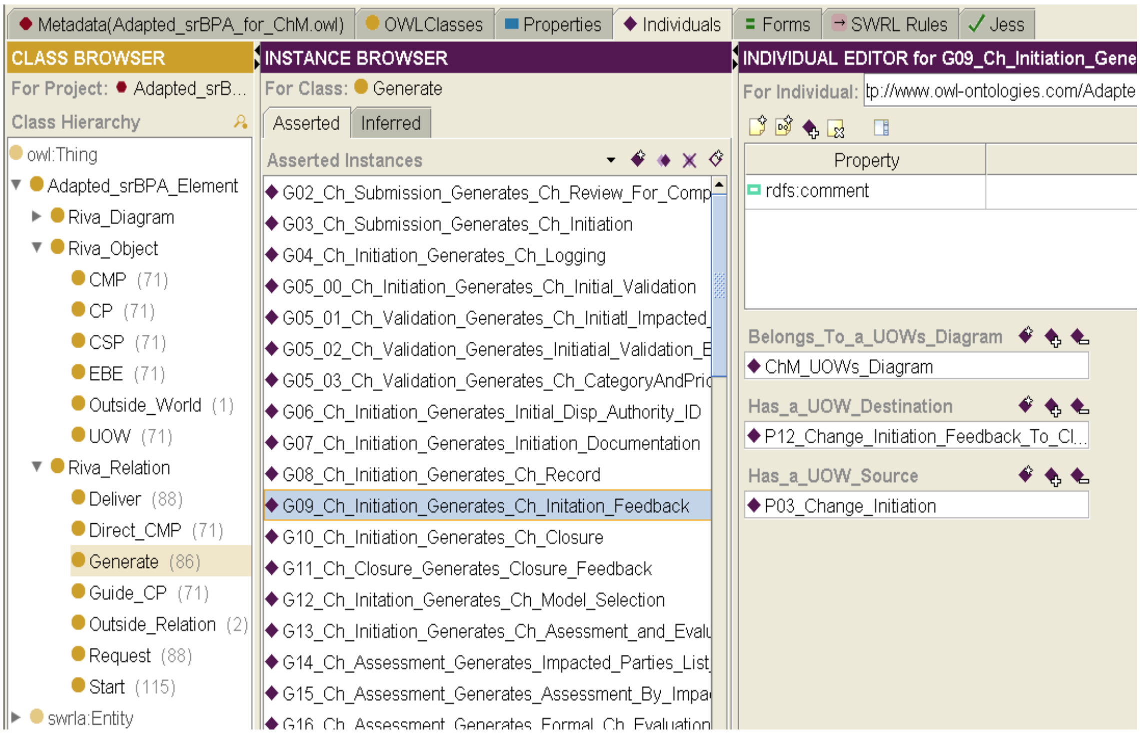


Figure 5. 5: Example of the Adapted srBPA ontology after instantiation for the ChM-BPA using Protégé.

Having carried out this stage, the developed ChM-BPA models' elements were semantically enriched. Furthermore, the Adapted srBPA ontology was found applicable to capture knowledge related to a BPA that is driven by the application of the adapted Riva-based approach.

5.2.3 The First Sub-Increment's Evaluation Stage

In this DSRM stage, evaluation of the developed adapted srBPA ontology for ChM was carried out.

5.2.3.1 The Evaluation Roadmap

This stage emphasises the verification and validation of the 'Adapted srBPA ontology for ChM-BPA' based on the evaluation framework adopted for this research (discussed in **Chapter 3**). Table 5.4 presents the part of the evaluation framework related to evaluating the component. The table presents an abstract description of the objectives for evaluation and lists the adopted evaluation types, criteria and techniques, which are discussed more thoroughly in the following sections.

Table 5. 4: The part of the evaluation framework related to evaluating the 'Adapted srBPA ontology for ChM'.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Second-DSRM-Increment) (First-Sub-Increment) Evaluating the Semantic Enrichment of the ChM-BPA (The Adapted srBPA ontology for ChM): (1) To inform the adherence of the adapted ontological meta-model to the ontology-based representation using OWL-specifications. (2) To further verify the correctness of the Adapted srBPA ontological meta-model by checking the completeness and redundancy aspects of its elements. (3) To inform the validity of the adapted ontological model in representing the developed ChM-BPA elements by checking the correctness, completeness and consistency of the ontological model's elements.	Verification		
	Consistency		Protégé Reasoner
	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
	Correctness	Completeness	Checklist-based Walkthroughs (By the researcher)
	Consistency		Protégé Reasoner

5.2.3.2 The Verification of the 'Adapted srBPA ontology for ChM-BPA' Component

In this category of evaluation, the correctness of the ontology-based 'Adapted srBPA' meta-model was verified before its instantiation. This was done by checking its consistency, completeness and redundancy. Table 5.5 provides a description of these criteria as adopted by the research.

Table 5. 5: The adopted verification criteria for the evaluation of the 'Adapted srBPA ontology for ChM'.

Verification Criteria	Description
Consistency	▪ The semantic enrichment of the 'Adapted srBPA' meta-model adheres to the rules and syntax of the OWL-specifications used to create it (i.e. no contradictory items or constraints are detected or inferred).
Completeness	▪ The semantically-enriched 'Adapted srBPA' meta-model contains all the elements that it should represent.
Redundancy	▪ Each construct of the semantically-enriched 'Adapted srBPA' meta-model contributes knowledge to the model (e.g. a real-world entity is not represented by more than one ontological construct).

Table 5.6 presents the used verification techniques linked to the adopted verification criteria. The table also provides a brief description of the used verification techniques.

Table 5. 6: The adopted verification techniques for the evaluation of the 'Adapted srBPA ontology for ChM'.

Verification Criteria	Verification Technique	Brief Description
Consistency	Protégé Reasoner	▪ Checking the consistency of ontology-based models can be done using a reasoner that supports an ontology development tool. For this research, the protégé reasoner - i.e. Pellet – was used to check the consistency of the ontology-based 'Adapted srBPA' meta-model. ▪ If no inconsistency is detected by the Protégé reasoner, it could be realised that the ontology-based meta-model of the 'Adapted srBPA' meta-model is consistent. ▪ This check was carried out by running the Protégé reasoner.
Completeness	Checklist-based Walkthroughs	▪ The ontology-based 'Adapted srBPA' meta-model should represent the original and adapted concepts and relations of the Riva-based BPA models. Accordingly, a checklist was designed and used to check if all the elements of the original and adapted Riva-based BPA models were represented by the developed ontology-based meta-model. In addition, adapting the srBPA ontology to further include the semantic representation of the UOWs synonyms was checked. ▪ This check was carried out by the researcher.
Redundancy	Checklist-based Walkthroughs	▪ Each element of the developed ontology-based 'Adapted srBPA' meta-model should contribute knowledge to the model. Accordingly, a checklist was designed and used to check that there is no redundant knowledge provided by the elements of the ontology-based meta-model by checking that each element of adapted Riva-based BPA models is not represented by more than one ontological construct. ▪ This check was carried out by the researcher.

Figure 5.6 and Table 5.7 show examples of the conducted verification techniques. Having conducted the verification for the 'Adapted srBPA ontology' meta-model, no inconsistencies were

detected by the Protégé reasoner. In addition, the original and adapted Riva-based BPA aspects were completely represented, and no redundancies were found.

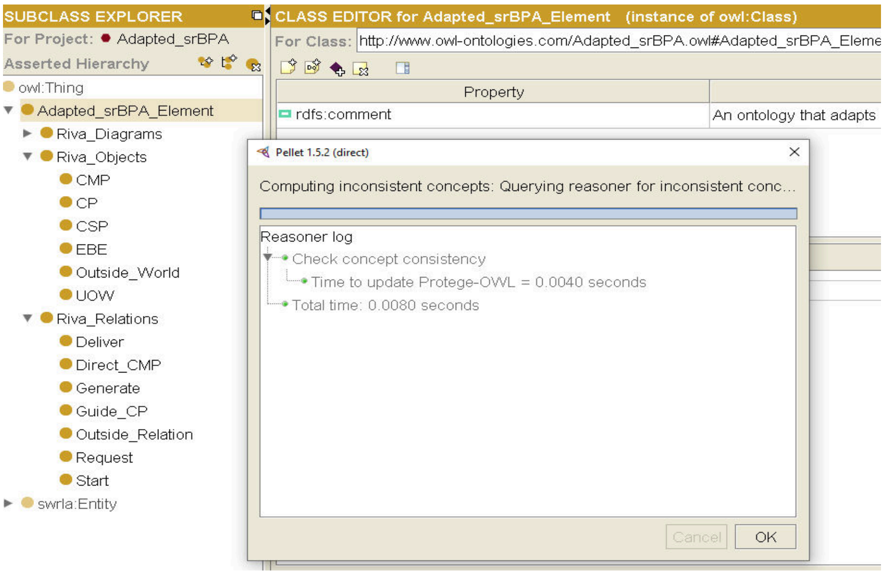


Figure 5. 6: Running the Protégé reasoner to check the consistency of the 'Adapted srBPA' meta-model.

Table 5. 7: Example of the checklist-based walkthrough carried out to check the completeness and redundancy of the 'Adapted srBPA' meta-model elements.

Main Adapted Riva-based BPA Aspect	Representing Adapted srBPA Ontology Element	Covered?	Redundant?
EBE	EBE : Construct	✓	×
UOWs Diagram	UOW_Diagram : Construct	✓	×
UOW	UOW : Construct	✓	×
A UOW is an EBE with a lifetime	Has_a_Related_Lifetime : Property	✓	×
Generate Relation	Generate Outside_Relation : Constructs	✓	×
During the lifetime of a UOW it may Generate another UOW	Has_a_UOW_Source Has_a_UOW_Destination Has_a_Generate_Relation : Properties	✓	×
Outside World Entity	Outside_World : Construct	✓	×
An outside Entity may Generate a UOW	Outside_Relation : Costruct Has_an_Outside_World_Source Has_a_UOW_Destination : Properties	✓	×
A UOW diagram Contains the Outside entities, UOWs, and the Generate Relations Between them	Belongs_To_a_UOW_Diagram : Property	✓	×
First Cut Process Architecture Diagram	PA_1st_Cut_Diagram : Construct	✓	×
CP	CP : Construct	✓	×
CMP	CMP : Construct	✓	×
CSP	CSP : Construct	✓	×

5.2.3.3 The Validation of the Ontology-based 'Adapted srBPA' Component

In this category of evaluation, the ontology-based 'Adapted srBPA' model was validated by checking its correctness, completeness and consistency after the ontology was instantiated with related ChM-BPA elements. Table 5.8 provides a description of these criteria as adopted by the research.

Table 5. 8: The adopted validation criteria for the evaluation of the 'Adapted srBPA ontology for ChM'.

Validation Criteria	Description
Correctness	▪ The elements identified in the ChM-BPA models are represented correctly in the adapted srBPA ontology (each element is represented as it should be). ▪ The relationships identified between the elements are correctly represented in the adapted srBPA ontology.
Completeness	▪ All the elements identified in the ChM-BPA models are represented in the ontology (no missing elements). ▪ All the relationships identified in the ChM-BPA models are represented in the ontology (no missing relations).
Consistency	▪ After instantiation, no contradictory items are detected or inferred in the ontology.

Table 5.9 presents the used validation techniques linked to the adopted validation criteria. The table also provides a brief description of the validation techniques.

Table 5. 9: The adopted validation techniques for the evaluation of the 'Adapted srBPA ontology for ChM'.

Validation Criteria	Validation Technique	Brief Description
Correctness	Checklist-based Walkthroughs	▪ Checklist-based walkthroughs were conducted to check that the elements identified in the ChM-BPA models and the relationships between them are represented correctly in the ontology (each element is represented as it should be). ▪ This check was carried out by the researcher
Completeness	Checklist-based Walkthroughs	▪ Checklist-based walkthroughs were conducted to check that all the elements identified in the ChM-BPA models and the relationships between them are represented in the ontology (no missing element). ▪ This check was carried out by the researcher
Consistency	Protégé Reasoner	▪ The Protégé reasoner (i.e. Pellet) was used to check that after instantiating the 'Adapted srBPA' ontology for ChM-BPA, no contradictory items are detected or inferred. ▪ If no inconsistency is detected by the Protégé reasoner, it could be realised that the ontology-based model is consistent. ▪ This check was carried out by running the Protégé reasoner.

Table 5.10 and Figure 5.7 show examples of the conducted validation techniques. As a result of conducting the validation for the 'Adapted srBPA ontology for ChM', all the ChM-BPA aspects were found correctly and completely represented. In addition, the Protégé reasoner detected no inconsistencies.

Table 5. 10: Part of validating the correctness and completeness of the 'Adapted srBPA ontology for ChM'.

Adapted ChM-BPA Aspect	Representing Adapted srBPA Element	Correct Representation?	Covered?
ChM-UOWs 71 Cases	UOWs Instances 71 Instances	✓	✓
ChM-UOW is an EBE with a lifetime 71 Cases	Has_a_Related_Lifetime 71 Instances	✓	✓
ChM-UOWs Diagram 1 Case	UOWs_Diagram Instance 1 Instance	✓	✓
Outside World Entity 1 Case	Outside_World Instance 1 Instance	✓	✓
ChM-Generate Relations 88 Cases	Generate Instances 86 Instances Outside_Relation Instances 2 Instances	✓	✓
During the lifetime of a UOW it may Generate another UOW 86 Cases	Has_a_UOW_Source 86 Instances Has_a_UOW_Destination 86 Instances Has_a_Generate_Relation 86 Instances	✓	✓
An outside Entity may Generate a UOW 2 Cases	Outside_Relation 2 Instances Has_an_Outside_World_Source 2 Instances Has_a_UOW_Destination 2 Instances Has_an_Outdside_World_Relation 2 Instances	✓	✓

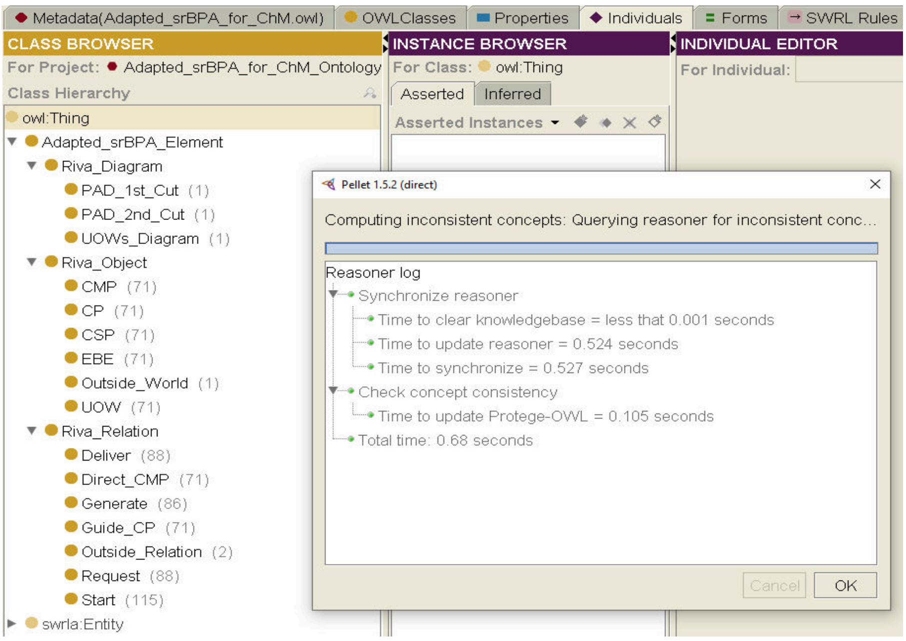


Figure 5. 7: Running the Protégé reasoner to check the consistency of the 'Adapted srBPA ontology for ChM'.

5.3 THE SEMANTIC EXTENSION OF THE ChM-BPA MODELS: (SECOND-SUB-DSRM-INCREMENT OF THE SECOND-DSRM-INCREMENT)

The ChM-BPA models (developed in Chapter 4 and semantically enriched in the previous sub-increment) are limited to representing Riva-based ChM-processes and the dynamic relationships between them. To achieve a more holistic level of ChM knowledge enrichment, the second-sub-DSRM-increment aims to develop an ontology-based model (ChM Extension Ontology) that extends the adapted srBPA ontology for ChM. This model is anticipated to represent the main documents (e.g. the Change Request Form) and roles (e.g. the Change Initiator) that are related to the ChM processes identified within the ChM-BPA models and resolve their semantic heterogeneity. An 'Integrated BPA-driven ChM' ontology is then created by linking the 'ChM Extension Ontology' with the 'Adapted srBPA Ontology for ChM'.

The second-sub-DSRM-increment for the development of the integrated BPA-driven ChM ontology went through three DSRM stages. The first was the design and development stage, where an ontology-based meta-model was developed to represent and link ChM documents and roles to BPA-driven ChM processes. Then there was the demonstration stage, where ChM documents and roles were identified, the developed ontological meta-model was instantiated with the identified ChM documents and roles, and then linkages between the represented documents and roles with related ChM processes were instantiated. Finally, there was the evaluation stage, where the developed ontology (the Integrated BPA-driven ChM ontology) was assessed.

5.3.1 THE SECOND SUB-INCREMENT'S DESIGN AND DEVELOPMENT STAGE

To extend the knowledge enrichment of the developed ChM-BPA, the ChM-BPA-driven EBEs that were considered as documents or roles related to handling the application of ChM processes can be captured and linked to their related processes. Figure 5.8 shows a simple UML conceptual meta-model proposed to represent the ChM documents and roles and their generic relations to related BPA-driven ChM processes.

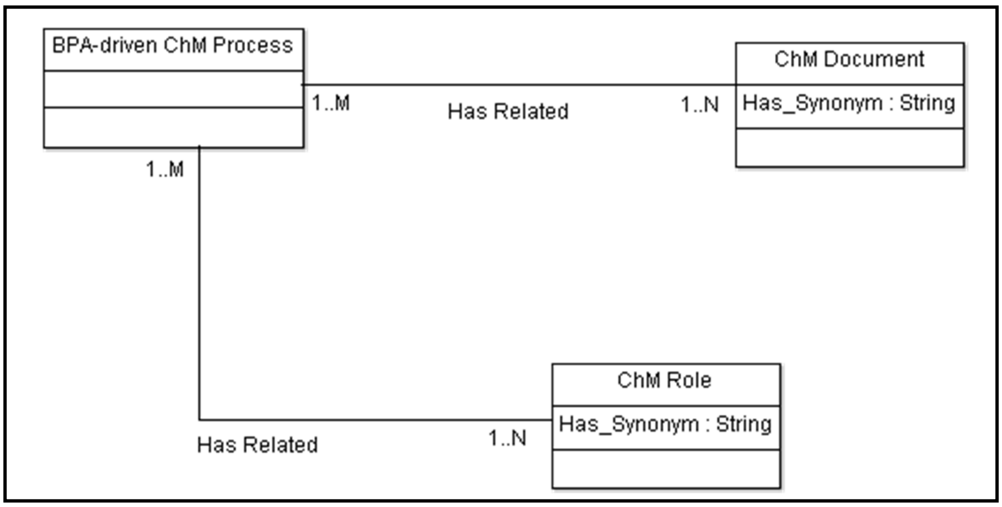


Figure 5. 8: An abstract conceptual meta-model that represents the proposed ChM-BPA-Driven Extension.

In Figure 5.8, each ChM process has one or more related ChM documents. In this context, the intended meaning of the 'Has Related' relation is that a document is considered as an input or output of the process, e.g. the application of the 'handle a ChM request submission' process results in filling and submitting a change request form. On the other hand, during the lifetime of each ChM process, one or more ChM roles need to be involved. This is what is referred to by the 'Has Related' relation depicted in Figure 5.8, located between the role and process concepts. For instance, a change request initiator and a change request receiver need to be involved during the application of the 'handle change request submission' process. Furthermore, some of the ChM documents or roles could be found represented in the investigated literature using different terminologies. Therefore, the 'Has_Synonym' property was proposed to represent the different detected terminologies.

Subsequently, an ontology-based meta-model was proposed to semantically enrich the conceptual meta-model for the ChM-BPA-driven extension. Table 5.11 presents the main elements defined in the proposed ontology-based meta-model (the ChM Extension Ontology), their types alongside brief descriptions of their roles.

Table 5. 11: Description of the main elements identified in the proposed ChM Extension ontology.

Ontology Element	Element Type	Description
ChM_Extension_Ontology_Element	Class	An Ontology-related element, which represents a super-class that entails the proposed ontology concepts.
ChM_Process	Class	Represents the 'BPA-driven ChM Process' class in the proposed conceptual meta-model
ChM_Document	Class	Represents the 'ChM Document' class in the proposed conceptual meta-model
ChM_Role	Class	Represents the 'ChM Role' class in the proposed conceptual meta-model
ChM_Document_Has_Related_Process	Object Property	Represents the 'Has Related' relationship in the proposed conceptual meta-model that exists between the 'ChM Document' class and the 'BPA-driven ChM Process' class.
ChM_Process_Has_Related_Document	Object Property	Represents the 'Has Related' relationship in the proposed conceptual meta-model that exists between the 'BPA-driven ChM Process' class and the 'ChM Document' class.
ChM_Role_Has_Related_ChM_Process	Object Property	Represents the 'Has Related' relationship in the proposed conceptual meta-model that exists between the 'ChM Role' class and the 'BPA-driven ChM Process' class.
ChM_Process_Has_Related_Role	Object Property	Represents the 'Has Related' relationship in the proposed conceptual meta-model that exists between the 'BPA-driven ChM Process' class and the 'ChM Role' class.

Table 5.11: Description of the main elements identified in the proposed ChM Extension ontology, "Continued"

Ontology Element	Element Type	Description
Has_Synonym	Data Property	Represents the 'Has Synonym' property in the proposed conceptual meta-model identified for the 'ChM Document' and 'ChM Role' classes.
ChM_Document_Has_Related_Process only ChM_Process	Quantifier Restriction	An ontology-related universal restriction to constrain the filler part for the property 'Has Related' of the ChM-Document to be ChM-Process.
ChM_Process_Has_Related_Document only ChM_Document	Quantifier Restriction	An ontology -related universal restriction to constrain the filler part for the property 'Has Related' of the ChM-Process to be ChM-Document.
ChM_Process_Has_Related_Role only ChM_Role	Quantifier Restriction	An ontology -related universal restriction to constrain the filler part for the property 'Has Related' of the ChM-Process to be ChM-Role.
ChM_Role_Has_Related_ChM_Process only ChM_Process	Quantifier Restriction	An ontology-related universal restriction to constrain the filler part for the property 'Has Related' of the ChM-Role to be ChM-Process.

Furthermore, Figures 5.9 shows an example of the developed ontology that represents the proposed ChM extension meta-model elements presented in Table 5.12.

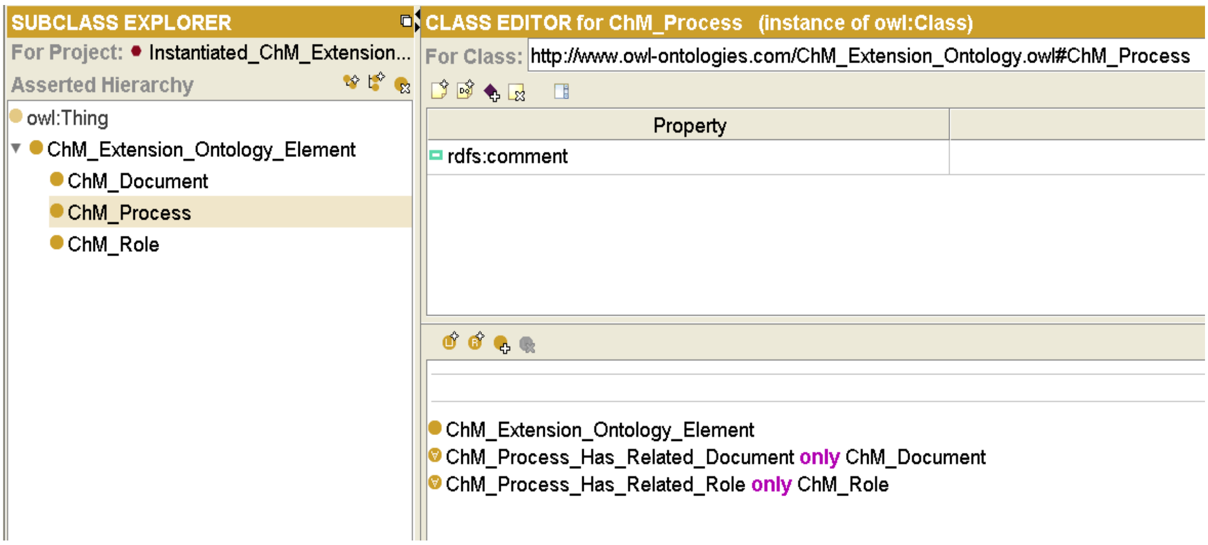


Figure 5. 9: Part of the developed ChM Extension ontology-based meta-model

Heretofore, an ontology-based meta-model to extend the adapted srBPA ontology for ChM was proposed and developed. Following this, a means to link the 'ChM-BPA Extension' ontology and the 'Adapted srBPA for ChM' ontology was considered in order to create the aimed at 'Integrated BPA-driven ChM' ontology.

In the developed ChM-BPA in **Chapter 4**, three process types were depicted: the CPs, CMPs and CSPs. When the different CM standards were investigated earlier for the elicitation of the ChM-EBEs, the main focus of these sources was to describe how the individual cases of ChM processes were handled (CPs). Considerations for handling the flow of ChM cases (CMPs) or strategic cases (CSPs) were found to be very limited or had no presence. Therefore, the documents and roles elicited as candidate EBEs for the ChM-BPA were mainly related to the ChM-CPs. Based on this, the considered ChM documents and roles are proposed to be linked to the captured BPA-driven ChM-CPs, as shown in Figure 5.10.

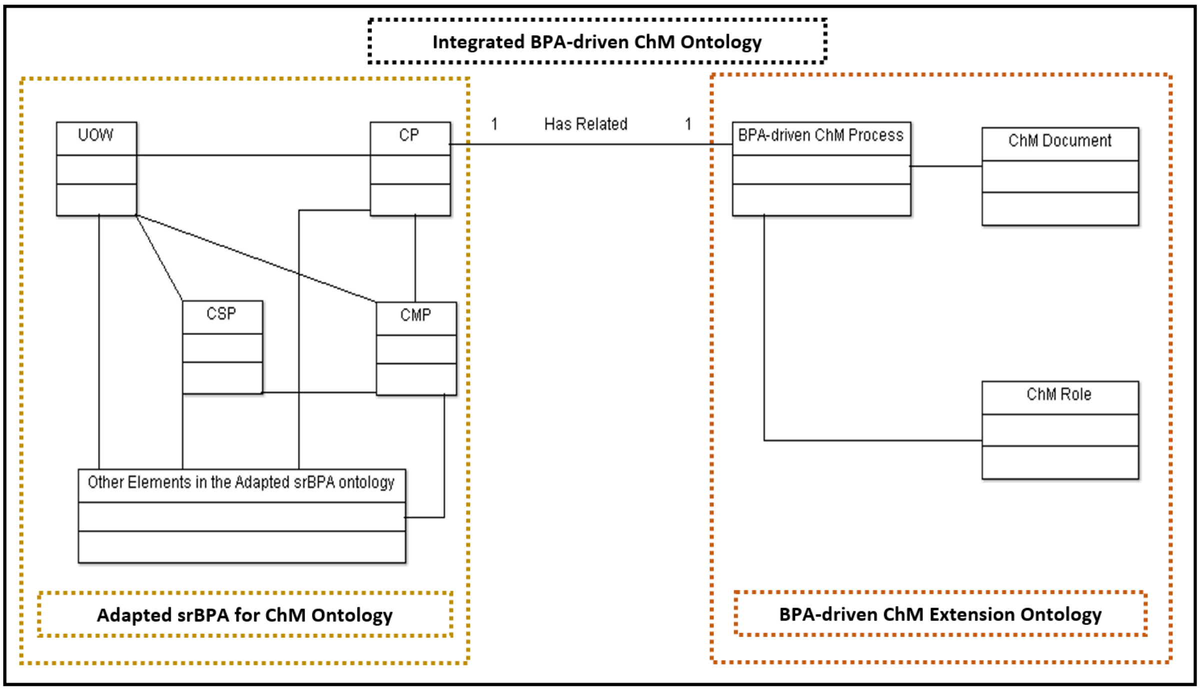


Figure 5. 10: An abstract conceptual meta-model for the Integrated BPA-driven ChM component.

The left-hand side of Figure 5.10 shows parts of the adapted srBPA ontology elements for ChM, especially the UOW, CP, CMP and CSP elements. It also highlights that there are relationships between these elements (discussed in **Chapter 4**). The right-hand side shows parts of the ChM-BPA extension ontology and the relationships between them (as discussed earlier in Section 5.3.1). In order to link the two ontologies, the 'Has Related' relation was proposed between the 'CP' instances of the 'Adapted srBPA for ChM' ontology and the related 'BPA-driven ChM Process' instances of the 'ChM-BPA Extension' ontology, where each instance from an ontology has one related instance from the other ontology. The creation of the 'Integrated BPA-driven ChM' ontology results from the merging and linking of these two ontologies.

5.3.2 The Second Sub-Increment's Demonstration Stage

This stage aims to instantiate the developed ontology-based meta-model for the 'ChM-BPA Extension' with related ChM documents and roles. It also aims to link the instantiated 'ChM Extension' ontology with the related ChM processes that exist in the 'Adapted srBPA ontology for ChM', which was instantiated for ChM-BPA in the previous sub-increment. Accordingly, the ChM-

EBEs that were considered as 'Documents' or 'Roles' during the development of the ChM-BPA (in Chapter 4) were investigated and captured. The different captured roles or documents were linked together based on their general objectives. In addition, a consolidated set of ChM-documents was proposed to represent the captured and linked ChM-documents. A consolidated set of ChM-roles was also proposed to represent the captured and linked ChM-roles.

For instance, Tables 5.12 and 5.13 show parts of the captured ChM documents and roles. Each table shows the different considered ChM sources (e.g. ITIL), the main ChM stage (e.g. Change Request Submission and Initiation) and the various elicited documents or roles linked together under the named ChM stages based on their general objectives. Furthermore, each row that contains the linked documents or roles was given an ID. The complete set of the elicited ChM documents and roles can be found in Appendix E. Moreover, Tables 5.14 and 5.15 show the proposed consolidated sets that represent the captured and linked ChM documents and roles. Each table shows the proposed set of ChM documents or roles and the row-ID (partially from Table 4.12 or Table 5.13) that the proposed elements represent.

Table 5. 12: Part of the captured and linked ChM-Documents.

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104: 2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	Change Proposal / Problem Report	Problem/Bug Report				Problem Statement			Problem Report			
2	Change Record, Change Document, or Change Log	Change Request Form	Change Record	Request For Change Document		Change Report		Change Documentation	Documented Change Request	Change File	Engineering Change Proposal/ Request For Variance Document	Change Request Form
3	RFC Form	Change Request	Change Request Form, Problem Report Form, Software Change Notice	Request For Change or Variance	Change Request Form	Request For Change/ Engineering Change Proposal/ Request for variance or Deviation	Request For Change/Variance/Deviation/ Waiver/Concession	Change Proposal Form	Change/ modification Proposal	Statement of Need/ Request Application	Engineering Change Proposal / Request For Variance	Change Request
4					Initiation Feedback							
	Change Evaluation and Assessment											
5	Evaluation Plan		SCM Plan as a reference for classification criteria	Classification Criteria	Assessment Criteria				Classification Criteria			
6	Formal Evaluation Request/ Work Order for Assessing											Notification

Table 5. 13: Part of the captured and linked ChM-Roles.

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	Change Request Initiator	Change Requester/ System Stakeholder	Change Originator		Change Request Initiator	Customer / Supplier		Organisation / Customer / provider		Request Originating Authority (Customer, user, supplier, sub-contractor)	Change Originator	Change Originator
2		Initial Validity Checker (Customer Support, Application Support, Member of the development team)	Receiving Authority (ChM Officer or Software CM team member)		Help Desk/ As a Process Owner						Configuration Management Officer	
3	Change Management Authority (for RFC Approval or Rejection in the Initiation stage)		ChM Authority (ChM, ChM Officer)		Configuration Control Manager (Initiation Resolution) / As a Process Owner					Management Authority		
	Change Evaluation and Assessment											
4					Configuration Control Manager As a Process Owner / (coordinates assessment and combines findings)						Configuration Management Officer	

Table 5. 14: The proposed consolidated set of ChM-Documents.

Proposed Artefact Name	Covered Row-ID
Change Statement	1
Change Record	2
Change Request Form	3
Change Initiation Feedback To Initiator Report	4
Pre-established Assessment Criteria	5
Change Assessment Request	6
Change Assessment Report	7
Integrated Change Assessment Document	8
Authority Tree Structure	9
Disposition Document And Directives	10
Change Disposition Feedback To Initiator Report	11
Disposition Notification For Distribution	12
Planning And Scheduling Request	13
Implementation Plan	14
Change Schedule	14
Projected Service Outage	14
Remediation Plan	14
Release and Deployment Plan	14
Implementation Request	15
Implementation Document	16
Implementation Evaluation Report	17
Release And Deployment Authorisation Report	18
Release And Deployment Request	19
Release And Deployment Document	20
Formal Evaluation Request	21
Formal Change Evaluation Report	22

Table 5. 15: The proposed consolidated set of ChM-Roles.

Proposed Role Name	Covered Row-ID
Change Request Initiator	1
Change Request Receiving Authority	2
ChM Authority	3
Change Assessment Coordination Authority	4
Change Assessment Authority	5
Change Disposition Coordination Authority	6
Change Disposition Authority	7
Change Disposition Feedback Authority	8
Change Planning Authority	9
Change Plans Reviewing Authority	10
Change Implementation Coordination Authority	11
Change Implementation Authority	12
Change Implementation Review Authority	13
Change Deployment and Release Coordination Authority	14
Change Deployment and Release Authority	15
Change Final Evaluation Authority	16
Change Closure Authority	17

The instantiation steps, as shown in Table 5.16, were conducted in order to instantiate the developed ontology-based ChM-BPA extension meta-model with the captured, linked and proposed ChM elements (ChM documents and roles). Table 5.16 shows the steps and provides a brief summary of what was done during the execution of the steps.

Table 5. 16: The instantiation steps for the ChM-BPA extension Ontology.

ChM-BPA Extension instantiation Step	**Step 1:** ▪ Instantiating the general ChM-Processes
Description of the conducted instantiation Step	▪ Instantiate the general ChM-Process class based on the UOWs of the ChM-BPA captured in **Chapter 4**.
ChM-BPA Extension instantiation Step	**Step 2:** ▪ Instantiating the proposed consolidated ChM-Documents
Description of the conducted instantiation Step	▪ Instantiate the ChM-Document class based on the consolidated set of the ChM-Documents proposed in Table 5.14. ▪ For each of the proposed documents, instantiate the 'Has_Synonym' object property with the related synonyms available in the linked ChM documents table.
ChM-BPA Extension instantiation Step	**Step 3:** ▪ Instantiating the proposed consolidated ChM-Roles
Description of the conducted instantiation Step	▪ Instantiate the ChM-Role class based on the consolidated set of the ChM-Roles proposed in Table 5.15. ▪ For each of the proposed roles, instantiate the 'Has_Synonym' object property with related synonyms available in the linked ChM roles table.
ChM-BPA Extension instantiation Step	**Step 4:** ▪ Instantiating the relationships between the ChM Process, Document, and Role classes' instances.
Description of the conducted instantiation Step	▪ Instantiate the 'ChM_Process_Has_Related_Document' object property. ▪ Instantiate the 'ChM_Process_Has_Related_Role' object property.

Figures 5.11 and 5.12 show examples of the ChM-BPA Extension ontology during instantiation.

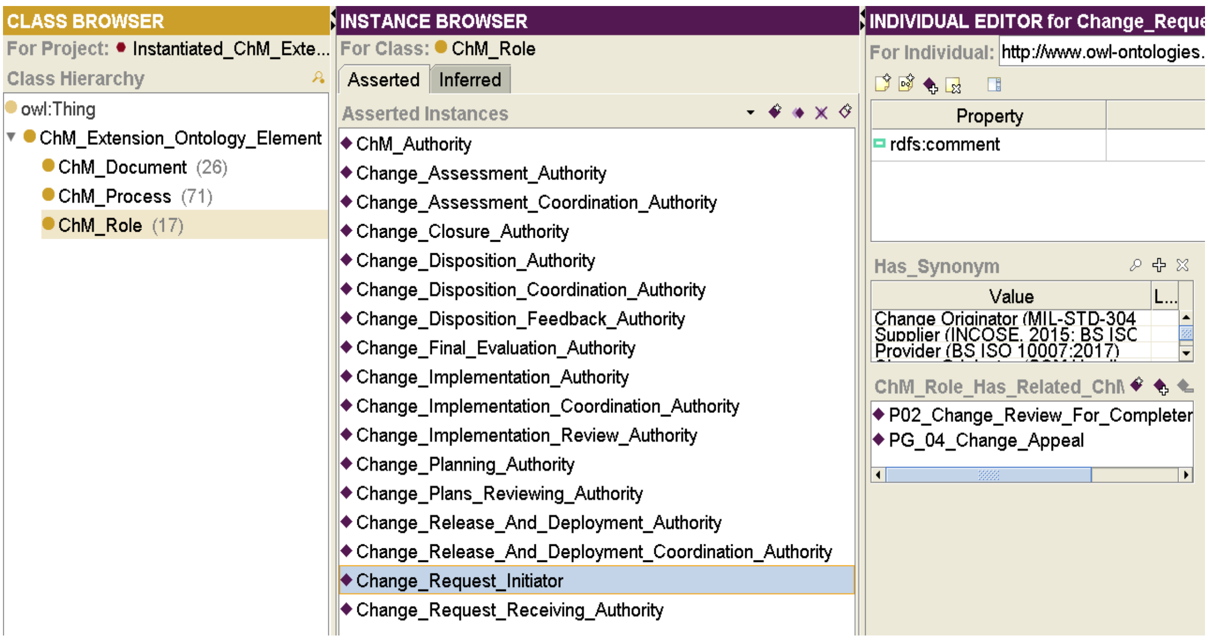


Figure 5. 11: An example of instantiating the ChM Extension ontology.

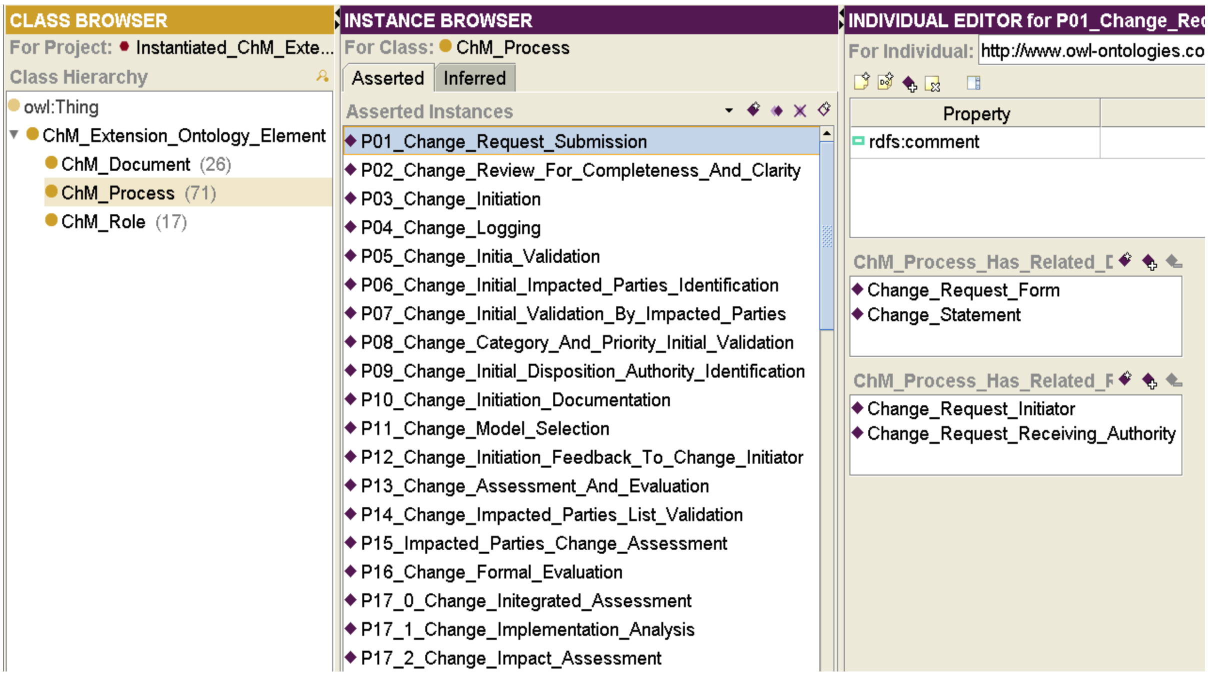


Figure 5. 12: An example of instantiating the ChM Extension ontology.

Heretofore, the 'ChM-BPA Extension' ontology instantiated with ChM elements was developed. To create and instantiate the 'Integrated BPA-driven ChM' ontology, the resulting instantiated 'ChM-BPA Extension' ontology and the instantiated 'Adapted srBPA for ChM' ontology were imported into a new ontology and linked together using relations derived from the 'Has_Related' relation proposed in the previous stage (as in Figure 5.10). Figures 5.13 and 5.14 show examples of the creation and instantiation of the 'Integrated BPA-driven ChM' ontology.

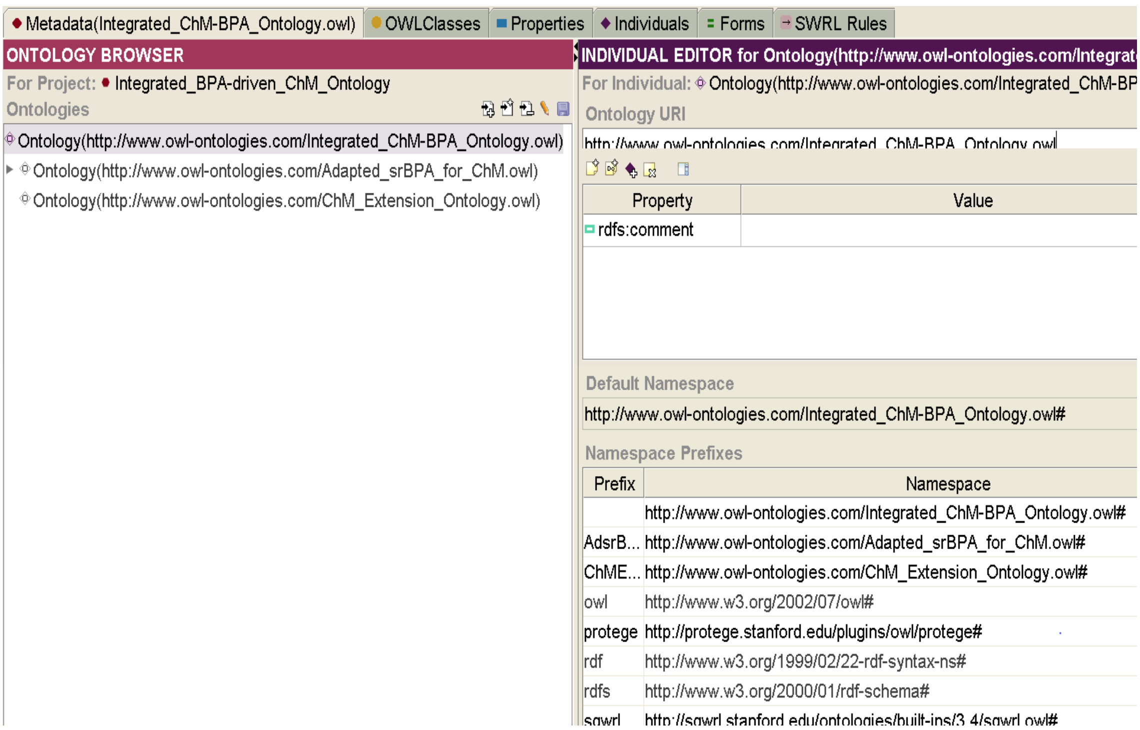


Figure 5. 13: Importing the developed ontologies as part of instantiating the Integrated BPA-driven ChM ontology.

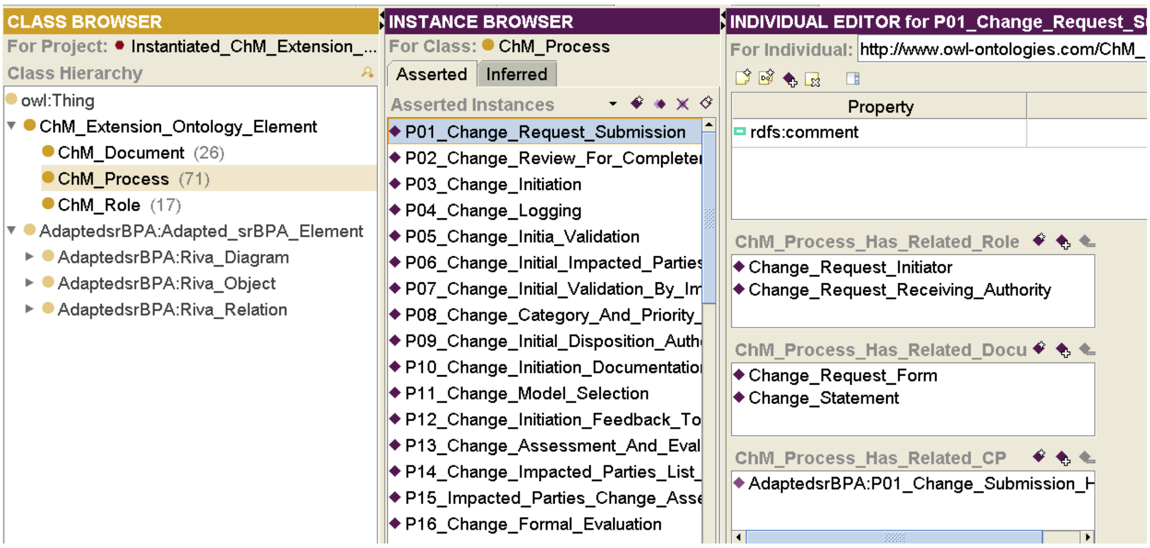


Figure 5. 14: An example of instantiating the Integrated BPA-driven ChM ontology.

5.3.3 The Second Sub-Increment's Evaluation Stage

In this DSRM stage, aspects related to the design and utility of the developed 'Integrated BPA-driven ChM' ontology were evaluated.

5.3.3.1 The Evaluation Roadmap

Based on the evaluation framework adopted for this research (discussed in **Chapter 3**), this stage emphasised the verification and validation of the 'Integrated BPA-driven ChM' ontological model. Table 5.17 presents the parts of the evaluation framework related to evaluating the 'Integrated BPA-driven ChM' ontological component. The table presents an abstract description of the objectives of the evaluation and lists the adopted evaluation types, criteria and approaches, which are discussed more thoroughly in the following sections.

Table 5. 17: The part of the evaluation framework related to evaluating the 'Integrated BPA-driven ChM ontology'.

Objective of Evaluation	Type and Criteria of Evaluation		Evaluation Technique
(Second-DSRM-Increment) (Second-Sub-Increment) Evaluating the 'Integrated BPA-driven ChM' ontological model (The Semantic Enrichment of the ChM-BPA linked to the ChM-BPA Extension):	Verification		
	Consistency		Protégé Reasoner
(1) To inform the adherence of the developed semantically-enriched models to the ontology-based representation using OWL-specifications.	Completeness	Redundancy	Checklist-based Walkthroughs (By the researcher)
	Validation		
(2) To further verify the correctness of the developed semantically-enriched models by checking the completeness and redundancy aspects of their elements.	Correctness	Completeness	Checklist-based Walkthroughs and Semi-structured interviews (By the researcher and by the domain experts)
(3) To inform the validity of the developed ontological-based models in representing the identified ChM-BPA extension elements and linking them to related elements in the ChM-BPA.	Consistency		Protégé Reasoner
(4) To inform if the 'Integrated BPA-driven ChM' component meets the identified objectives that motivated its development.	Appropriateness		A Checklist-based Walkthrough by a Semi-structured Interview (By the researcher with support of the domain experts)

5.3.3.2 The Verification of the Ontology-based 'Integrated BPA-driven ChM' Component

In this category of evaluation, the correctness of the ontology-based 'Integrated BPA-driven ChM' meta-model was verified before its instantiation. This was done by checking its consistency, completeness and redundancy. Table 5.18 provides a description of these criteria as adopted by the research.

Table 5. 18: The adopted verification criteria for the evaluation of the 'Integrated BPA-driven ChM meta-model'.

Verification Criteria	Description
Consistency	▪ The semantic enrichment of the 'Integrated BPA-driven ChM' meta-model adheres to the rules and syntax of the OWL-specifications used to create it (i.e. no contradictory items or constraints are detected or inferred).
Completeness	▪ The semantically-enriched 'Integrated BPA-driven ChM' meta-model contains all the elements that it should represent.
Redundancy	▪ Each construct of the semantically-enriched 'Integrated BPA-driven ChM' meta-model contributes knowledge to the model (i.e. a real-world entity is not represented by more than one ontological construct).

Table 5.19 presents the used techniques linked to the verification criteria. The table also provides a brief description of the used verification techniques.

Table 5. 19: The adopted verification techniques for the evaluation of the 'Integrated BPA-driven ChM meta-model'.

Verification Criteria	Verification Technique	Brief Description
Consistency	Protégé Reasoner	▪ Checking the consistency of ontology-based models can be done using a reasoner that supports an ontology development tool. For this research, the protégé reasoner - i.e. Pellet – was used to check the consistency of the ontology-based 'Integrated BPA-driven ChM' meta-model. ▪ If no inconsistency is detected by the Protégé reasoner it could be realised that the ontology-based meta-model of the 'Integrated BPA-driven ChM' is consistent. ▪ This check was carried out by running the Protégé reasoner.
Completeness	Checklist-based Walkthroughs	▪ The ontology-based 'ChM-BPA Extension' meta-model as part of the 'Integrated BPA-driven ChM' meta-model should represent the concepts and relations that appear in the proposed conceptual meta-model (presented in Figure 5.8). Accordingly, a checklist was designed and used to check if all the elements of the conceptual meta-model were represented by the developed ontology-based meta-model. ▪ In addition, the checklist was extended to inspect that all the identified ontology elements needed for merging and linking the 'Adapted srBPA ontology for ChM' with the 'ChM-BPA Extension ontology' to produce the 'Integrated BPA-driven ChM' ontology were represented. ▪ This check was carried out by the researcher.

Table 5.20: The adopted verification techniques for the evaluation of the 'Integrated BPA-driven ChM meta-model', "Continued".

Verification Criteria	Verification Technique	Brief Description
Redundancy	Checklist-based Walkthroughs	▪ A checklist was designed and used to check that each element in the conceptual meta-models used to develop the 'ChM-BPA Extension' and the 'Integrated BPA-driven ChM' ontologies is not represented by more than one ontological construct. At the same time, the checklist was used to check that each element of the developed ontology-based 'Integrated BPA-driven ChM' meta-model contributes knowledge to the model (i.e. to check that there is no redundant knowledge provided by the elements of the ontology-based meta-model). ▪ This check was carried out by the researcher.

Tables 5.20 and 5.2` show examples of the conducted verification techniques.

Table 5. 20: Part of the checklist-based walkthrough carried out to check the completeness of the 'ChM-BPA Extension' meta-model elements.

ChM-BPA Extension Conceptual Meta-Model Element	Representing Ontology Element	Represented?		Remarks
		Yes	No	
BPA-driven ChM Process: Class	'ChM_Process': Construct	✓		
ChM Artefact: Class	'ChM_Artefact': Construct	✓		
ChM Role: Class	'ChM_Role': Construct	✓		
'Has_Related': Relationship Between the ChM-Process and ChM-Artefact classes	'ChM_Process_Has_Related_ Artefact' and 'ChM_Artefact_Has_Related _Process' : Object properties	✓		
'Has_Related': Relationship Between the ChM-Process and ChM-Role classes	'ChM_Process_Has_Related_ Role' and 'ChM_Role_Has_Related_Ch M_Process' :Object Properties	✓		
The 'Has_Synonym': Property for the ChM-Artefact Class	'Has_Synonym' :Data Property	✓		
The 'Has_Synonym': Property for the ChM-Role Class	'Has_Synonym' :Data Property	✓		

Table 5. 21: Part of the checklist-based walkthrough carried out to check the redundancy of the 'Integrated BPA-driven ChM' meta-model.

Integrated BPA-driven ChM Conceptual Meta-Model Element	Representing Ontology Element	Redundancy Found?		Remarks
		Yes	No	
The elements of the Adapted srBPA ontology	The imported Adapted srBPA ontology Elements		✓	
The Elements of the ChM-BPA Extension ontology	The imported ChM-BPA Extension ontology elements		✓	
CP: Class of the ChM-BPA	CP: construct of the Adapted srBPA ontology	✓		These two constructs are representing the same real-world entity.
BPA-driven ChM Process: Class of the ChM-BPA Extension	ChM-Process: construct of the ChM-BPA Extension ontology	✓		
'Has Related': relation between the CP and The BPA-driven ChM process classes	'CP_Has_Related_ChM_Process' and 'ChM_Process_Has_Related_CP' :Object Properties	✓		The knowledge can be reached (inferred) from using only one object property that is symmetric.

As a result of conducting the verification of the 'Integrated BPA-driven ChM' ontological component (including the 'ChM-BPA Extension' ontological component), the reasoner detected no inconsistencies. All the intended elements were also represented. However, the BPA-driven ChM-CP real-world entity was found redundant when the two ontologies were merged together. This happened as the same process was represented by the CP and ChM-Process classes in the Adapted srBPA and ChM-BPA Extension ontologies respectively. Although there is a form of redundancy here, keeping these two representing constructs enables the separation of concerns between the developed ontologies and their independency of the 'Integrated BPA-driven ChM ontology'. Furthermore, with some of the used object properties (e.g. ChM_Process_Has_Related_Document and ChM_Document_Has_Related_Process) the knowledge can be reached (inferred) from using only one symmetric object property. However, using two relations make knowledge more specific and explicit.

5.3.3.3 The Validation of the Ontology-based 'Integrated BPA-driven ChM' Component

In this category of evaluation, the ontology-based 'Integrated BPA-driven' model was validated by checking its correctness, completeness and consistency after the 'ChM-BPA Extension' and the 'Adapted srBPA for ChM' ontologies were instantiated with related ChM elements and then merged and linked together. Table 5.22 provides a description of these criteria as adopted by the research.

Table 5. 22: The adopted validation criteria for the evaluation of the 'Integrated BPA-driven ChM ontology'.

Validation Criteria	Description
Correctness	▪ The instances identified as ChM documents or roles are correct from a ChM point of view. ▪ The relationships identified between the instances in the 'ChM-BPA Extension' are correct from a ChM point of view. ▪ The instances identified as ChM documents or roles are represented correctly in the ontology (each element is represented as it should be). ▪ The identified relationships between the instances in in the 'ChM-BPA Extension' are represented correctly in the ontology. ▪ The relationships instantiated to link between the 'ChM-BPA Extension' and the 'Adapted srBPA for ChM' ontological elements are correct and correctly represented in the ontology.
Completeness	▪ The instances identified as ChM documents or roles are complete from a ChM point of view. ▪ The relationships identified between the instances in the 'ChM-BPA Extension' are complete from a ChM point of view. ▪ All the instances identified as ChM documents or roles are represented in the ontology (no missing constructs). ▪ All the relationships identified between the instances are represented in the ontology (no missing relations), including the links instantiated to develop the 'Integrated BPA-driven ChM' ontological model.
Consistency	▪ After instantiation, no contradictory items are detected or inferred in the ontology.
Appropriateness	▪ The ontological component meets the objectives that motivated its development.

Table 5.23 presents the used validation techniques, linked to the adopted validation criteria. The table also provides a brief description of the used validation techniques.

Table 5. 23: The adopted validation techniques for the evaluation of the 'Integrated BPA-driven ChM ontology'.

Validation Criteria	Validation Technique	Brief Description
Correctness	Checklist-based Walkthroughs through Semi-structured Interviews	▪ Checklist-based walkthroughs through semi-structured interviews were conducted to check that the instances identified as ChM documents or roles and their relationships to the related ChM processes are correct from a ChM point of view and correctly represented in the ontology. In addition, to check that the identified linkages between the 'ChM-BPA Extension' and the 'Adapted srBPA for ChM' ontological models are correct from a ChM point of view and correctly presented in the ontology. ▪ This check was carried out by the researcher with the support of domain experts at the KHCC-CTAG.

Table 5.23: The adopted validation techniques for the evaluation of the 'Integrated BPA-driven ChM ontology', "Continued".

Validation Criteria	Validation Technique	Brief Description
Completeness	Checklist-based Walkthroughs through Semi-structured Interviews	Checklist-based walkthroughs through semi-structured interviews were conducted to check that the instances identified as ChM documents or roles and their relationships to the related ChM processes are complete from a ChM point of view and completely represented in the ontology. In addition to, check that the identified linkages between the 'ChM-BPA Extension' and the 'Adapted srBPA for ChM' ontological model's instances are complete and completely represented in the ontology. ▪ This check was carried out by the researcher with the support of domain experts at the KHCC-CTAG.
Consistency	Protégé Reasoner	▪ The Protégé reasoner (i.e. Pellet) was used to check that after instantiating the 'Integrated BPA-driven ChM' ontology with the related ChM elements, no contradictory items are detected or inferred. ▪ If no inconsistency is detected by the Protégé reasoner, it could be realised that the ontology-based is consistent. ▪ This check was carried out by running the Protégé reasoner.
Appropriateness	Checklist-based walkthrough through a Semi-structured Interview	▪ A checklist-based walkthrough through a semi-structured interview was conducted to check that the 'Integrated BPA-driven for ChM' framework component meets the objectives that motivated its development. ▪ This check was carried out by the researcher with the support of domain experts at the KHCC-CTAG.

Tables 5.24, 5.25 and 5.26 presents examples of the conducted validation techniques.

Table 5. 24: Part of the completeness check conducted for the proposed ChM Documents instances, their relations to the ChM Processes instances, and their representation in the ontological model.

ChM-Process	Related Document	Completeness		
		Agree	Partially Agree	Disagree
P01_Change_Submission	Change Statement Change Request Form	✓		
P02_Change_Review_For_ Completeness_And_Clarity	Change Request Form	✓		
P03_Change_Initiation	Change Statement Change Request Form Change Record	✓		
P04_Change_Logging	Change Request Form Change Record	✓		
P05_Change_Initial_Validation	Change Request Form Change Record		✓	
	Remarks: Change Initial Validation Document Change Initial Validation Request Change Record Notification (Update Request) Change Closure Notification (Closure Request)			
P06_Change_Initial_Impacted_ Parties_Identification	Change Request Form		✓	
	Remarks: Impacted Parties List			
P07_Change_Initial_Validation_ By_Impacted_Parties	Change Request Form		✓	
	Remarks: Change Initial Validation Request Change Impacted Party Initial Validation Report			

Table 5. 25: Part of the completeness check conducted for the proposed ChM Roles instances, their relations to the ChM Processes instances, and their representation in the ontological model.

ChM-Process	Related Role	Completeness		
		Agree	Partially Agree	Disagree
P01_Change_Submission	Change Request Initiator Change Request Receiving Authority	✓		
P02_Change_Review_For_Completeness_And_Clarity	Change Request Receiving Authority Change Request Initiator	✓		
P03_Change_Initiation	ChM Authority	✓		
P04_Change_Logging	ChM Authority	✓		
P05_Change_Initial_Validation	ChM Authority	✓		
P06_Change_Initial_Impacted_Parties_Identification	ChM Authority	✓		
P07_Change_Initial_Validation_By_Impacted_Parties	Assessment Authority	✓		
	Remarks: Impacted Party as Change Validator			
P08_Change_Category_And_Priority_Initial_Validation	ChM Authority	✓		
P09_Change_Initial_Disposition_Authority_Identification	ChM Authority	✓		
P10_Change_Initiation_Documentation	ChM Authority		✓	
	Remarks: Help Desk			
P11_Change_Model_Selection	ChM Authority	✓		
P12_Change_Initiation_Feedback_To_Change_Initiator	ChM Authority		✓	
	Remarks: Help Desk			

Table 5. 26: Checking the appropriateness of the developed ontological models.

#	Objective	Addressed?		Remarks
		Agree	Disagree	
1	The Adapted srBPA ontological meta-model provides a semantic representation of the original and adapted aspects of the Riva-based BPA modelling approach.	✓		
2	The Adapted srBPA ontology for ChM provides an explicit, formal and semantic representation of the developed ChM-BPA models.	✓		
3	The Adapted srBPA ontology for ChM provides a semantic representation of terminologies detected for the BPA-driven ChM UOWs. Thus, it enables resolving semantic heterogeneity.	✓		
4	The ChM-BPA Extension ontology provides an explicit, formal and semantic representation of the BPA-driven ChM Documents and Roles and their relationships to BPA-driven ChM-Processes.	✓		
5	The ChM-BPA Extension ontology provides a semantic representation of the terminologies detected for the BPA-driven ChM Documents and Roles. Thus, it enables resolving semantic heterogeneity.	✓		
6	The ChM-BPA Extension ontology provides an extension to the Adapted srBPA ontology for ChM.	✓		

Table 5.26: Checking the appropriateness of the developed ontological models, "Continued".

#	Objective	Addressed?		Remarks
7	The Integrated BPA-driven ChM ontology provides knowledge about the BPA-driven ChM processes, the relationships between them and the main ChM Documents and Roles needed to handle the application of the ChM-CPs. Thus, The Integrated BPA-driven ChM ontology provides more holistic knowledge about ChM aspects than each of its constituent ontologies does.	✓		
8	Using the Integrated BPA-driven ChM ontology enables reducing the lack of shared understanding of and consensus on the semantics of the ChM processes, the relationships between them and their related Documents and Roles between practitioners in the systems and software engineering domains and in in heterogenetic contexts like an SoS context.	✓*		Subject to providing means that enables stakeholders to retrieve such knowledge.

As a result of conducting the validation for the 'Integrated BPA-driven ChM' ontological component with the domain experts, a number of correctness and completeness aspects related to the identified documents and roles and their relationships to the ChM-Processes were identified, e.g. the separation of the 'Implementation' related documents or roles into 'Build and Test' documents or roles to emphasise the importance of the build and test aspects in ChM application. Another example is the lack of the representation of documents used as an input or output during handling the application of ChM processes, such as 'Change Impacted Party Initial Validation Report'. This is to be linked with the 'P07_Change_Initial_Validation_By_ Impacted_Parties' ChM process. Some further roles were proposed to be linked with a number of the BPA-driven ChM processes, such as the 'Help Desk' role and its linkages to the 'Change Feedback to Initiator' processes. The 'Integrated BPA-driven ChM' ontology was consequently revised and updated to include or resolve the identified aspects. Figures 5.15 and 5.16 present part of the updated ontology after being revised. Furthermore, the domain experts found the developed ontological component fulfils the objectives that motivated its development. This is subject to providing means that enable enriching the awareness of ChM stakeholders with the represented ChM knowledge.

Having the 'Integrated BPA-driven ChM' ontological component enables the OntoSoS.BPA.ChM framework to retrieve and provide knowledge related to the ChM application. This allows for and guides the application of ChM in heterogenetic contexts, including SoS contexts. **Chapter 7** discusses how this ontological component fits into the OntoSoS.BPA.ChM framework and how it can be used to provide knowledge that guides the application of ChM in SoS contexts.

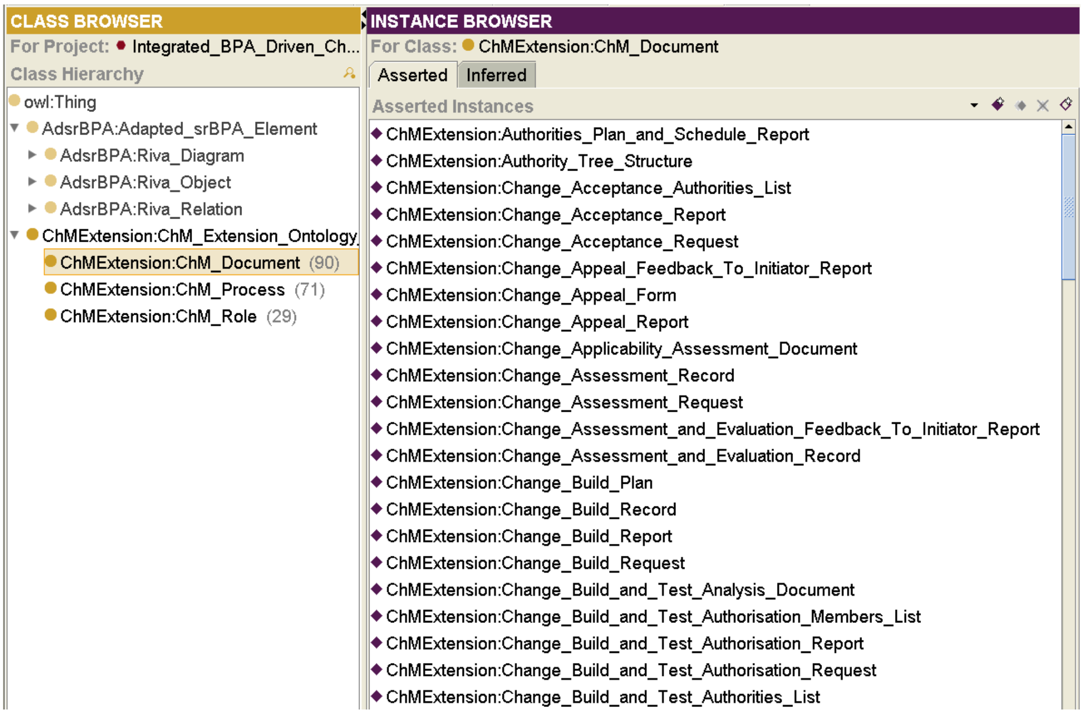


Figure 5. 15: Part of the revised Integrated BPA-driven ChM ontology.

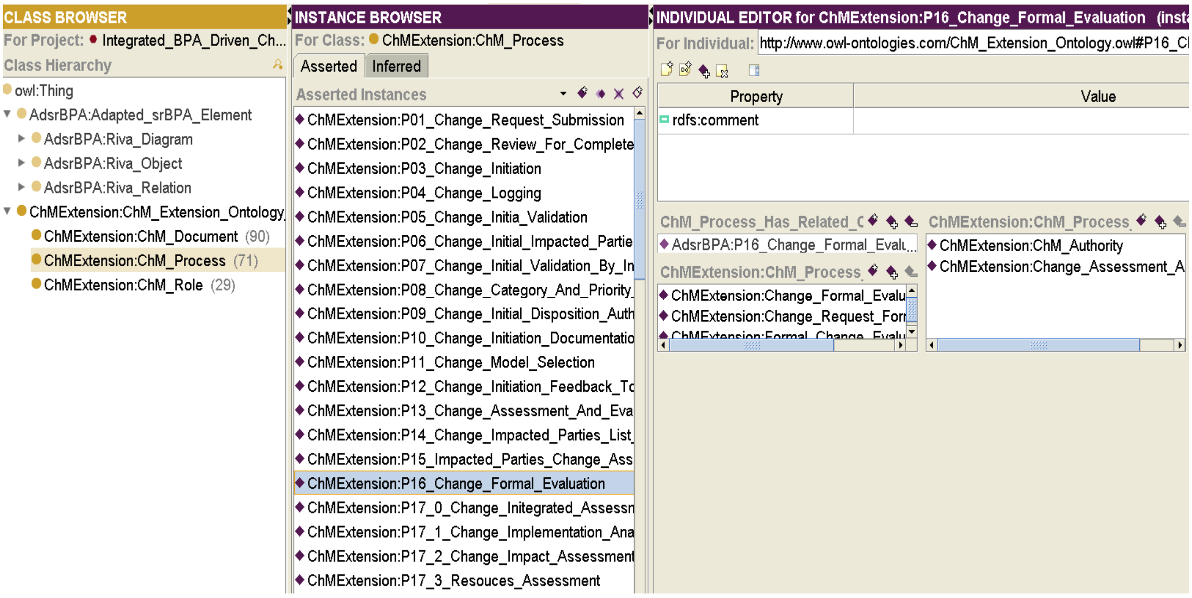


Figure 5. 16: Part of the revised Integrated BPA-driven ChM ontology.

5.4 Chapter Summary And Discussion

Having developed the ChM-BPA models in **Chapter 4**, this chapter focused on semantically enriching the developed ChM-BPA models and extending them to obtain a more holistic knowledge base that represents BPA-driven ChM processes and the relationships between them in addition to the main related ChM documents and roles and their linkages to identified ChM-processes.

The Second-DSRM-Increment (including two sub-DSRM-increments) was conducted in order to achieve this chapter's objective. The first-sub-DSRM-increment focused on the semantic enrichment of the ChM-BPA models that were developed by adapting the Riva-based BPA modelling approach. The semantic heterogeneities detected between the main ChM concepts during the development of the ChM-BPA models were also semantically enriched. Carrying out this sub-increment resulted in developing the 'Adapted srBPA ontology for ChM' component.

The 'Adapted srBPA ontology for ChM' component is limited to representing the BPA-driven ChM processes and the relationships between them. A BPA-driven ChM extension was proposed to represent the main ChM documents and roles related to the identified BPA-driven ChM-processes (ChM-CPs) in order to be linked to them. The second-sub-DSRM-increment focused on the development and evaluating the proposed extension (the ChM-BPA Extension ontology) and linking it to the 'Adapted srBPA ontology for ChM' to obtain a more holistic knowledge representation.

Adapting the Riva-based BPA modelling approach alongside its semantic-enrichment to develop a semantically-enriched BPA-driven ChM model has enabled the semantic identification and representation of further ChM aspects related to the identified BPA-driven ChM processes (Sections 5.3 and 7.2.4). This has led to extending the ontology-based ChM-BPA models to constitute an 'Integrated BPA-driven ontology for ChM' aka 'the ChM framework component', which is a novel generalised semantically-enriched BPA-driven model that provides knowledge about: generalised main ChM stages, their related flow and decision gates; ChM-BPA models' elements; BPA-driven ChM documents, roles and dependency relationships identified for the ChM processes; and interrelated linkages between the ChM processes and the aforementioned identified aspects. This provides the research with a more holistic and traceable semantic representation of BPA-driven knowledge that represents the aforementioned ChM aspects.

As demonstrated by the CTAG-KHCC case study, this contributes to addressing the ChM concepts' heterogeneity existing in ChM standards and practices. Also, it contributes to enabling the achievement of a shared understanding of and consensus on the ChM processes and relationships between them amongst the various ChM practitioners. Moreover, having generic and agreed knowledge about ChM is anticipated to enable its adoption by different business settings, for example, healthcare or industrial settings. The Integrated BPA-driven ChM' ontological component provides the OntoSoS.BPA.ChM framework with a form of ChM knowledge repository. This enables stakeholders to retrieve, share and agree upon knowledge about the ChM processes required to manage changes in general and especially in a heterogenetic context such as a SoS arrangement context. Having such knowledge then plays a key role in meeting the goal of this research by improving the application of ChM in a SoS context. Accordingly, the fourth-DSRM-increment (**Chapter 7**) describes how ChM knowledge, related to managing a submitted change request in a SoS arrangement, can be retrieved and utilised.

This chapter contributed to addressing **RQ1**, which has contributed to the fulfilment of **RO1** in addition to bridging the first three research gaps identified in Section 2.7. The developed semantically-enriched BPA-driven ChM model provides a novel explicit and formal representation of ChM knowledge that has not been provided by the current ChM frameworks. Being an object-based BPA-driven enables a stable, clear and abstract understanding of the ChM core processes and the relationships between them (Chapter 4). In addition, being formally specified and semantically-enriched makes the represented elements machine-readable and appropriate for knowledge reasoning and retrieval (Chapter 5), which facilitates sharing and agreeing on ChM aspects by resolving semantic heterogeneities. As informed by using the CTAG-KHCC case study, having such knowledge has demonstrated the enrichment of ChM stakeholders' awareness of different generalised ChM aspects required to manage a change request (Chapter 7). This, in turn, has contributed to facilitating and improving the application of ChM processes. Table 5.27 maps between the main research questions and the thesis chapters where they were addressed up to this point.

Furthermore, having followed a DSRM-based process, ensured that answering **RQ1** was conducted methodologically, where after developing the anticipated ChM artefacts, their applicability and validity were assessed and informed using a sufficient and representative real-world case study, the CTAG-KHCC, with support of ChM and BPA domain experts

Table 5. 27: The status of addressing the identified RQs by the main research chapters up to this point.

Research Question	Chapter 4	Chapter 5	Chapter 6	Chapter 7
RQ1	✓✗	✓		
RQ2				
RQ3				
RQ4				

CHAPTER 6

A BPA-DRIVEN AND SEMANTICALLY ENRICHED VIEW FOR SYSTEM OF SYSTEMS OPERATIONAL CONTEXT

6.1 INTRODUCTION

Chapters 4 and 5 discussed the development of the ChM framework component, which is considered the first key component of the OntoSoS.BPA.ChM framework. This chapter focuses on developing the second key component of the OntoSoS.BPA.ChM framework, namely the SoS Context View component, which results from carrying out the third-DSRM-increment. It represents a SoS context view by developing a BPA-driven ontological metal-model that captures SoS contextual elements to support global-local levels alignment and BITA during ChM application.

Developing the 'SoS Context View' component within the third-DSRM-increment involves three main stages. The Design and Development stage, which focuses on the development of a generic ontological meta-model that semantically represents global-local levels and BIT- driven aspects of the SoS operational context. The Demonstration stage, where the CTAG-KHCC/Jordan case study is used to instantiate the developed ontological meta-model. After instantiation, the increment concludes with the Evaluation stage, where the developed ontology is assessed based on utilising the evaluation framework adopted for this purpose (introduced in Chapter 3). Based on the evaluation outcomes, the framework component is revised if modifications found needed.

The SoS context view component is aimed at providing a generic BPA-driven knowledge about the operational context of a SoS arrangement, which is anticipated to address the detected lack of an explicit and formal representation of the SoS global-local levels aspects, including BITA aspects, and the linkages between them for the application of ChM. Furthermore, instantiating the developed component for a domain-specific SoS arrangement provides the OntoSoS.BPA.ChM framework with a knowledge base (e.g. instantiated ontology) that enables adapting the configuration item concept to further include SoS main business aspects. This, in turn, enables the provision of comprehensive traceability of the SoS candidate impacted elements and related authorities that the ChM stakeholders need to be aware of when managing a change request submitted in a SoS context (Chapter 7). Having such a piece of knowledge contributes to improving the application of ChM in a SoS context, which is the fundamental goal of this research. Subsequently, the fourth-DSRM-increment (Chapter 7) discusses the alignment of SoS context view component with the ChM component in order to enable identifying the anticipated candidate impacted elements and related authorities.

The rest of this chapter is organised as follows. Section 6.2 discusses the design and development of the SoS context view component. Section 6.3 discusses the instantiation and demonstration of the developed SoS context view component using the CTAG-KHCC case study. The related parts of the adopted evaluation framework applied to assess the developed SoS context view component are presented in Section 6.4. Section 6.5 summarises the chapter.

6.2 Third-DSRM-Increment's First Stage: Design and Development of the SoS Context View Artefact

This stage aims to develop a (global-local levels alignment and BITA)-driven conceptual meta-model for the SoS operational context that is under the consideration of this research. Thereafter, it aims to semantically-enrich the developed conceptual meta-model using ontology and then link the developed ontological meta-model (i.e. SoS context view ontology) to related ontological meta-models (e.g. BPA ontologies for global and local levels, BPM ontologies for the participating constituent systems and BPAOntoSOA-driven models (Yousef, 2010)) in order to form an 'Integrated SoS Context View' ontology that provides a more comprehensive view.

6.2.1 Considerations for the Artefact Design and Development

As discussed in Chapter 2, the linkages between the global and local levels of SoS arrangements are insufficiently represented and considered during SoS investigations, particularly when ChM processes are applied. Furthermore, no ChM framework within the SoS domain considers and captures the linkages between a SoS arrangement's business aspects and the related supporting IT aspects. In addition, the researcher was unable to identify literature with ChM frameworks that formally capture the linkages between the main items and their related stakeholders in traditional or SoS context. Accordingly, the above-mentioned gaps motivated the development of the SoS context view component.

In the literature, two general SoS architecture design approaches have been adopted, and these are: a top-down approach, which starts from recognising the SoS capabilities then recognising the capabilities of the constituent systems (e.g. capability engineering); and a bottom-up approach, which starts from recognising the local capabilities of the constituent systems then the benefits of having SoS behaviours (e.g. dynamic optimisation) (DANSE Consortium, 2012b).

Driven by the above-mentioned approaches, two levels of systems need to be deeply considered when dealing with a SoS arrangement: the SoS level and the Constituent Systems level. Table 6.1 provides a brief description of these two levels as considered by this research.

The existence of these levels necessitates the existence of different levels of stakeholders and governing bodies, who must be aware of the roles of the constituent systems in the arrangement and need to effectively collaborate to achieve a successful alignment between the global and local levels.

Table 6. 1: levels of systems considered for the SoS operational context.

Considered Level	Brief Description
The SoS Level	▪ Referred to in this study as the **'Global-Level'** (GL) of the arrangement. ▪ Refers to the high-level system resulting from integrating the constituent systems. ▪ Has services and processes that are satisfied and supported by integrating the services, processes and capabilities of the constituent systems. But, the SoS is typically developed to deliver services and address goals that are unable to be delivered or addressed by its individual constituent systems.
The Constituent Systems Level	▪ Referred to in this study as the **'Local-Level'** (LL) of the arrangement. ▪ Refers to the constituent systems which participate in forming the SoS arrangement. ▪ At the local-level, each constituent system has its own services, processes and capabilities, which may differ from those of the other constituent systems. ▪ Two or more of the participating constituent systems should be managerially and operationally independent, with their participation in the SoS arrangement dependent upon the agreed classification (i.e. Directed, Acknowledged, Collaborative or Virtual) (ISO/IEC/IEEE, 2019).

6.2.2 THE DESIGN OF THE SoS CONTEXT VIEW COMPONENT

Investigating the literature of the SoS, BPA and BPM, and BITA domains guided by the considerations highlighted in the previous section, a number of aspects were identified to be considered for the representation of the SoS arrangement and its operational context by this research. Table 6.2 lists these aspects. In addition, Figure 6.1 illustrates them.

Table 6. 2: SoS context view related representation aspects considered by this research.

#	SoS Context View Aspects
1	▪ The context of an SoS arrangement is seen as a virtual organisation which has an organisational architecture with identified business nature and boundary.
2	▪ There are two key business levels in an SoS arrangement, the 'GL-Business Area' and the 'LL-Business Area'.
3	▪ The GL-Business Area of the SoS arrangement has acknowledged GL-Business Services and has an associated BPA that incorporates the Business Processes (BPs) of the GL-Business Area and the relationships between them, which are identified to support the declared GL-Business Services.
4	▪ The fulfilment of any GL-Business Service depends on carrying out a segment of the supporting GL-BPA model.
5	▪ A GL-BPA Model Segment entails BPs and related relations identified within the GL-BPA.
6	▪ There should be at minimum one BP entailed in a GL-BPA Model Segment.
7	▪ The GL-Business Area is supported by a LL-Business Area.
8	▪ The GL-BPA is comprised of the composition of the LL-BPAs, and each of the GL-BPs has an associated LL-BP.
9	▪ The LL-Business Area of the SoS arrangement is comprised of a number of Constituent Business Areas (CBAs) that collectively participate in supporting and achieving the set of GL-business related aspects (i.e. GL-Business Services, GL-BPA, and GL-BPs).

Table 6.2: SoS context view related representation aspects considered by this research, "Continued".

#	SoS Context View Aspects
10	▪ The minimum number of the participating independent CBAs should be two.
11	▪ Each of the CBAs has its own LL-Business Services and associated supporting LL-BPA.
12	▪ The LL-BPAs incorporate BPs and relationships between them, which are identified to support the declared LL-Business Services of the CBAs, which in turn support the related identified GL-business aspects.
13	▪ The fulfilment of any LL-Business Service depends on carrying out a segment of the supporting LL-BPA model.
14	▪ A LL-BPA Model Segment entails BPs and related relations identified within the LL-BPA.
15	▪ There should be at minimum one BP entailed in a LL-BPA Model Segment.
16	▪ LL-BPMs can be identified to show the workflows of the related tasks required to address the LL-BPs.
17	▪ The fulfilment of any given LL-BP depends on carrying out the tasks entailed in a related LL-BPM, therefore each LL-BP can be associated with a LL-BPM.
18	▪ Having the BPAs of the CBAs and their supporting BPMs alongside the utilisation of the BPAOntoSOA framework (Yousef, 2010) allows the identification of linkages between the modelled BPA-BPs and the tasks and participants that are correlated to them. In addition, it enables the identification of the As-Is Software-Services or to propose candidate Software-Services that are able to support the identified business aspects (creating links between business and IT).
19	▪ Each of the identified Software-Services is enabled by a supporting Constituent Information System (CIS).

To conceptually model the discussed SoS context aspects, Figure 6.2 presents a UML class diagram for the main elements of a SoS context view considered for the scope of this research.

Having investigated the literature, the Riva-based BPA modelling approach (Ould, 2005) alongside the BPAOntoSOA framework (Yousef, 2010) were the only means available that suit the objectives and nature of this DSRM-increment. Therefore, Riva was adapted to model the BPA of a SoS arrangement in order to identify the main business processes and the relationships between them for the global and local levels of the arrangement. In addition, BPAOntoSOA framework was adopted to enable the semantic identification of linkages between the BPAs of the participating constituent business areas and the corresponding BPMs. Moreover, it was adopted to enable the semantic identification of local-level software-services and their linkages to related Riva-driven business processes, BPM-Tasks and BPM-Pools.

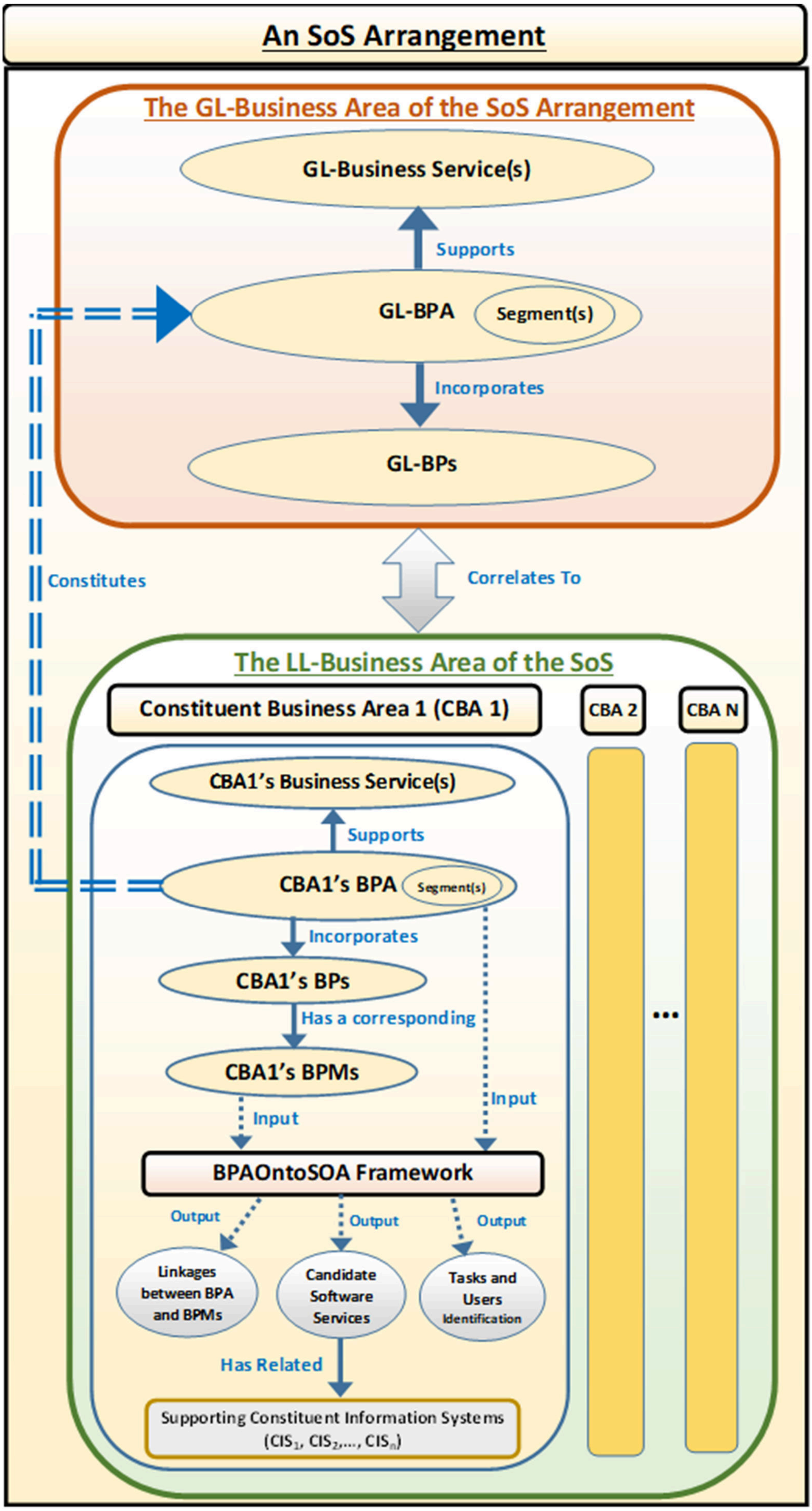


Figure 6. 1: Global-local levels alignment and BITA -driven view of SoS context.

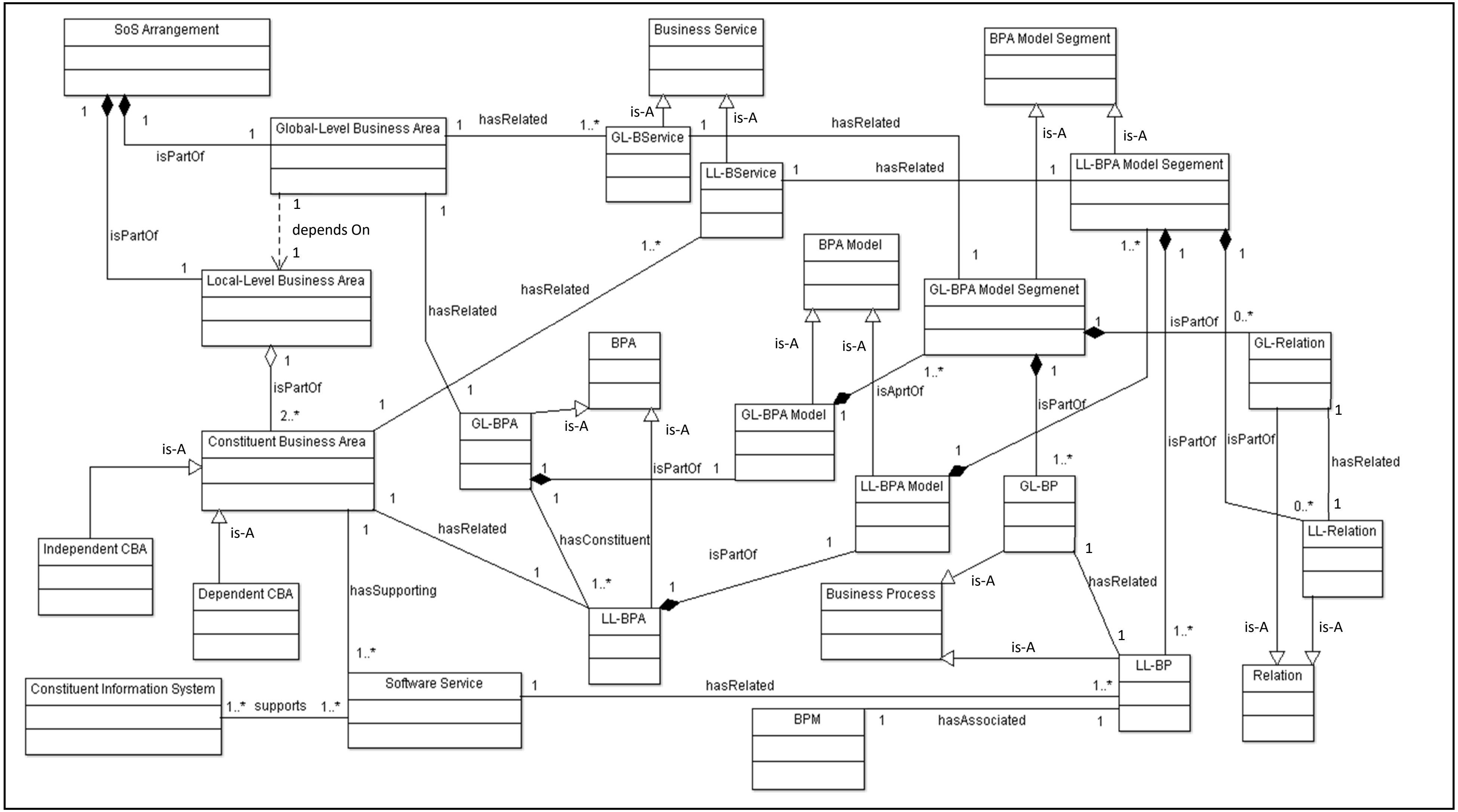


Figure 6. 2: An abstract conceptual meta-model for SoS context view.

6.2.3 The Development of the SoS Context View Component

There is a range of anticipated contributions behind the development of SoS context view artefact. As an independent artefact, it is anticipated to provide an explicit, business-driven, semantically-enriched, formal and generic representation of SoS arrangement operational context with a focus on representing the linkages between the global and local levels, as well as between the business and IT aspects of a SoS arrangement. This enables sharing knowledge amongst researchers that need to acquire a common understanding of SoS arrangement operational context. This includes a machine-interpretable representation of related identified basic concepts and the relationships between them; it enables the reuse of the represented knowledge, and it allows the domain assumptions to be made explicit.

Conversely, as part of the OntoSoS.BPA.ChM framework, this artefact allows the 'Configuration Item' (CI) concept to be adapted to include business-driven CIs in order to support holistic traceability and supporting a high degree of global-local levels alignment and BITA (discussed in **Chapter 7**). This also allows enriching the awareness of ChM processes by providing the ChM layer with comprehensive knowledge that enables the identification of domain-specific SoS elements related to managing proposed changes (for example, main impacted elements, relationships, linkages and participants). Achieving these contributions requires the intended ontology-based SoS context view artefact to be able to capture and represent a number of aspects by developing or adopting a number of ontologies. Table 6.3 provides a brief description of the needed aspects and mention which ontologies can be developed or reused to obtain them.

Table 6. 3: Aspects to be considered for the development of the SoS context view artefact.

#	Aspects need to be captured and represented by the intended SoS context view ontology
1	▪ The semantic-enrichment of the Riva-based BPA elements related to the global and local levels business areas, which is obtainable by adopting the '**Adapted-srBPA Ontology**' (introduced in **Chapter 5**) to represent the BPAs of the global and local level business areas of an SoS arrangement.
2	▪ The semantic-enrichment of the related local-level BPMs' elements, which is obtainable by adopting the '**sBPMN Ontology**' (SUPER 2008, cited in Yousef, 2010) to represent BPMs related to the local-level BPs of the participating local-level constituent business areas.
3	▪ The semantic-enrichment of the abstract SoS context view meta-model, which is obtainable by developing an ontology to capture and represent the conceptual model introduced in the previous section, namely the '**Abstract SoS Context View Ontology**'.
4	▪ The Integration of the resulting ontologies' elements in mentioned the previous points into one ontology, namley the '**Integrated SoS Context View Ontology**', which inlcudes the previously developed or reused ontologies' elements and the semantic enrichment of linkages between them.
5	▪ The semantic identification of software services and encapsulated tasks, which is obtainable by enacting the 'BPAOntoSOA Framework' (Yousef, 2010), this results into having a '**BPAOntoSOA Framework-driven Elements'** added to the integrated SoS context view ontology and linked to related elements exist in other improted ontologies.

Appendix F provides a more detailed discussion of how the SoS context view artefact related aspects and their representation using ontologies (as mentioned in Table 6.3) were designed and developed. It starts by presenting the main concerns of each ontology linked to the aspects mentioned in Table 6.3. Thereafter, it discusses how the 'Abstract SoS Context View Ontology' was developed to semantically represent the conceptual model presented in Figure 6.2. Furthermore, it discusses how the 'Adapted srBPA Ontology', 'sBPMN Ontology' and 'BPAOntoSOA Framework' were reused to semantically represent elements related to the global and local levels BPAs, BPMs and Software Services. Finally, it discusses how 'properties' were reused or proposed to integrate and link the previously mentioned ontologies, which resulted in having the aimed at 'Integrated SoS Context View Ontology'.

6.3 Third-DSRM-Increment's Second Stage: The Demonstration of the Developed SoS Context View Component

The intended SoS context view component was designed and developed in the previous section. This section discusses and highlights the 'Demonstration' stage. To demonstrate the applicability of the developed ontology, it was applied to a real-world SoS context in a healthcare setting. Accordingly, the CTAG-KHCC at Jordan was used to instantiate the developed BPA-driven and semantically-enriched SoS context view artefact. Demonstrating the artefact also enables an assessment of the aspects considered within the evaluation stage, as discussed in Section 6.4.

Generally, to demonstrate the ontology-based SoS context view artefact for a given SoS arrangement (called SoS_Arr_x), which has GL-Business Area (called GL_BA_a) and a LL-Business Area (called LL_BA_b), and the LL_BA_b entails the participant Constituent Business Areas CBA_1, CBA_2 and CBA_3, the following will be necessary to form the proposed semantically-enriched holistic view for the SoS context of the SoS_Arr_x (i.e. the Integrated SoS Context View Ontology instantiated for the SoS_Arr_x):

1. The Adapted Riva-based BPA ontology instantiated for the GL_BA_a.
2. The Adapted Riva-based BPA ontology instantiated for the LL_ CBA_1, CBA2 and CBA_3.
3. The sBPMN ontology instantiated for the LL_ CBA_1, CBA2 and CBA_3.
4. The Abstract SoS context view ontology instantiated for the SoS_Arr_x.
5. The integration and linkages between the aforementioned ontologies' elements.
6. The BPAOntoSOA-driven elements captured and represented for the LL_ CBA_1, CBA_2 and CBA_3 within the integrated ontology.

Viewing the CTAG-KHCC from the proposed SoS context view artefact point of view highlights a number of aspects. Table 6.4 provides a description of these aspects that are used for the demonstration of the ontology-based SoS context view artefact for the CTAG-KHCC case study derived from the aforementioned aspects alongside the CTAG-BPA introduced in (Tbaishat *et al.*, 2018) and related BPMs introduced in (Odeh *et al.*, 2018)

Table 6. 4: CTAG-KHCC aspects from SoS context view artefact point of view.

<table>
<tr><th>#</th><th>CTAG-KHCC Aspects from SoS Context View Artefact Point of View</th></tr>
<tr><td>1</td><td>▪ The CTAG-SoS arrangement entails two main business areas: the ‘GL-CTAG Business Area’; and the ‘LL-CTAG Business Area’.</td></tr>
<tr><td>2</td><td>▪ The GL-CTAG business area provides a number of ‘GL-Business Services’, these are:
(i) Flow Cytometry (FC)-based patients samples analysis;
(ii) Molecular Diagnostics Immunogenetics (MDI)-based patients samples analysis;
(iii) Blood and Marrow Transplantation (BMT)-based patients samples analysis;
(iv) Cytogenetics (Cyto)-based patients samples analysis; and
(v) Support for devising personalised treatment informed by analysing the patient laboratory samples related to any FC, MDI, Cyto, or BMT respectively.</td></tr>
<tr><td>3</td><td>▪ To achieve the GL-business services, the GL-CTAG business area depends on the capabilities of four independent ‘Constituent Business Areas’ (CBAs) entailed within the LL-CTAG business area:
(i) the FC CBA;
(ii) the MDI CBA;
(iii) the BMT CBA; and
(iv) the Cyto CBA.</td></tr>
<tr><td>4</td><td>▪ Each CBA has its own LL-business services.

▪ For example, the Cyto CBA provides three main Cyto related business services:
(i) Cyto1 business service, bone marrow and peripheral blood analysis;
(ii) Cyto2 business service, solid tissues analysis by FISH technology; and
(ii) Cyto3 business service, breakage analysis.</td></tr>
<tr><td>5</td><td>▪ Each CBA has its related BPA, which includes the collective BPs and the relationships between them that support the provision of the business services related to a specific CBA.</td></tr>
<tr><td>6</td><td>▪ Each business service identified for the CBAs has a supporting segment derived from the CBA’s BPA.</td></tr>
<tr><td>7</td><td>▪ The driven BPA segments include specific BPs and the relationships that support the achievement of a specific identified business service.</td></tr>
<tr><td>8</td><td>▪ Each identified LL-BPs has a related BPM to show the workflows of the related tasks needed to address them.</td></tr>
<tr><td colspan="2">For example, the Cyto CBA has its own related Cyto Riva-based BPA. The Cyto-BPA includes seven business processes and six relations between the identified processes.

For the three business services defined for the Cyto CPA, there are three related BPA-Segments that include the BPs and relationships that support the Cyto business services achievement. For instance, the Cyto1 business service, bone marrow and peripheral blood analysis has a Cyto-BPA Segment that supports it. This BPA Segment includes the CP handle financial coverage for Cyto, CP handle specimen for Cyto1, and CP handle approval for Cyto1 business processes. Furthermore, it includes two main relations between the processes. The first relation has the source of CP financial coverage for Cyto and the destination CP handle specimen for Cyto1, while the second relation has the source CP handle specimen for Cyto1 and the destination CP handle approval for Cyto1. All three processes entailed in the BPA Segment have related BPM elements that highlight the main tasks, connections, and pools related to conducting each of them.</td></tr>
</table>

Table 6.4: CTAG-KHCC aspects from SoS context view artefact point of view, "Continued".

#	CTAG-KHCC Aspects from SoS Context View Artefact Point of View
9	▪ Applying the BPAOntoSOA framework to each of the CTAG-CBAs enables the identification of the related candidate software services for them. This will derive further ontological-based elements (e.g. RPA_Cluster Class, Cluster_Has_Capability object property, etc.) which can be linked to the LL and GL business-driven aspects to emphasise the BIA within the proposed SoS context view artefact. ▪ For example, applying the BPAOntoSOA framework to the Cyto CBA results in the identification of four main candidate software services. The identified services are, the Financial Coverage for Cyto candidate software service, the bone marrow and peripheral blood analysis candidate software service, the solid tissues by FISH technology analysis candidate software service, and the breakage analysis candidate software service. By adopting the BPAOntoSOA framework, each identified candidate software service has members which are BPs identified within the Cyto BPA and has capabilities which are Tasks identified within the Cyto BPMs.
10	▪ For each of the identified software services there is a supporting constituent information system within the CTAG-KHCC SoS arrangement.
11	▪ The collective BPAs of the four CPAs form the GL-BPA for the GL-CTAG business area.
12	▪ To capture how the BPA supports the GL-business services, the GL-BPA of the CTAG business area is segmented into GL-BPA segments that support the identified GL-business services.
13	▪ Each GL-BPA segment includes the BPs and the relations needed to support a specific defined GL-business service. ▪ For example, the GL-Cyto BPA segment includes the BPA of the Cyto CPA, with this segment supporting the GL-Cyto business service identified for the GL-CTAG business area.
14	▪ Each GL-BPA segment is linked to a LL-BPA of a related CPA by linking the GL-BPA to the constituent LL-BPAs, linking the GL-BPs to the related LL-BPs, and linking the GL-Relations to the related LL-Relations.
15	▪ All the aforementioned ontological based aspects can be linked using the object properties discussed in the Section 6.2.3 and Appendix F. ▪ For example, the GL-Processes' instances identified in the abstract SoS context view ontology for the CTAG SoS arrangement can be linked to the related Processes' instances in the related Adapted-srBPA ontology developed for the identified GL-CTAG BPA. ▪ Together, all these ontologies linked form an Integrated SoS Context View Ontology for CTAG-KHCC SoS arrangement.

To demonstrate the SoS context view artefact for the CTAG-KHCC based on the above-mentioned aspects a number of steps have been applied. Table 6.5 lists these steps and provides a brief description for each of them.

Table 6. 5: Steps applied to demonstrate the SoS context view artefact to CTAG-KHCC.

Demonstration Step	**Step 1:** ▪ Instantiating the Adapted srBPA Ontology for the CTAG-KHCC Global-Level Business Area
Description of the conducted demonstration Step	▪ The adapted srBPA ontology (developed in **Chapter 5**) was instantiated for the CTAG-KHCC GL-BA based on the BPA models developed for CTAG-KHCC, which are presented in (Tbaishat *et al.*, 2018).
Demonstration Step	**Step 2:** ▪ Instantiating the Adapted srBPA Ontology for each of the CTAG-KHCC Local-Level Constituent Business Areas
Description of the conducted demonstration Step	▪ The adapted srBPA ontology (developed in **Chapter 5**) was instantiated for the CTAG-KHCC LL-CBAs (FC, Cyto, MDI, and BMT) based on the BPA models developed for the CTAG-KHCC, which are presented in (Tbaishat *et al.*, 2018).
Demonstration Step	**Step 3:** ▪ Instantiating the sBPMN Ontology for each of the KHCC-CTAG Local-Level Constituent Business Areas
Description of the conducted demonstration Step	▪ The sBPMN ontology (SUPER 2008, cited in Yousef, 2010) was instantiated for each of the CBPAs-BP-related BPMs based on the BPMNs developed for the CTAG-KHCC, which are presented in (Odeh *et al.*, 2018).
Demonstration Step	**Step 4:** ▪ Instantiating the Abstract SoS Context View Ontology for the CTAG-KHCC SoS Arrangement
Description of the conducted demonstration Step	▪ The abstract SoS context view ontological meta-model was instantiated for the CTAG-KHCC SoS arrangement based on the aspects captured above and considered in Table 6.4.
Demonstration Step	**Step 5:** ▪ Merging and linking all of the above mentioned ontologies into an 'Integrated SoS Context View Ontology for CTAG-KHCC SoS Arrangement'
Description of the conducted demonstration Step	▪ All the aforementioned ontological based models were imported into one ontology. Thereafter, the ontologies were linked together using the properties proposed in Section 6.2.3 and Appendix F. ▪ Together, all these ontologies linked formed an Integrated SoS Context View Ontology for the CTAG-KHCC SoS Arrangement.
Demonstration Step	**Step 6:** ▪ Applying the BPAOntoSOA-driven Framework to each of the KHCC-CTAG Local-Level Constituent Business Areas, adding the identified elements to the Integrated ontology, and linking the BPAOntoSOA-driven elements to related elements exist in the other imported ontologies
Description of the conducted demonstration Step	▪ For each of the CTAG-KHCC CBAs (FC, Cyto, MDI, and BMT) the BPAOntoSOA framework (Yousef, 2010) was applied for the identification of software services, related capabilities and pools. ▪ The identified BPAOntoSOA-driven elements (e.g. PA Elements and RPA Clusters) were added to the Integrated SoS context view ontology and then the identified 'Properties' were used to link the added elements with the related elements exist in the other imported ontologies.

Figures 5.3 to 5.8 show examples of the Integrated SoS context view ontology during instantiation for the CTAG-KHC SoS context.

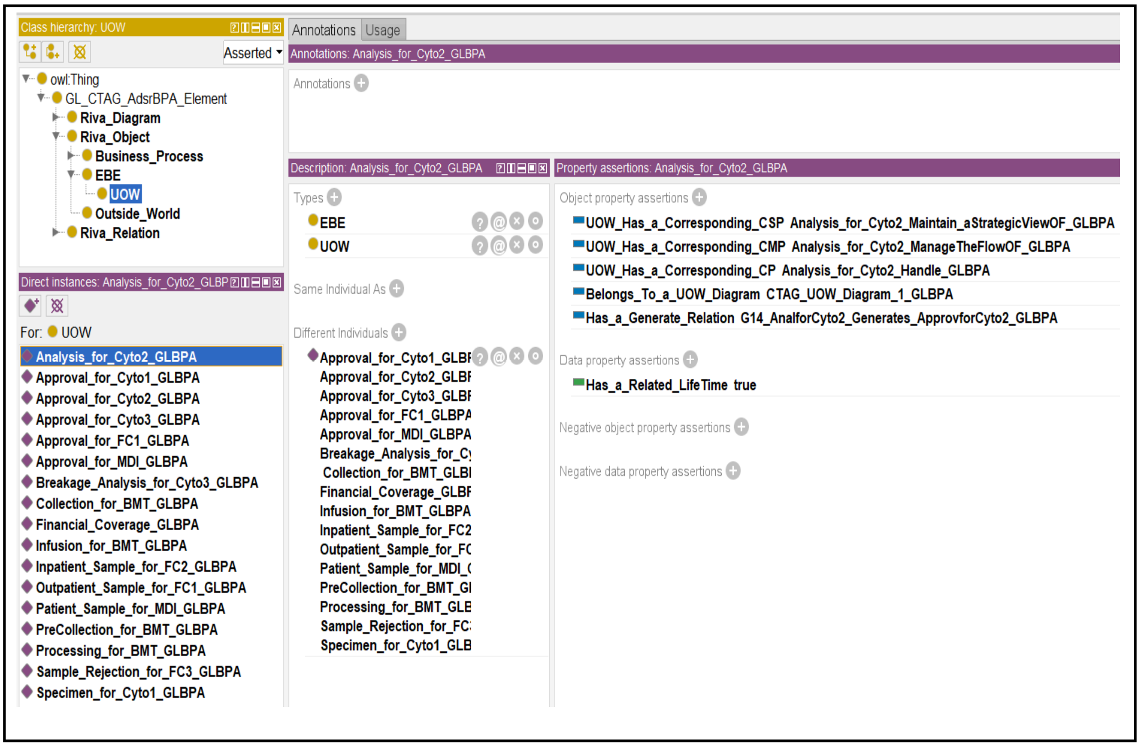


Figure 6. 3: An example of the Adapted-srBPA Ontology instantiated for the CTAG-KHCC GL-BPA, as part of Step 1 application.

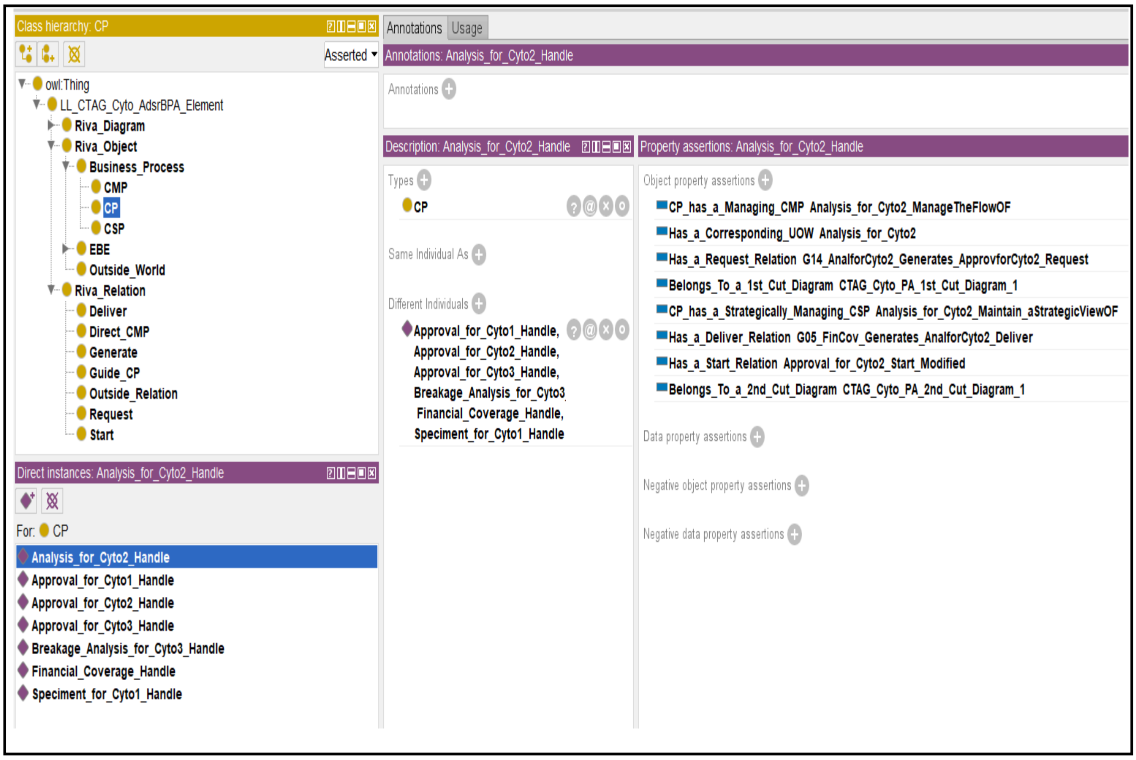


Figure 6. 4: Examples of the Adapted-srBPA Ontology instantiated for the Cyto Constituent Business Area's BPA, as part of Step 2 application.

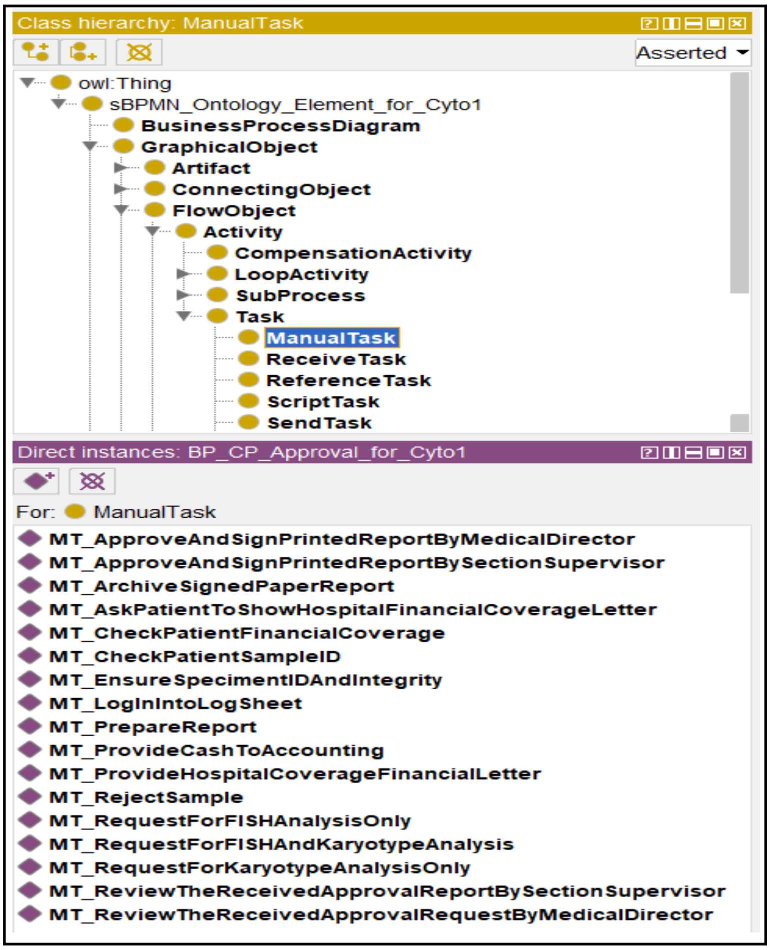


Figure 6. 5: An example of the sBPMN ontology instantiated for the Bone Marrow and Peripheral Blood Analysis Process of the Cyto Constituent Business Area, as part of Step 3 application.

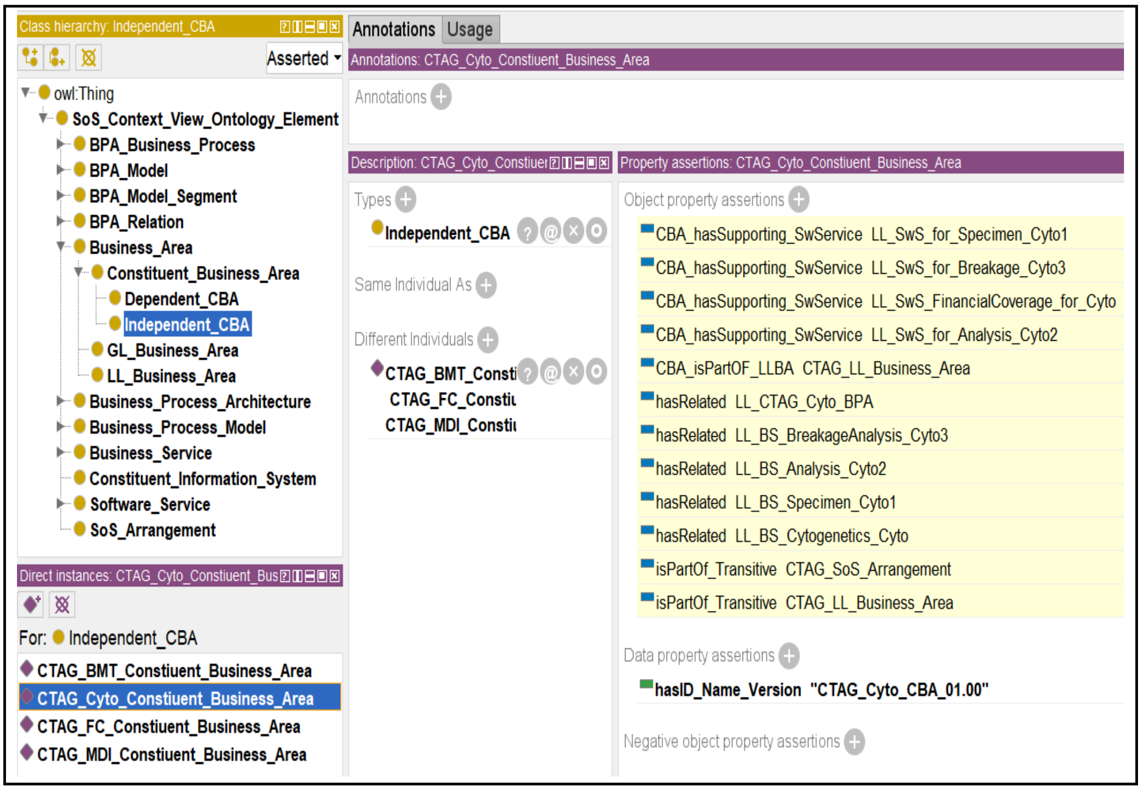


Figure 6. 6: An example of the Constituent Business Area Concept instantiated for the CTAG-KHCC within the Abstract SoS Context View Ontology, as part of Step 4 application.

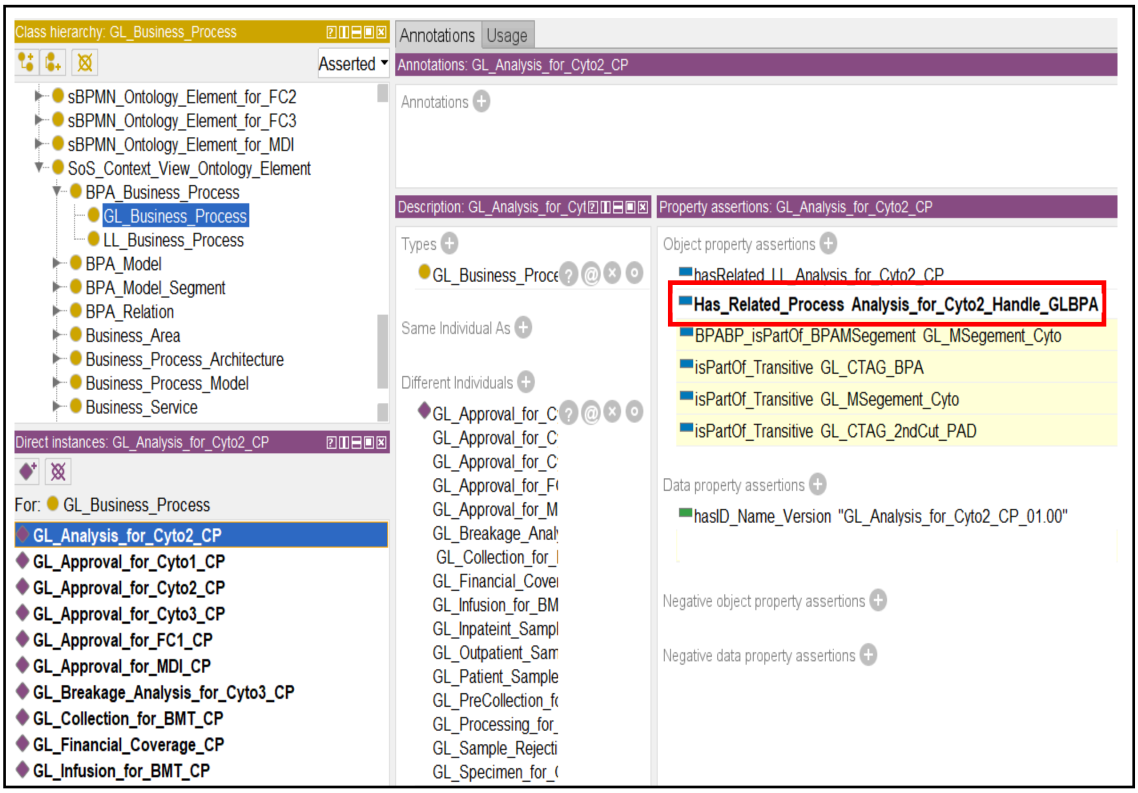


Figure 6. 7: An example of semantically linking the Abstract SoS Context View Ontology and the Adapted-srBPA ontologies instantiated for the CTAG-KHCC SoS Arrangement, as part of Step 5 application.

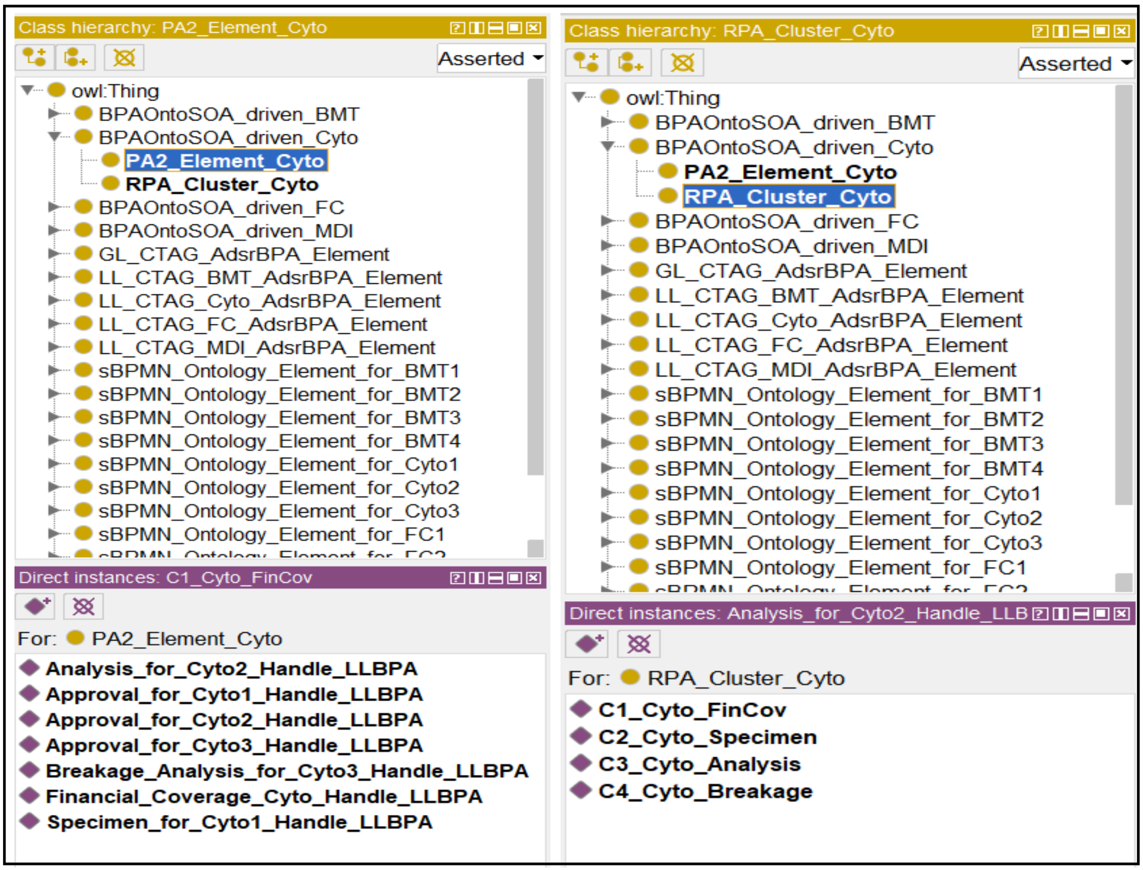


Figure 6. 8: Examples of adding and instantiating BPAOntoSOA-driven ontological concepts for the CTAG-KHCC SoS arrangement within the integrated SoS context view ontology, as part of Step 6 application.

6.4 Third-DSRM-Increment's Third Stage: The Evaluation of the SoS Context View Component

In this DSRM stage, aspects related to the design and utility of the developed SoS context view component were evaluated.

6.4.1 The Evaluation Roadmap

Based on the evaluation framework adopted for this research (discussed in **Chapter 3**), this stage emphasises the verification and validation of the 'Integrated SoS Context View' ontological model. Table 6.6 presents the parts of the evaluation framework related to evaluating the 'Integrated SoS Context View' ontological component. The table presents an abstract description of the objectives of the evaluation and lists the adopted evaluation types, criteria and approaches, which are discussed more thoroughly in the following sections.

Conversely, the verification and validation of the Adapted srBPA ontology, sBPMN ontology and BPAOntoSOA-driven ontology do not need to be conducted individually in this stage since it was previously done for the Adapted srBPA ontology (in **Chapter 5**) and in previous research for the sBPMN (SUPER 2008, cited in Yousef, 2010) and BPAOntoSOA-driven ontological elements (Yousef, 2010). What must be considered here is the newly developed 'Abstract SoS Context View' ontology and the integration of the used ontologies within the developed 'Integrated SoS Context View' ontology.

Table 6. 6: The part of the evaluation framework related to evaluating the 'Integrated SoS Context View' ontological component.

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="8">(Third-DSRM-Increment)

Evaluating the 'Integrated SoS Context View' ontological model
(The semantic enrichment of the SoS Context View artefact and its demonstration to CTAG-KHCC):

(1) To inform the adherence of the developed semantically-enriched models to the ontology-based representation using OWL-specifications.

(2) To further verify the correctness of the developed semantically-enriched models by checking the completeness and redundancy aspects of their elements.

(3) To inform the correctness of the developed SoS context view conceptual meta-model from a domain experts' point of view.

(4) To inform the validity of the developed ontological-based models in representing the CTAG-KHCC SoS arrangement context.

(5) To inform if the 'SoS Context View' component meets the identified objectives that motivated its development.</td><td colspan="2">Verification</td><td></td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td>Completeness</td><td>Redundancy</td><td>Checklist-based Walkthroughs
(By the researcher)</td></tr>
<tr><td colspan="2">Validation</td><td></td></tr>
<tr><td colspan="2">Correctness</td><td>A Checklist-based Walkthrough
(By the researcher or with support of the domain experts)</td></tr>
<tr><td colspan="2">Completeness</td><td>Checklist-based Walkthroughs
(By the researcher)</td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td colspan="2">Appropriateness</td><td>A Checklist-based Walkthrough by a Semi-structured Interview
(By the researcher with support of the domain experts)</td></tr>
</table>

6.4.2 The Verification of the SoS Context View Artefact

In this category of evaluation, the correctness of the ontology-based 'Integrated SoS Context View' meta-model, including the entailed newly developed Abstract SoS Context View ontology, was verified before its instantiation. This was done by checking its consistency, completeness and redundancy. Table 6.7 provides a description of these criteria as adopted by the research.

Table 6. 7: The adopted verification criteria for the evaluation of the 'SoS Context View' artefact.

Verification Criteria	Description
Consistency	▪ The semantic enrichments of the 'Abstract SoS Context View' and the 'Integrated BPA-driven ChM' meta-models adhere to the rules and syntax of the OWL-specifications used to create it (i.e. no contradictory items or constraints are detected or inferred).
Redundancy	▪ Each construct of the semantically-enriched 'SoS Context View' and 'Integrated BPA-driven ChM' meta-models contributes knowledge to the model (i.e. a real-world entity is not represented by more than one ontological construct).
Completeness	▪ The semantically-enriched 'SoS Context View' and 'Integrated BPA-driven ChM' meta-models contain all the elements that it should represent.

Table 6.8 presents the used techniques for verification linked to the verification criteria. The table also provides a brief description of the used verification techniques.

Table 6. 8: The adopted verification techniques for the evaluation of the 'SoS Context View' artefact.

Verification Criteria	Verification Technique	Brief Description
Consistency	Protégé Reasoner	▪ Checking the consistency of ontology-based models can be done using a reasoner that supports an ontology development tool. For this research, the protégé reasoner - i.e. Pellet – was used to check the consistency of the ontology-based 'Abstract SoS Context View' and 'Integrated SoS Context View' meta-models. ▪ If no inconsistency is detected by the Protégé reasoner it could be realised that the ontology-based meta-model is consistent. ▪ These checks were carried out by running the Protégé reasoner.
Redundancy	Checklist-based Walkthroughs	▪ Checklists were designed and used to check that each element of the 'Abstract SoS Context View Ontology' and the 'Integrated SoS Context View Ontology' contributes knowledge to the entailed model (i.e. to check that there is no redundant knowledge provided by the elements of the ontology-based meta-model). ▪ These checks were carried out by the researcher.

Table 6.8: The adopted verification techniques for the evaluation of the 'SoS Context View' artefact, "Continued".

Verification Criteria	Verification Technique	Brief Description
Completeness	Checklist-based Walkthroughs	▪ The ontology-based 'Abstract SoS Context View' meta-model should represent the concepts and relations that appear in the proposed conceptual meta-model (presented in Figure 6.2). Accordingly, a checklist was designed and used to check if all the elements of the conceptual meta-model were represented by the developed ontology-based meta-model. ▪ A further checklist was used to inspect that all the identified ontology elements needed for merging and linking the 'Adapted srBPA', 'sBMPN', 'BPAOntoSOA-driven', and 'Abstract SoS Context View' ontologies to produce the 'Integrated SoS Context View ontology' were represented. ▪ These checks were carried out by the researcher.

Figure 6.9 and Tables 6.9 and 6.10 show examples of the conducted verification techniques.

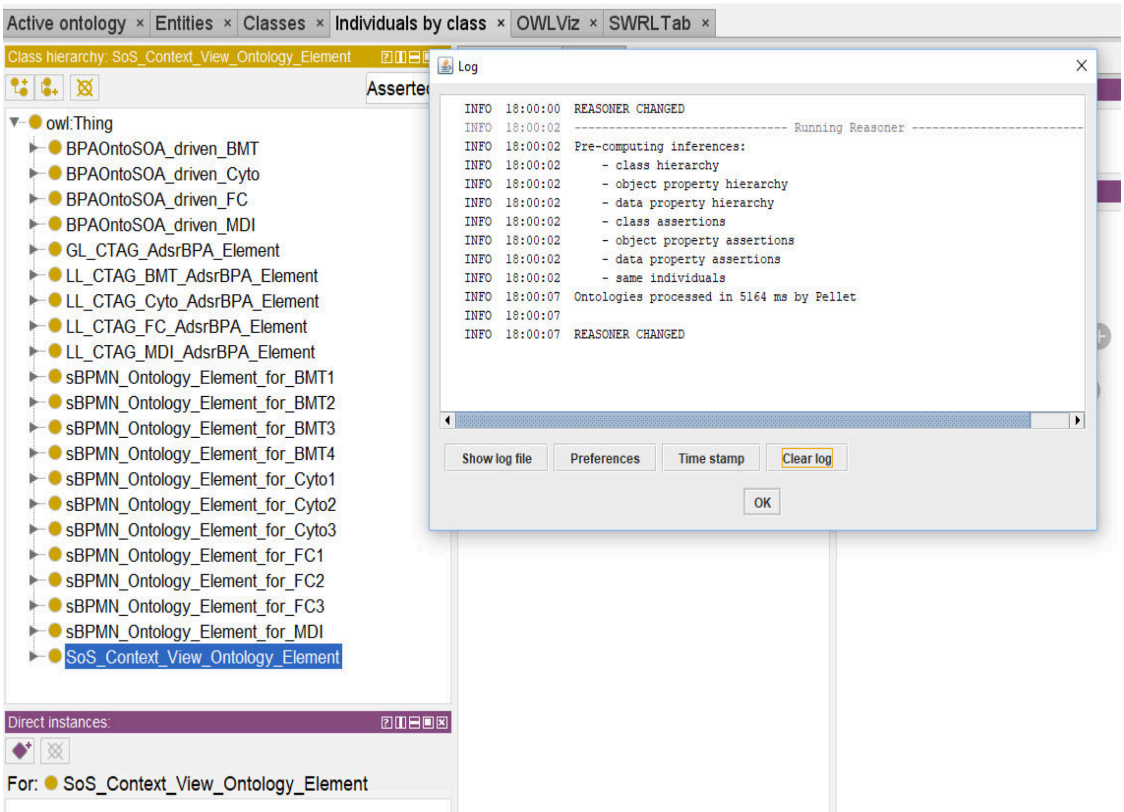


Figure 6. 9: Example of running the Protégé Reasoner to check the syntax consistency of the Integrated SoS Context View Ontology.

Table 6. 9: Checklist-based walkthrough to check that all of the elements of the SoS context view conceptual-model (presented in Figure 6.2) were represented by the Abstract SoS Context View ontology.

ID	Conceptual Meta Model Aspect	Completeness		Remark
		Represented	Not Represented	
1	Class: SoS Arrangement	✓		
2	Class: Global-Level Business Area	✓		
3	Class: Local-Level Business Area	✓		
4	Class: Constituent Business Area	✓		
5	Class: Independent CBA	✓		
6	Class: Dependent CBA	✓		
7	Class: Business Service	✓		
8	Class: GL-Business Service	✓		
9	Class: LL-Business Service	✓		
10	Class: BPA	✓		
11	Class: GL-BPA	✓		
12	Class: LL-BPA	✓		
13	Class: BPA Model	✓		
14	Class: GL-BPA Model	✓		
15	Class: LL-BPA Model	✓		
16	Class: BPA Model Segment	✓		
17	Class: GL-BPA Model Segment	✓		
18	Class: LL-BPA Model Segment	✓		
19	Class: Business Process	✓		
20	Class: GL- Business Process	✓		
21	Class: LL- Business Process	✓		
22	Class: Relation	✓		

Table 6. 10: Example of the checklist-based walkthrough to check the redundancy of the elements entailed in the Integrated SoS Context View ontology.

ID	Ontology Aspect	Redundancy?		Remark
		Yes	No	
1	Abstract SoS Context View Ontology Elements		✓	
2	Adapted srBPA Ontology Elements		✓	
3	sBPMN Ontology Elements		✓	
4	BPAOntoSOA Driven Ontology Elements		✓	
5	Linkages Between the utilised Ontologies:		✓	
5.1	Has_Related_Process		✓	
5.2	Has_Related_Relation		✓	
5.3	Has_Related_PADiagram		✓	
5.4	Has_Related_BPM		✓	
5.5	Has_a_Corresponding_BPMProcess		✓	
5.6	Cluster_Has_Member		✓	
5.7	Cluster_Has_Capability		✓	
5.8	Has_InOrOUt_Relation		✓	
5.9	Has_Related_RPACluster_SwService		✓	

Having conducted the verification for the 'Integrated SoS Context View' Ontology component (including the 'Abstract SoS Context View' ontology), the reasoner detected no inconsistencies. All of the identified elements for the Integrated SoS context view in addition to the elements of the conceptual model for the SoS context view were represented. However, redundancy was only found when 'transitive' properties were used (e.g. isPartOf_Transitive). Although there is a form of redundancy detected here, keeping the use of these properties enables inferring knowledge that cannot be inferred by the properties used specifically to relate two individuals (e.g. BPAModel_isPartOf_BPA). In addition, keeping the use of the specific properties make knowledge more specific and explicit.

6.4.3 THE VALIDATION OF THE SOS CONTEXT VIEW ARTEFACT

In this category of evaluation, the correctness of the SoS context view conceptual meta-model was validated. Furthermore, the ontology-based 'Integrated SoS Context View' model was validated by checking its correctness, completeness and consistency after instantiation with CTAG-KHCC data (resulting from conducting the demonstration stage). Table 6.11 provides a description of these criteria as adopted by the research.

Table 6. 11: The adopted validation criteria for the evaluation of the 'SoS Context View' component.

Validation Criteria	Description
Correctness	▪ The elements of the developed SoS context view conceptual meta-model are correct from domain experts' point of view. ▪ The instances and relationships captured for the CTAG-KHCC case study are correctly represented by the related ontologies (i.e. Abstract SoS Context view and Integrated SoS Context View ontologies).
Completeness	▪ All the instances identified for the CTAG-KHCC case study are represented by the related ontologies (i.e. Abstract SoS Context view and Integrated SoS Context View ontologies). ▪ All the relationships identified between the instances are represented in the ontology (no missing relations), including the links instantiated to develop the 'Integrated SoS Context View' ontological model.
Consistency	▪ After instantiation, no contradictory items are detected in the ontology.
Appropriateness	▪ The ontological component meets the objectives that motivated its development.

Table 6.12 presents the used validation techniques, linked to the adopted validation criteria. The table also provides a brief description of the used validation techniques.

Table 6. 12: The adopted validation techniques for the evaluation of the 'SoS Context View' component.

Validation Criteria	Validation Technique	Brief Description
Correctness	Checklist-based Walkthroughs through Semi-structured Interviews	▪ Checklist-based walkthroughs were used through semi-structured interview to validate the correctness of the developed SoS context view conceptual-meta model from a domain experts' point of view. ▪ This check was carried out by the researcher with support of domain experts.
	Checklist-based Walkthroughs	▪ Checklist-based walkthroughs were designed and used to check that the instances driven from the CTAG-KHCC case study and their relationships were correctly represented in the related ontologies (i.e. Abstract SoS Context view and Integrated SoS Context View ontologies). ▪ These checks were carried out by the researcher.
Completeness	Checklist-based Walkthroughs	▪ Checklist-based walkthroughs were designed and used to check that the instances driven from the CTAG-KHCC case study and their relationships were completely represented in the related ontologies (i.e. Abstract SoS Context view and Integrated SoS Context View ontologies). ▪ These checks were carried out by the researcher.
Consistency	Protégé Reasoner	▪ The Protégé reasoner (i.e. Pellet) was used to check that after instantiating the 'Integrated SoS Context View' ontology with the related CTAG-KHCC elements, no contradictory items were detected. ▪ If no inconsistency is detected by the Protégé reasoner, it could be realised that the ontology-based model is consistent. ▪ This check was carried out by running the Protégé reasoner.
Appropriateness	Checklist-based walkthrough through a Semi-structured Interview	▪ A checklist-based walkthrough through a semi-structured interview was designed and used to check that the 'SoS Context View' framework component meets the objectives that motivated its development. ▪ This check was carried out by the researcher with the support of domain experts at the KHCC-CTAG.

Tables 6.13 to 6.16 present examples of the conducted validation techniques.

Table 6. 13: Part of checking the correctness of the developed SoS context view conceptual meta-model.

ID	Conceptual Meta Model Aspect	Correct?		Remark
		Yes	No	
1	Class: SoS Arrangement	✓		
2	Class: Global-Level Business Area	✓		
3	Class: Local-Level Business Area	✓		
4	Class: Constituent Business Area	✓		
5	Class: Independent CBA	✓		
6	Class: Dependent CBA	✓		
7	Class: Business Service	✓		
8	Class: GL-Business Service	✓		
9	Class: LL-Business Service	✓		
10	Class: BPA	✓		
11	Class: GL-BPA	✓		
12	Class: LL-BPA	✓		
13	Class: BPA Model	✓		
14	Class: GL-BPA Model	✓		
15	Class: LL-BPA Model	✓		
16	Class: BPA Model Segment	✓		
17	Class: GL-BPA Model Segment	✓		
18	Class: LL-BPA Model Segment	✓		
19	Class: Business Process	✓		
20	Class: GL- Business Process	✓		
21	Class: LL- Business Process	✓		
22	Class: Relation	✓		

Table 6. 14: Part of the checking the correctness and completeness of the instantiated concepts within the abstract SoS context view ontology.

ID	CTAG Individuals Instantiation	Correctness?	Completeness?	Remarks
1	**Class: SoS_Arrangement**	✓	✓	
	CTAG_SoS_Arrangement	✓	✓	
2	**Class: Global-Level Business Area**	✓	✓	
	CTAG_GL_Business_Area	✓	✓	
3	**Class: Local-Level Business Area**	✓	✓	
	CTAG_LL_Business_Area	✓	✓	
4	**Class: Constituent Business Area**	✓	✓	
5	**Class: Independent CBA**	✓	✓	
	CTAG_BMT_Constiuent_Business_Area	✓	✓	
	CTAG_Cyto_Constiuent_Business_Area	✓	✓	
	CTAG_FC_Constiuent_Business_Area	✓	✓	
	CTAG_MDI_Constiuent_Business_Area	✓	✓	
6	**Class: Dependent CBA**	✓	✓	
7	**Class: Business Service**	✓	✓	
8	**Class: GL-Business Service**	✓	✓	
	GL_BS_Blood_and_Marrow_Transplant_BMT	✓	✓	
	GL_BS_Cytogenetics_Cyto	✓	✓	
	GL_BS_Flow_Cytometry_FC	✓	✓	
	GL_BS_Molecular_Diagnostics_Immunogenetics_MDI	✓	✓	
	GL_BS_Personalised_Patient_Treatement_Support	✓	✓	

Table 6. 15: Checklist-based walkthrough to validate instantiated aspects within the Integrated SoS Context View Ontology.

ID	Instantiated Aspect	Correctness?	Completeness?	Remark
1	**Abstract SoS Context View Ontology Elements**			
	CTAG_SoS_Context_View_Ontology	✓	✓	
2	**Adapted srBPA Ontology Elements**			
	GL_CTAG_AdsrBPA_Ontology	✓	✓	
	LL_CTAG_BMT_AdsrBPA_Ontology	✓	✓	
	LL_CTAG_Cyto_AdsrBPA_Ontology	✓	✓	
	LL_CTAG_FC_AdsrBPA_Ontology	✓	✓	
	LL_CTAG_MDI_AdsrBPA_Ontology	✓	✓	
3	**sBPMN Ontology Elements**			
	sBPMN_Ontology_for_BMT1	✓	✓	
	sBPMN_Ontology_for_BMT2	✓	✓	
	sBPMN_Ontology_for_BMT3	✓	✓	
	sBPMN_Ontology_for_BMT4	✓	✓	
	sBPMN_Ontology_for_Cyto1	✓	✓	
	sBPMN_Ontology_for_Cyto2	✓	✓	
	sBPMN_Ontology_for_Cyto3	✓	✓	
	sBPMN_Ontology_for_FC1	✓	✓	
	sBPMN_Ontology_for_FC2	✓	✓	
	sBPMN_Ontology_for_FC3	✓	✓	
	sBPMN_Ontology_for_MDI	✓	✓	
4	**BPAOntoSOA Driven Ontology Elements**			
	BPAOntoSOA_Driven_BMT	✓	✓	
	BPAOntoSOA_Driven_Cyto	✓	✓	
	BPAOntoSOA_Driven_FC	✓	✓	
	BPAOntoSOA_Driven_MDI	✓	✓	
5	**Linkages Between the utilised Ontologies**			
	Has_Related_Process (Symmetric Property) GL-Process (Abstract SoS Ontology) -> GL-BPA Process (Adapted srBPA Ontology) (17 Occurrences) LL-Process (Abstract SoS Ontology) -> LL-BPA Process (Adapted srBPA Ontology) (20 Occurrences) LL-BPM (Abstract SoS Ontology) -> Process (sBPMN ontology) (17 Occurrences)	✓	✓	

Table 6. 16: Checklist-based walkthrough to validate the appropriateness of the SoS Context View component.

#	Integrated SoS Context Ontology Objective	Achieved?		Remark
		Yes	No	
1	The provision of generalised, explicit and formal semantic representation of elements that represent SoS operational context and the relationship between them driven by global-local levels alignment and business-IT alignment perspectives.	✓		
2	The provision of common knowledge about SoS operational context that can be shared and agreed on amongst SoS stakeholders.	✓		
3	Enabling that adaptation of the configuration items concept for the ChM framework under consideration to include business aspects.	✓✗		Subject to further development (in Chapter 7)
4	The support of holistic traceability of candidate impacted elements that enables maintaining global-local levels alignment and BITA.	✓✗		Subject to further development (in Chapter 7)
5	The SoS context view component can be instantiated for different SoS arrangements.	✓✗		Subject to further case studies (Future directions)
6	Provision of knowledge that enriches the awareness of ChM-stakeholders of SoS elements and related stakeholders that need to be considered during the management of a change request.	✓✗		Subject to further development (in Chapter 7)

Having conducted the validation for the SoS context view component (including its constituent artefacts), the SoS context view conceptual meta-model was found correct from a domain experts' point of view. Furthermore, the CTAG-KHCC elements were found correctly and completely instantiated. Moreover, part of the objectives of the SoS context view component was found fully addressed. However, further development (in **Chapter 7**) is required to fully address the remaining objects.

6.5 Chapter Summary And Discussion

This chapter focused on the development of a semantically-enriched meta-model that represents a generic global-local levels alignment and BITA -driven point of view for a SoS arrangement (SoS context view framework component). Accordingly, the third-DSRM-increment (including three main DSRM stages) was conducted in order to achieve this chapter's objective.

The design and development stage focused on the development of a BPA-driven conceptual meta-model for the SoS context view then on semantically enriching the developed conceptual model using ontology (Abstract SoS Context View Ontology). Using a BPA-driven view to model and semantically enrich the SoS operational context has enabled attaining a more comprehensive and fine-grained semantically-enriched representation, where further BPA-driven models - BPAOntoSOA framework models (Yousef, 2010)- were adopted and linked to the developed 'Abstract SoS Context View Ontology' (Sections 6.2.3 and 6.3). This has led to the semantic representation of the main Riva BPA-driven business processes and relationships between them (BPAs), which are identified for the global and local levels of a given SoS arrangement. In addition, it has led to the semantic representation of the BPMs related to the participating constituent business areas and their linkages to related Riva-driven BPAs. Besides, it has enabled the semantic identification and representation of local-level software-services and their linkages to related Riva-driven business processes, BPM-tasks and BPM-pools, alongside linkages to related supporting constituent information systems; resulting in an 'Integrated SoS Context View Ontology' aka 'the SoS context view framework component'.

In the demonstration stage, the CTAG-KHCC/Jordan case study was used to instantiate the developed integrated ontology. After instantiation, the increment concludes with the evaluation stage, in which identified evaluation aspects for the developed ontology (e.g. syntax correctness check) were applied to assess its design and utility based on utilising the evaluation framework adopted for this purpose (introduced in Chapter 3).

There is a range of contributions behind the development of an ontology-based SoS context view artefact that can be instantiated to a given SoS context. By its own, it provides an explicit business-driven, semantically-enriched, machine-readable and generic representation of a SoS arrangement operational context's aspects with a focus on representing the linkages between the global and local levels, as well as between the Business and IT aspects. This, in turn, enables a clearer and more abstract shared understanding of the SoS operational context elements amongst the concerned stakeholders.

On the other hand, as part of the OntoSoS.BPA.ChM framework, the SoS context view component paves the ground towards adapting the 'CI' concept to include business-driven CIs. This, in turn, enables achieving more holistic traceability of the identified CIs and supports maintaining a high degree of global-local levels alignment and BITA. This also allows enriching the awareness of ChM processes by providing the ChM layer with comprehensive knowledge that enables identifying domain-specific SoS elements related to managing proposed changes (e.g. main impacted elements, relationships and participants). Accordingly, the following chapter discusses the Fourth-DSRM-Increment adopted for the development of the research framework. The artefact resulting from the present chapter will be used as an input to achieve the identified objectives of the next increment.

This chapter mainly addressed RQ2. The fulfilment of answering RQ2 has contributed to addressing RO2 in addition to bridging the first and fourth research gaps identified in Section 2.7. The developed SoS context view framework component provides a novel explicit and formal representation that covers a part of the knowledge found absent from the ChM and SoS domains and is needed to support ChM application in a SoS context. Where a DSRM-based process was adopted for the development and evolution of the research artefacts, the applicability and validity of the 'the SoS context view framework component' were demonstrated using a sufficient and representative real-world case study (i.e. CTAG-KHCC) with support of domain experts (Sections 6.3 and 6.4). As has been informed by using the CTAG-KHCC case study, the semantically-enriched representation has facilitated sharing and agreeing on knowledge related to the operational context of a given SoS arrangement amongst its stakeholders. It has also established the grounds for achieving comprehensive traceability of change related implications on a SoS arrangement and an effective identification of related stakeholders (Chapter 7), leading to supporting SoS global-local level alignment and BITA during ChM application in a SoS context. This has contributed to facilitating and improving the application of ChM processes in a SoS context. Table 6.17 maps between the main research questions and the thesis chapters where they were addressed up to this point.

Table 6. 17: The status of addressing the identified RQs by the main research chapters up to this point.

Research Question	Chapter 4	Chapter 5	Chapter 6	Chapter 7
RQ1	✓✗	✓		
RQ2			✓	
RQ3				
RQ4				

CHAPTER 7

AN ALIGNMENT AND KNOWLEDGE RETRIEVAL COMPONENT

7.1 INTRODUCTION

This Chapter continues the incremental development of the OntoSoS.BPA.ChM framework by elaborating on its fourth and last DSRM-increment. The fourth-DSRM-increment discusses the 'Alignment and Knowledge Retrieval' framework component, including its design and development, demonstration and evaluation stages. This component is aimed at using the 'ChM component' (discussed in Chapters 4 and 5) and the 'SoS context view component' (discussed in Chapter 6) to equip the OntoSoS.BPA.ChM framework with the ability of providing the ChM stakeholders with purposeful knowledge that can be utilised in guiding and improving the ChM application in a SoS context.

During the design and development stage, aspects related to the development of the aimed at alignment and knowledge retrieval component are identified and then the component is built by adopting a phased-approach that is comprised of three main phases. In the demonstration stage, the resulting component-driven documents are instantiated and put into work within a real-world context. Accordingly, the CTAG-KHCC case study is used to continue instantiating the OntoSoS.BPA.ChM framework. After instantiation, the increment concludes with the evaluation stage, in which the design and utility of the developed component (i.e. verification, validation and effectiveness) are assessed based on utilising the evaluation framework adopted for this purpose (introduced in Chapter 3). Based on the evaluation outcomes, the framework component and its related documents are revised, and modifications are applied if needed.

The rest of this chapter is organised as follows. Section 7.2 discusses the design and development of the 'Alignment and Knowledge Retrieval' component. Section 7.3 discussed the demonstration of the developed component using the adopted CTAG-KHCC case study. The related parts of the adopted evaluation framework applied to evaluate the developed component are presented in Section 7.4. Then, the chapter is summarised in Section 7.5.

7.2 FOURTH-DSRM-INCREMENT'S FIRST STAGE: DESIGN AND DEVELOPMENT OF THE ALIGNMENT AND KNOWLEDGE RETRIEVAL COMPONENT

As mentioned earlier, the alignment and knowledge retrieval component aims at *aligning* between the previously developed ChM and SoS context view framework components and using them to enable *enriching* the awareness of the ChM stakeholders with purposeful knowledge, contributing to *improving the effectiveness* of ChM application in a SoS context. To address the aforementioned aim in a piecemeal and clear way, a phased-approach, that entails three main stages, was adopted and utilised to guide the design and development of the alignment and knowledge retrieval component. Figure 7.1 presents the adopted phased-approach.

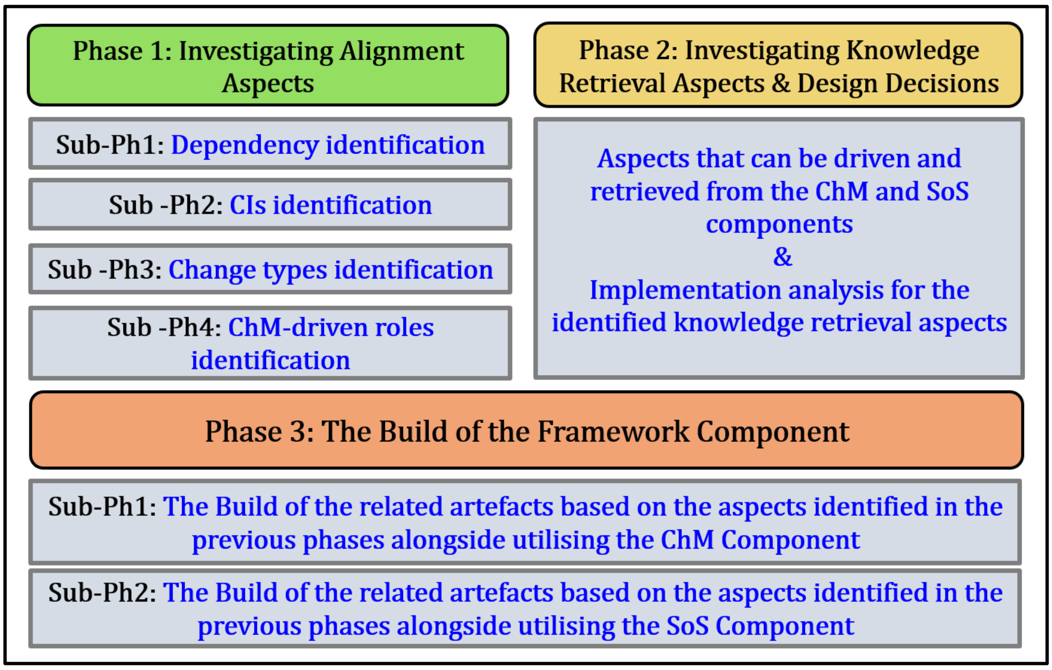


Figure 7. 1: The Adopted phased-approach for the design and development of the alignment and knowledge retrieval component.

7.2.1 Phase 1: Investigating Alignment Aspects

Conducting this phase enabled realising aspects to align the ChM and SoS context view framework components in order to complement each other when utilised to address the aim of the OntoSoS.BPA.ChM framework. Four main objectives were considered the intended alignment: (i) to investigate the dependency of ChM processes on the SoS context elements; (ii) to investigate the SoS context CIs that need to be considered for the application of the OntoSoS.BPA.ChM framework; (iii) to investigate the main change types that need to be considered for the application of the OntoSoS.BPA.ChM framework; and (iv) to investigate the SoS-CIs related ChM-driven roles that are needed to be considered for the application of the OntoSoS.BPA.ChM framework. Accordingly, Phase 1 entails four sub-phases to address these identified objectives. Table 7.1 lists the four entailed sub-phases and provides a brief description of them.

Table 7. 1: Description of the first phase related sub-phases.

Sub-Phase	Description
Sub-Phase 1: Dependency Identification	▪ Is concerned with identifying which of the Riva-driven ChM processes -identified in Chapter 4- are 'dependent on' the domain-specific SoS context. This enables empowering ChM-stakeholders with knowledge about the ChM processes that need to be aware of the SoS operational context to operate successfully. ▪ The dependency relations were identified based on answering the question: *'Is it crucial for any of the identified ChM business processes (a CP, CMP, or CSP) to be aware of elements from the SoS context -that are related to a submitted change request- to operate successfully?'* If the answer is 'Yes', this means that the ChM process has a form of dependency on the SoS context. ▪ The CMPs are only interested in managing the flow of the related CPs. Therefore, the answer to their dependency check question is always 'No'. However, the CSP that is identified as dependent on the SoS context will be labelled as having 'partial dependency', since the dependency of its related CMP is defined as 'No' by default. ▪ Table 7.2 shows a part of the ChM processes with their dependency relationships identified answers.

Table 7.1: Description of the first phase related sub-phases, "Continued".

Sub-Phase	Description
Sub-Phase 2: Main Configuration Items Identification	▪ If a change that is applied to an SoS related business aspect is not traced to the related constituent business area(s) that support(s) it, a gap between the SoS global and local levels and between the business aspects and supporting IT might occur. Furthermore, if a change applied to an SoS business aspect is not traced to the related BPA elements, a gap between the As-Is BPA and the business aspects that are supported by the As-Is BPA might occur. On the other hand, if a change that is applied to a constituent business area is not traced to the related SoS business elements, a gap between the local CBA and the global SoS level and also between the SoS business and IT aspects might occur. ▪ The concept 'Configuration Item' (CI) is used within the software and systems engineering CM context to generally refer to any IT-related component or asset that supports the delivery of IT services and functionalities, which are decided to be under configuration control. Hence, ChM is responsible for managing changes that affect these identified CIs (AXELOS, 2011; INCOSE, 2015; Leon, 2015). ▪ To facilitate achieving more comprehensive traceability of change-related implications than traditional ChM frameworks and improving global-local levels alignment and BIA during ChM application, a wider CI scope that is business-driven was proposed. The concept 'CI' is proposed to refer to *'an SoS-driven element identified within the global or local levels, where a change applied to might have a notable impact on the global-local levels alignment and/or BITA, and needs to be under the control of ChM'.* ▪ Based on analysing the SoS context view meta-model's elements (developed and presented in Chapter 6, Figure 6.2), related SoS context-driven CIs were identified for the OntoSoS.BPA.ChM framework consideration and presented in Table 7.3.
Sub-Phase 3: Change Types Identification	▪ In the domain of ChM, the identified CIs establish the grounds for identifying which change types need to be considered by any given ChM-framework. Based on the CIs identified in the previous sub-phase, a number of related abstract change types were identified and proposed for the consideration of the OntoSoS.BPA.ChM framework. Table 7.4 lists the identified change types. ▪ The adaptation and identification of the main CIs and change types to be considered by the OntoSoS.BPA.ChM framework assisted in identifying a more precise application scope for the research framework. Furthermore, it assisted in identifying the starting points and implementation routes (discussed in Section 7.2.2) that enable reaching more comprehensive traceability of submitted change-related implications than considering only IT-related CIs aspects.
Sub-Phase 4: ChM-Driven Roles Identification	▪ The ChM processes identified as having a dependency on the SoS context rely heavily on being aware of which SoS-CIs are involved to operate successfully. However, these identified ChM processes (e.g. change validation, disposition and planning) also rely on being aware of the SoS-CIs-related authorities that are required to be involved during the management of a submitted change. For example, the 'disposition' of a change request requires the involvement of the affected CIs-Owners or Managers. However, the current developed SoS context view meta-models do not represent such authorities. ▪ Driven from the general aims of the identified BPA-driven ChM processes, ChM-driven roles were identified and proposed to be linked to the SoS-CIs. ▪ The identification of these roles is anticipated to enable better alignment between the ChM and SoS components and identify more comprehensive knowledge related to the roles and authorities that are needed during the application of a number of ChM processes (e.g. impacted parties' identification). Table 7.5 describes the proposed ChM-driven roles.

Table 7. 2: Part of the ChM processes dependency relationship identification table.

Key question: Does the Riva-based ChM process need to be aware of related SoS elements to operate effectively?				
ID	**UOW**	**CP**	**CMP**	**CSP**
1	Change Request (CR) Submission	No	No	No
2	Change Request Review for Completeness and Clarity	No	No, Folded (Does Not appear in the final 2nd-Cut-PAD)	No, Folded (Does Not appear in the final 2nd-Cut-PAD)
3	Change Initiation	Yes	No	Yes, (Partially)
4	Change Logging	No	No, Folded	No, Folded
5	Change Initial Validation	Yes	No, Folded	Yes, Folded
6	Initial Impacted Parties Identification	Yes	No, Folded	Yes, Folded
7	Change Initial Validation	Yes	No	Yes, (Partially)
8	Change Category and Priority Validation	Yes	No, Folded	Yes, Folded
9	Initial Disposition Authority Identification	Yes	No, Folded	Yes, Folded
10	Change Initiation Documentation	No	No, Folded	No, Folded
11	Change Record	No	No	No
12	Change Closure	No	No	No
13	Change Initiation Feedback to Change Request Initiator	No	No, Folded	No, Folded
14	Change Model Selection	No	No, Folded	No, Folded
15	Change Assessment and Evaluation	Yes	No	Yes, (Partially)
16	Impacted Parties List Validation	Yes	No, Folded	Yes, Folded

Table 7. 3: The identified CIs for the OntoSoS.BPA.ChM framework application.

#	CI-Level	Identified CI
1	A CI identified for the SoS global level	▪ A **Business Service** identified for the SoS global-level. ▪ A **BPA** modelled for the SoS global-level, more precisely: ○ A **UOW** identified within the global-level BPA. ○ A **Generate Relation** identified within the global-level BPA. ○ A **Business Process** identified within the SoS global level. ▪ A **Constituent Business Area** that participates in an SoS arrangement.
2	A CI identified for the Constituent Business Area (CBA) level, which supports the CBA participation in an SoS arrangement	▪ A **Business Service** identified for an SoS-CBA. ▪ A **BPA** modelled for an SoS-CBA, more precisely: ○ A **UOW** identified within a CBA-BPA. ○ A **Generate Relation** identified within a CBA-BPA. ○ A **Business Process** identified within a CBA-BPA. ▪ A **BPM** identified for an SoS-CBA, more precisely: ○ A **Task** identified within a CBA-BPM. ○ A **Pool** identified within a CBA-BPM. ▪ A **Software Service** identified for an SoS-CBA. ▪ A **Constituent Information System** that supports a software service identified for an SoS-CBA.

Table 7. 4: The identified Change Types for the OntoSoS.BPA.ChM framework application.

#	Identified Change Type
1	▪ A Global-Level **Business Service** Related Change.
2	▪ A Global-Level **BPA** Related Change, more precisely: ○ A Global-Level **UOW** Related Change. ○ A Global-Level **Generate Relation** Related Change. ○ A Global-Level **Business Process** Related Change.
3	▪ A **Constituent Business Area** Related Change.
4	▪ A Local-Level **Business Service** Related Change.
5	▪ A Local-Level **BPA** Related Change, more precisely: ○ A Local-Level **UOW** Related Change. ○ A Local-Level **Generate Relation** Related Change. ○ A Local-Level **Business Process** Related Change.
6	▪ LL-**BPM** Related Change, more precisely: ○ A Local-Level **Task** Related Change. ○ A Local-Level **Pool** Related Change.
7	▪ A Local-Level **Software Service** Related Change.
8	▪ A Local-Level **Constitute Information System** Related Change.

Table 7. 5: Proposed ChM-driven Roles.

Proposed ChM-driven Role	Brief Description
CI-Owner	▪ The authority that is accountable for the CI. It is the go-to authority which represents the CI across the entire SoS arrangement. In addition, it is the authority that makes sure that the CI is clearly defined, designed and documented and, if needed, to make sure that the related policies are set for governance.
CI-Manager	▪ The authority that manages the CIs on a day-to-day basis. Furthermore, it makes sure that the policies and procedures related to a CI are carried out and adhered to.
CI-Engineer	▪ The authority that is accountable for the specification, design and documentation of a CI, besides managing and coordinating the build, test, evaluation, releasing and deploying the CI.
CI-Builder	▪ The authority that is responsible for building a CI based on its identified specifications, besides maintaining the developed CI.
CI-Tester	▪ The authority that is responsible for testing the developed CI to ensure its validity, usability and usefulness alongside testing any other criteria defined by the CI-Engineer.
CI-Evaluator	▪ The authority that is responsible for assessing the developed CI from technical and business point of views to decide on authorising the developed CI for release, deployment or final acceptance.
CI-Releaser	▪ The authority that is responsible for preparing a stable version (i.e. a baseline) of CI to be put in use within an operational context.
CI-Deployer	▪ The authority that is responsible for making sure that a CI is adopted, tested and operated successfully within its operational context.

7.2.2 Phase 2: Investigating Knowledge Retrieval Aspects and Related Design Decisions

To continue addressing this chapter's objectives, this sub-phase focused on investigating the aimed at knowledge retrieval aspects and related design decisions. Table 7.6 presents the knowledge that can be realised and obtained based on using the ChM and SoS context view components and the aspects identified in the previous phase. The table also shows the implementation decisions proposed for each of the identified aspects.

Table 7. 6: The anticipated knowledge aspects to be retrieved, their related sources and design decisions.

#	Aspect	Anticipated Knowledge Source & Recommended Implementation Decision
1	**Knowledge about the 'Main ChM Stages' that a normal change request should go through and their related 'Decision Gates'.**	▪ Can be retrieved using the **ChM** framework component. ▪ During the validation of the ChM component (in **Chapters 4 and 5**), domain experts were interviewed. One of the comments received by the interviewed domain experts (which was out of the validation scope at that time) is the probability of representing generalised ChM stages and related decision gates driven from the modelled generalised BPA-driven ChM processes. ▪ Having the ChM-BPA models (developed in **Chapter 4**) enables the investigation, identification and modelling main generalised ChM stages and their related decision gates. In addition, the modelled ChM stages can be semantically enriched and linked to the previously developed BPA-driven and ontology-based ChM models (**Chapter 5**). ▪ To enable retrieving the ChM stages and their related decision gates, algorithmic and SQWRL-based capabilities can be developed to be applied to the semantically-enriched ChM component.
2	**Knowledge about the main 'ChM Processes' entailed in each 'ChM Stage'**	▪ Can be retrieved using the **ChM** framework component. ▪ Having the ChM processes and their linkages to their encapsulating ChM stages identified within the ChM framework component enables identifying and retrieving knowledge about them. ▪ Further algorithmic and SQWRL-based capabilities can be developed to enable retrieving knowledge about the main ChM processes entailed in any of the identified main ChM Stages.
3	**Knowledge about the generic 'Relationships' exist between the 'ChM Processes'**	▪ Can be retrieved using the **ChM** framework component. ▪ Having the ChM processes and the relationships between them identified within the ChM framework component enables identifying and retrieving knowledge about them. ▪ Further algorithmic and SQWRL-based capabilities can be developed to enable retrieving knowledge about the main dynamic relationships identified between the ChM processes.
4	**Knowledge about the 'ChM Main Documents and Roles' related to the identified 'ChM Processes'**	▪ Can be retrieved using the **ChM** framework component. ▪ Having the ChM processes linked to their main related ChM- documents and roles identified within the ChM framework component enables identifying and retrieving knowledge about them. ▪ Further algorithmic and SQWRL-based capabilities can be developed to enable retrieving knowledge about the main ChM- documents and roles identified and linked to the ChM processes.
5	**Knowledge about the 'Heterogenous Terminologies' related to the identified ChM Processes, Documents and Roles**	▪ Can be retrieved using the **ChM** framework component. ▪ Having the terminologies related to the modelled ChM processes, documents and roles identified within the ChM component enables identifying and retrieving knowledge about them. ▪ Further algorithmic and SQWRL-based capabilities can be developed to enable retrieving knowledge about the terminologies related to the identified ChM processes and their related ChM- documents and roles.
6	**Knowledge about the 'Dependency Relationships of the 'ChM processes' on SoS context**	▪ Can be retrieved using the **ChM** framework component. ▪ Having the dependency relationships related to the ChM processes identified within the ChM component enables identifying and retrieving knowledge about them. ▪ Further algorithmic and SQWRL-based capabilities can be developed to enable retrieving knowledge about dependency relationships related to the identified ChM Processes. ▪ The current status of the developed ChM component does not represent the dependency relationships identified during phase 1 of the design and development stage. Therefore, these relationships need to be added to the developed ChM framework component.

Table 7.6: The anticipated knowledge aspects to be retrieved, their related sources and design decisions, "Continued".

#	Aspect	Anticipated Knowledge Source &Recommended Implementation Decision
7	**Knowledge about direct and indirect candidate 'CIs'**	▪ Can be retrieved using the **SoS context view** framework component. ▪ The SoS context view component (developed in **Chapter 6**) provides ontology-based meta-model that can be instantiated to represent business-driven elements and the linkages between them within the operational context of a given SoS arrangement. ▪ Having identified the main CIs for this research, algorithmic and SQWRL-based capabilities can be developed and used to retrieve knowledge about the main CI that is identified in a change request and also about the CIs that are related to it based on the linkages modelled between them within the SoS context view component.
8	**Knowledge about the candidate 'Users'**	▪ Can be retrieved using the **SoS context view** framework component. ▪ Having the CIs identified based on the elements of the SoS context component (developed and semantically-enriched in **Chapter 6**), further algorithmic and SQWRL-based capabilities can be used to retrieve the main users (i.e. Pools) related to them.
9	**Knowledge about the related 'Management and Authorisation Authorities'**	▪ Can be retrieved using the **SoS context view** framework component. ▪ The current state of the developed SoS context artefact does not capture the roles related to who manages, owns or engineers the identified CIs. These are considered ChM-driven roles needed for the application ChM processes and they were not considered during the development of the SoS context view meta-models in **Chapter 6**. Therefore, these ChM-driven roles (which were identified in Phase 1-Sub-Phase 4) need to be added to the previously developed SoS context view artefact. ▪ The algorithmic and SQWRL-based capabilities proposed to address the previous points can be extended to retrieve knowledge about the main roles (i.e. Manager, Owner and Engineer) related to the identified main CI and its related CIs.
10	**Knowledge about the related candidate 'Planning, Building, Testing, Evaluation, Releasing and Deploying Authorities'**	▪ Can be retrieved using the **SoS context view** framework component. ▪ The current status of the developed SoS context view artefact does not include elements that represent roles related to who planned, built, tested, evaluated and accountable for the identified CIs. These are considered ChM-driven roles needed for the application ChM processes and they were not considered during the development of the SoS context view meta-models in **Chapter 6**. Therefore, these ChM-driven roles (which were identified in Phase 1-Sub-Phase 4) need to be added to the previously developed SoS context view artefact. ▪ The algorithmic and SQWRL-based capabilities proposed to address the previous points can be extended to retrieve knowledge about the candidate Planning, Building, Testing, Evaluation, Releasing and Deploying authorities that are related to a specific CI.

Identifying a starting point (CI) for the traceability route of change request related candidate implications and stakeholders enables investigating and understanding the ways available to retrieve the aimed at knowledge aspects mentioned in the previous table for points 7 to 10. This, in turn, supports achieving the traceability required to guide and facilitate the ChM application in a SoS context. For the purpose of this research, the identification of the change candidate implications traceability routes is done based on understanding an identified starting point (a CI identified in a submitted change request form) and the available linkages between the related CIs. Subsequently, algorithmic and SQWRL-based capabilities can be proposed and used to guide the implementation of implications traceability routes and retrieve knowledge about the intended candidate implications and CIs related stakeholders as proposed in Tables 7.6 and 7.7.

Table 7.7 shows a part of the change candidate implications and stakeholders traceability routes that were identified based on the linkages between the identified CIs and between the CIs and their related stakeholders, also based on an identified starting point. These routes formulate the grounds for establishing algorithmic and SQWRL-based capabilities to retrieve the intended knowledge. The complete set can be found in Appendix G. Furthermore, achieving this enables holistic identification of submitted change related candidate implications and stakeholders. As an example, Figure 7.2 illustrates the traceability route presented in table 7.7.

Table 7. 7: Part of the identified change related candidate implications and stakeholders traceability routs.

#	Change Traceability Starting Point	Candidate Implications and related ChM-driven Stakeholders Traceability Route For Related Cis and ChM-driven Stakeholders Identification
1	GL-Business Service	Related ChM-driven Roles
		Related GL-BPA Segment
		Related GL-BPs
		Related GL-Relations
		Related GL-BPA and its related entailed elements
		Related GL-BPA's ChM-driven Roles
		Related GL-Business Area
		Related LL-Business Area
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-BPs
		Related LL-BPA Segment
		Related LL-Relations
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related LL-BPA and its related entailed elements
		Related LL-BPA's ChM-driven Roles
		Related LL-BPMs
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles

7.2.3 Phase 3: The Build of the Alignment and Knowledge Retrieval Component

This phase focused on the development of the alignment and knowledge retrieval framework component based on the aspects realised in the previous two phases. It starts with developing the component-driven documents based on utilising the ChM component. After that, the phase progresses with developing the component-driven documents based on utilising the SoS context view component.

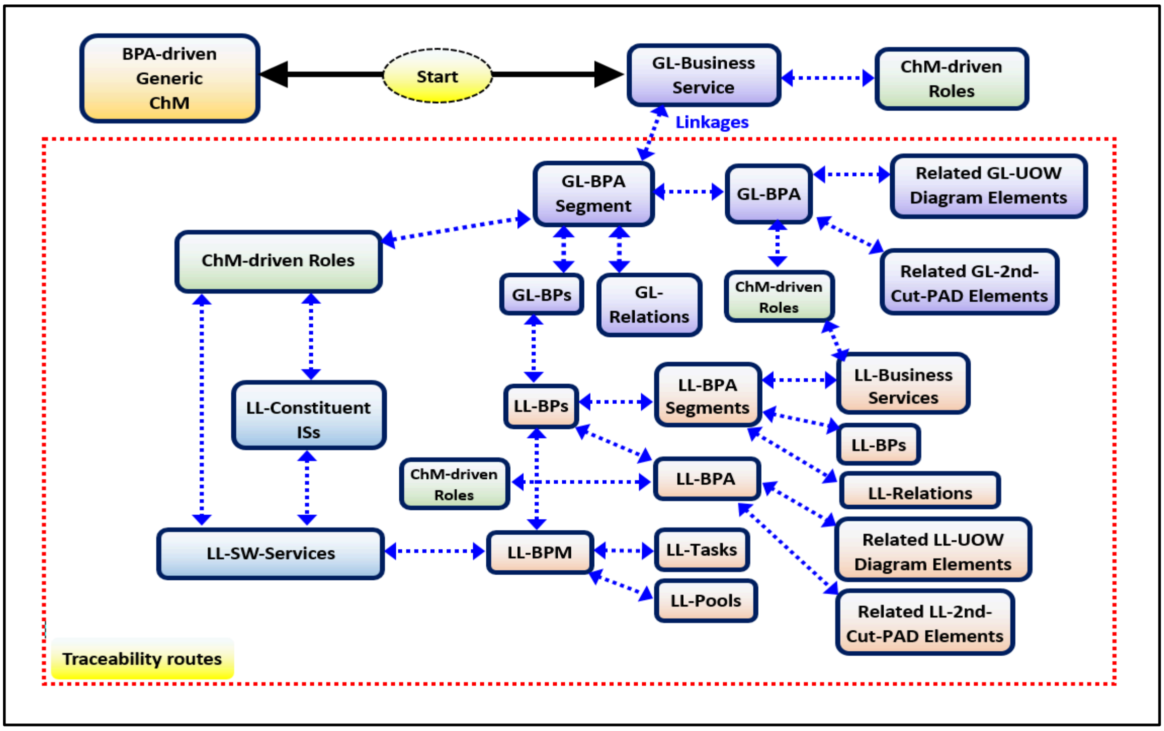


Figure 7. 2: Example of a traceability route for GL-Business Service-related.

7.2.3.1 Phase 3- Sub-Phase 1: Building the Alignment and Knowledge Retrieval Component Based on Utilising the ChM Component

This sub-phase focused on developing the alignment and knowledge retrieval component by implementing the design aspects identified in the previous phases related to utilising the ChM framework component. This includes conducting four sub-phases: (i) developing a BPA-driven conceptual flowchart model that represents the main generalised ChM stages and their related decision gates and then semantically enriching the developed conceptual model; (ii) updating the adapted srBPA ontology for ChM to include the dependency relationships identified for the BPA-driven ChM processes; (iii) updating the integrated BPA-driven and ontology-based ChM model to include the newly developed ChM aspects (stages flow and dependency relationships); and (iv) developing algorithmic and SQWRL-based knowledge retrieval capabilities that enable retrieving knowledge about the ChM aspects identified and represented in the ChM component. Table 7.8 describes the four entailed sub-phases.

Generally, the retrieved ChM knowledge can empower the ChM-stakeholders with knowledge that enriches their awareness of the ChM stages, related decision gates, entailed ChM processes and the processes related documents and roles. In addition, the retrieved ChM knowledge can empower ChM-stakeholders with knowledge that enriches their awareness of the detected terminologies identified for the modelled ChM processes, documents and roles. In a SoS context, having such a piece of knowledge is reduces the SoS heterogeneity impact on sharing, agreeing on and using knowledge in relation to ChM application within the SoS context.

Table 7. 8: Description of the first phase related sub-phases.

Sub-Phase	Description
Sub-Phase 1: Development Of Semantically-Enriched ChM-Stages Flow Meta-Model	▪ The ChM BPA-driven models developed in **Chapter 4** were investigated to identify the main generalised ChM stages and related decision gates that a change request should go through. The identification was based on analysing the general objectives of the presented ChM-BPA. ▪ A conceptual flowchart meta-model was developed to capture the identified ChM stages alongside their related decision gates and sequence flow. Figure 7.3 presents the modelled conceptual ChM stages flowchart. Furthermore, Appendix H lists and describes the main identified elements. ▪ Ontology-based meta-model was developed to semantically enrich the developed conceptual flowchart meta-model. ▪ Two main ontological constructs were identified: the 'ChM_Stage' and the 'ChMStage_Decision_Gate'. In addition, object properties were identified to represent the relationships between the constructs' instances, these properties are:'ChMStage_Has_Related_DirectStage','ChMStage_Has_Related_ StageDecisionGate', 'NextSage_IF_Positive', 'NextStage_IF_ Negative' and 'StageGate_Has_Related_ChMStage'. Later, during the DSRM demonstration stage, the developed ChM stages meta-model was instantiated with the identified ChM stages, decision gates and relationships.
Sub-Phase 2: Development Of Semantically-Enriched Dependency Relationships	▪ The adapted srBPA meta-model for ChM was updated with ontological elements that semantically enrich the dependency relationships identified in Phase 1- Sub-Phase 1. ▪ 'Boolean' data properties (i.e. 'CP_IsDependentOn_SoS', 'CMP_IsDependentOn_SoS' and 'CSP_IsPartiallyDependentOn_SoS') were identified and linked to the BPA-driven ChM processes constructs identified in the adapted srBPA meta-model for ChM. ▪ Later, during the DSRM demonstration stage, these object properties were instantiated with the identified dependency relationships (Section 7.2.1).
Sub-Phase 3: Updating the Integrated BPA-driven and Ontology-based ChM Meta-Model	▪ The integrated BPA-driven ChM meta-model was updated to include all the of newly developed ontological ChM elements and link the ChM stage construct to their related BPA-driven ChM processes constructs. ▪ The ChM related ontology-based meta-models were linked by using the object property 'ChMStage_Entailes_AbstractChMProcess' between the identified ChM stage construct and the adapted srBPA UOW construct. ▪ Later, during the DSRM demonstration stage, these identified linkages will be instantiated for the ChM stages and ChM processes instances.
Sub-Phase 4: Development Of Algorithmic and SQWRL-based ChM-Knowledge Retrieval Capabilities	▪ Algorithmic and SQWRL-based capabilities to retrieve knowledge about the ChM aspects represented in the updated ChM component were developed. ▪ For some general queries, the knowledge that can be retrieved might be complex to users (e.g. detailed knowledge about all ChM stages, including its related ChM processes). Therefore, the considered knowledge retrieval capabilities were limited to three main categories: (i) retrieving knowledge about all ChM stages, without retrieving detailed knowledge about their ChM processes related documents, roles, related terminologies and relationships; (ii) retrieving knowledge about a specific ChM stage, without retrieving detailed knowledge about its ChM processes documents, roles, related terminologies and relationships; and (iii)retrieving knowledge about a specific ChM process, which includes retrieving the detailed knowledge captured for the identified ChM process. For the first and second categories, if the user requires more knowledge about the entailed ChM processes, (s)he can execute the capabilities related to the third category. ▪ Figure 7.4 presents parts of the algorithms designed to guide retrieving ChM knowledge aspects related to the identified categories. ▪ Table 7.9 shows part of the supporting SQWRL-based capabilities developed to retrieve knowledge about the aspects identified in the designed algorithms from the updated Integrated BPA-driven ChM ontology. ▪ Further examples of the identified algorithms and related supporting SQWRL-based capabilities can be found in Appendix I. Later, during the DSRM demonstration stage, the identified knowledge retrieval capabilities are instantiated to retrieve knowledge from the ChM ontological model.

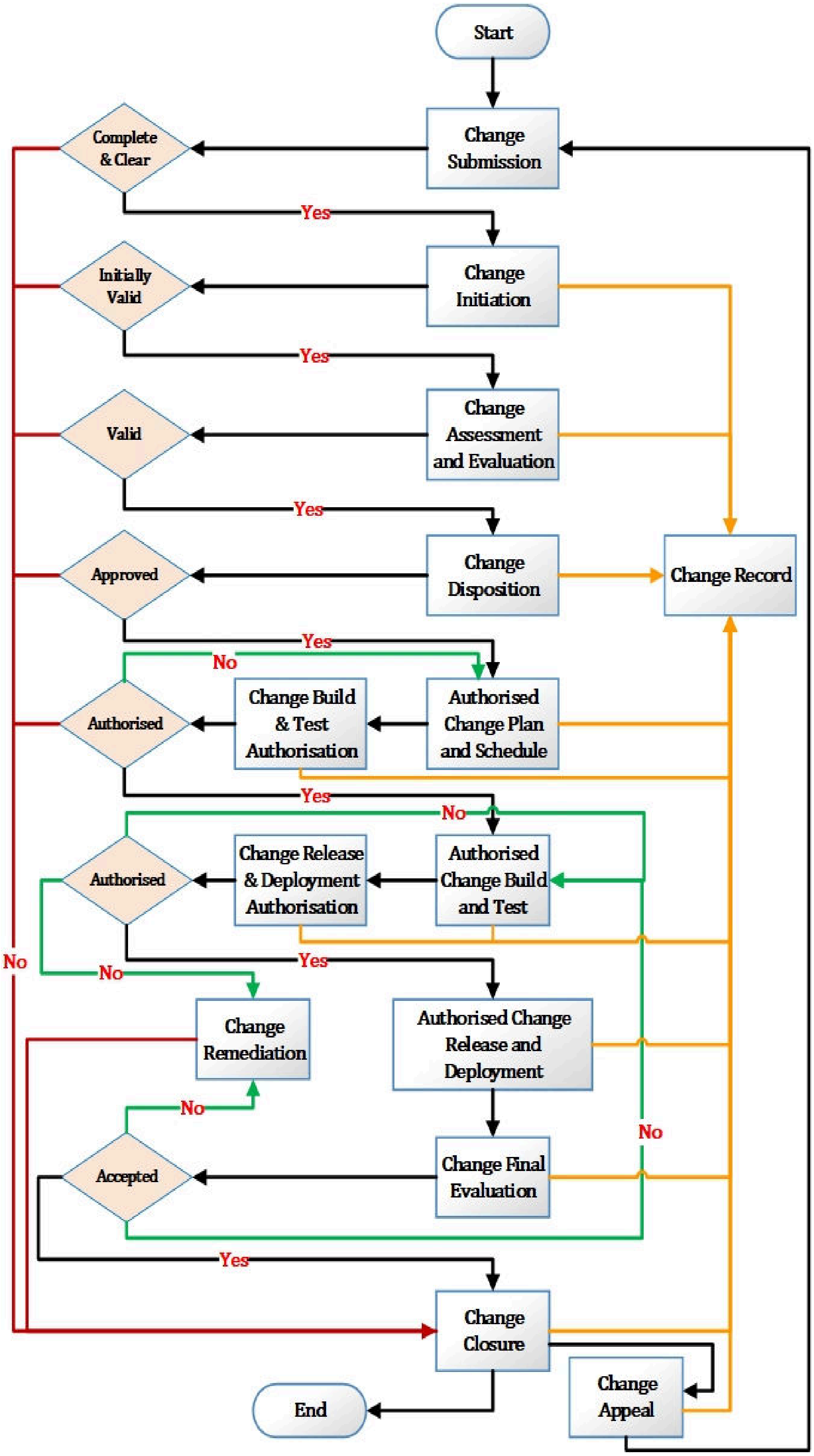


Figure 7. 3: Proposed ChM stages conceptual meta-model.

ALGORITHM III: SPECIFIC CHM STAGE KNOWLEDGE RETRIEVAL

INPUT:

- The Integrated BPA-driven Ontology for ChM

OUTPUT:

- Knowledge Retrieved Related to a Specific Main ChM Stage.

BEGIN

Main-ChM-Stage = **Retrieve** the '**ChM-Stage**' that is sent to the Algorithm.

Direct-ChM-Stages [ ] = **Retrieve** the '**ChM Stages**' that are directly connected to the identified **Main-ChM-Stage** without decision gates.

Main-Decision-Gate = **Retrieve** the '**Decision Gate**' that is related to the identified **Main-ChM-Stage.**

Next-ChM-Stage-IF-Positive = **Retrieve** the '**ChM Stage**' that follows the identified **Main-Decision-Gate** if its status is **Positive.**

Next-ChM-Stage-IF-Negative = **Retrieve** the '**ChM Stage**' that follows the identified **Main-Decision-Gate** if its status is **Negative.**

Related-ChM-Processes [ ] = **Retrieve** the '**Abstract ChM Processes**' that are related to the identified **Main-ChM-Stage.**

Outgoing-Dynamic-Relationships [ ] = **Retrieve** the '**Outgoing Dynamic Relationships**' for each **ChM Processes** identified in the **Related-ChM-Processes [ ]**

Riva-based-CPs [ ] = **Retrieve** the '**Riva-based Case Process**' for each **ChM Process** identified in the **Related-ChM-Processes [ ]**

Riva-based-CPs-IsActive [ ] = **Retrieve** the '**Is Active Value**' related to each **Rive-based-CP** identified in the **Riva-based-CPs [ ]**

Riva-based-CPs-DepednecyOnSoS [ ] = **Retrieve** the '**Dependency Relation Value**' related to each **Rive-based-CP** identified in the **Riva-based-CPs [ ]**

Riva-based-CMPs [ ] = **Retrieve** the '**Riva-based Case Management Process**' for each **ChM Process** identified in the **Related-ChM-Processes [ ]**

Riva-based-CMPs-IsActive [ ] = **Retrieve** the '**Is Active Value**' related to each **Rive-based-CMP** identified in the **Riva-based-CMPs [ ]**

Riva-based-CPs-DepednecyOnSoS [ ] = **Retrieve** the '**Dependency Relation Value**' related to each **Rive-based-CMP** identified in the **Riva-based-CMPs [ ]**

Riva-based-CMPs [ ] = **Retrieve** the '**Riva-based Case Management Process**' for each **ChM Process** identified in the **Related-ChM-Processes [ ]**

Riva-based-CMPs-IsActive [ ] = **Retrieve** the '**Is Active Value**' related to each **Rive-based-CMP** identified in the **Riva-based-CMPs [ ]**

Figure 7. 4: Part of the developed algorithms to guide ChM aspects knowledge retrieval.

Table 7. 9: Example of the SQWRL-based capabilities developed to enable retrieving the identified ChM knowledge aspects.

Supporting SQWRL-Based Statements To Enable Knowledge Aspects Retrieval Related to a Specific ChM Stage Flow
ChM-SQWRL-01: For a specific ChM Stage, retrieve the ChM Stages that are directly connected to it.
ChM_Stage(Specific ChM Stage) ^ ChMStage_Has_Related_DirectStage(Specific ChM Stage, ?direct_related_stage) -> sqwrl:select(Specific ChM Stage, ?direct_related_stage)
ChM-SQWRL-02: For a specific ChM Stage, retrieve its related Decision Gates.
ChM_Stage(Specific ChM Stage) ^ ChMStage_Has_Related_StageDecisionGate (Specific ChM Stage, ?related_decision_gate) -> sqwrl:select(Specific ChM Stage, ?related_decision_gate)
ChM-SQWRL-03: For a specific ChM Stage, retrieve its related Decision Gates and the Next ChM main Stages following the identified Decision Gates.
ChM_Stage(Specific ChM Stage) ^ ChMStage_Has_Related_StageDecisionGate(Specific ChM Stage, ?related_decision_gate) ^ NextSage_IF_Positive (?related_decision_gate, ?next_stage_if_positive) ^ NextStage_IF_Negative(?related_decision_gate, ?next_stage_if_negative) -> sqwrl:select(Specific ChM Stage, ?related_decision_gate, ?next_stage_if_positive, ?next_stage_if_negative)
ChM-SQWRL-04: For a specific ChM Stage, retrieve the entailed Abstract ChM Processes.
ChM_Stage(Specific ChM Stage) ^ ChMStage_Entailes_AbstractChMProcess (Specific ChM Stage, ?entailed_abstract_chm_process) -> sqwrl:select(Specific ChM Stage, ?entailed_abstract_chm_process) ^ sqwrl:orderBy(?entailed_abstract_chm_process)
ChM-SQWRL-05: For a specific ChM Stage, retrieve the entailed Abstract ChM Processes and the Dynamic Relationships identified between the entailed ChM Processes.
ChM_Stage(Specific ChM Stage) ^ ChMStage_Entailes_AbstractChMProcess(Specific ChM Stage, ?entailed_abstract_chm_process) ^ AdsrBPA:Has_a_Generate_Relation(?entailed_abstract_chm_process, ?process_has_a_dynamic_relation) -> sqwrl:select(Specific ChM Stage, ?entailed_abstract_chm_process, ?process_has_a_dynamic_relation) ^ sqwrl:orderBy(?entailed_abstract_chm_process) ^ sqwrl:orderBy(?process_has_a_dynamic_relation)

7.2.3.2 Phase 3- Sub-Phase 2: Building the Alignment and Knowledge Retrieval Component Based on Utilising the SoS Context View Component

This sub-phase focused on developing the alignment and knowledge retrieval component by implementing the design aspects identified in the previous phases related to utilising the SoS context view component. This includes conducting three sub-phases: (i) updating the SoS context view meta-model (Chapter 6) with constructs and object properties related to the ChM-driven roles identified in Phase 1; (ii) developing a change type form to assist in realising the CI that can be considered as the starting point for change candidate implications and stakeholders traceability routes related to a submitted change request; and (iii) developing algorithmic and

SQWRL-based SoS-knowledge retrieval capabilities to retrieve knowledge about change related candidate implications and stakeholders from the SoS context view component. Table 7.10 describes the three entailed sub-phases.

Table 7. 10: Description of the second phase related sub-phases.

Sub-Phase	Description
Sub-Phase 1: Updating the SoS Context View Meta-Model to Include the ChM-driven Roles	▪ To semantically enrich the identified ChM-driven roles (presented in Table 7.5) and their linkages to the SoS-CIs modelled in the developed abstract SoS context view meta-model (Chapter6), a number of classes and object properties were added to the SoS context view ontological meta-model. Table 7.11 shows the added classes/sub-classes and related properties.
Sub-Phase 2: Development of a Change Type Form	▪ A Change Type Form (CTF) is proposed to be filled by the related ChM authorities. This CTF is considered as a means to identify the CI that need to be realised by the knowledge retrieval framework component as a starting point for a traceability route. ▪ The CTF should be filled successfully and reviewed by an allocated authority (e.g. change officer) before implementing knowledge retrieval capabilities. ▪ When reviewing the submitted CTF, the reviewer should make sure that the CI identified for a given change type is valid. The term 'valid' here is used in the sense of 'the CI exists in an instantiated SoS context view component'. ▪ Figure 7.5 shows an example of the proposed CTF.
Sub-Phase 3: Development of Algorithmic and SQWRL-based Knowledge Retrieval Capabilities	▪ Algorithmic and SQWRL-based capabilities for the traceability and identification of change candidate implications and related authorities were developed based on the change types and related traceability routes identified in Phases 1 and 3 and the starting point identified in a CTF. ▪ Table 7.12 lists the 13 proposed algorithms to be used in guiding the traceability, identification and retrieval of candidate implications and authorities related to a submitted change. ▪ Figures 7.6 presents part of algorithm II designed to guide retrieving knowledge related to the first category identified in Table 7.12. Further examples of the identified algorithms can be found in Appendix J. ▪ SQWRL-based capabilities were developed to retrieve the anticipated elements from the updates SoS context view ontology. The SQWRL-based knowledge retrieval capabilities are categorised into 13 categories based on the related ChM types and algorithms. Tables 7.14 shows part of the developed SQWRL-based capabilities as an example. Further examples of the identified SQWRL-based capabilities can be found in Appendix J. Later, during the DSRM demonstration stage, these capabilities were instantiated to retrieve knowledge from the CTAG SoS context view ontology.

Table 7. 11: The added classes, sub-classes and related properties to support the semantic enrichment of the identified SoS-CIs related ChM-driven roles.

Added Class	Added Sub-Class	Added Properties
ChM_Driven_Role	**CI_Owner**	Has_Owner
		Is_a_CI_Owner
	CI_Manager	Has_Manager
		Is_a_CI_Manager
	CI_Engineer	Has_Engineer
		Is_a_CI_Engineer
	CI_Evaluator	Has_Evaluator
		Is_a_CI_Evaluator
	CI_Builder	Has_Builder
		Is_a_CI_Builder
	CI_Tester	Has_Tester
		Is_a_CI_Tester
	CI_Releaser	Has_Releaser
		Is_a_CI_Releaser
	CI_Deployer	Has_Deplyer
		Is_a_CI_Deployer

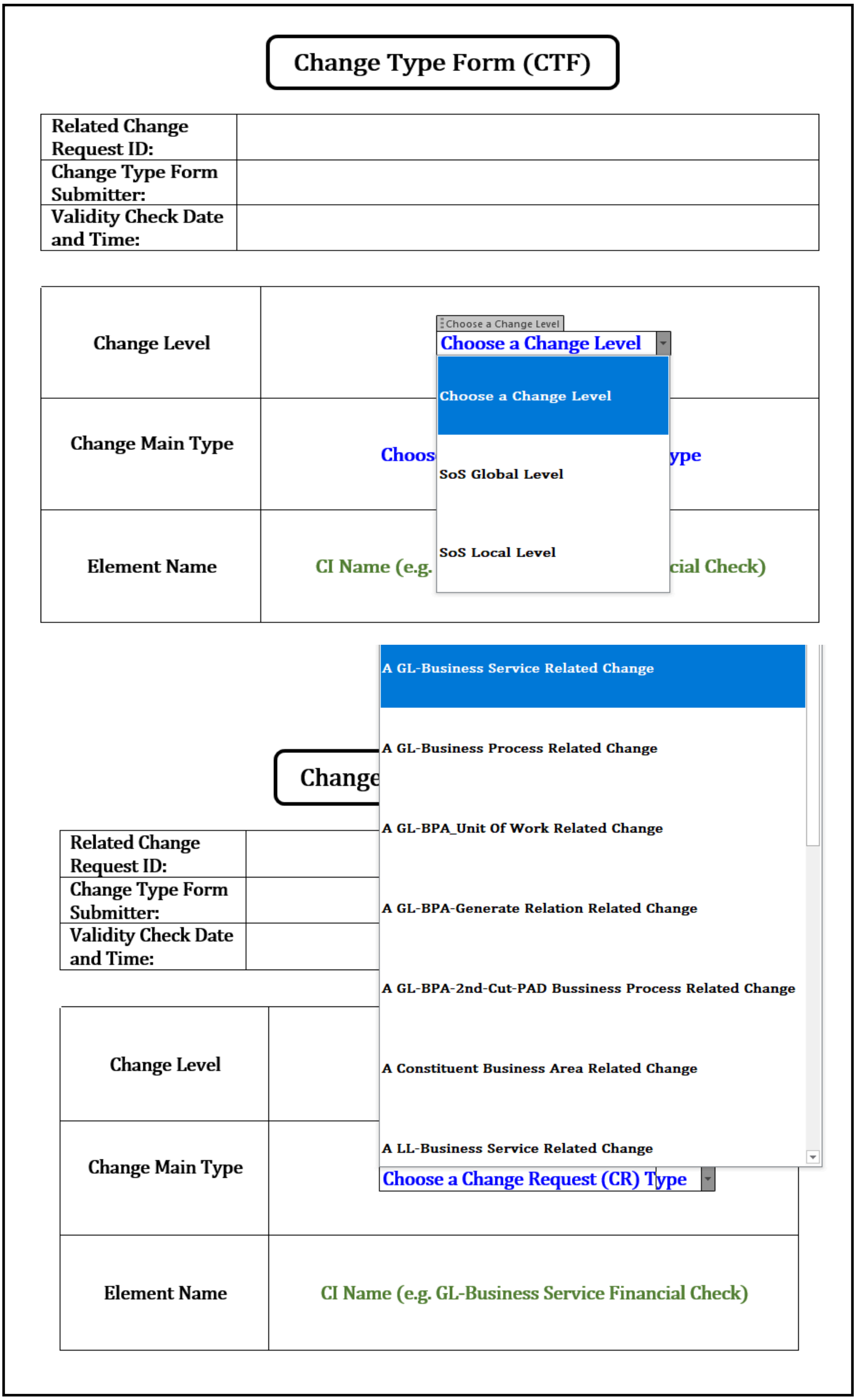


Figure 7. 5: An example of the proposed change type form for the identification of a starting point for traceability routes.

Table 7. 12 : The identified change types and their related traceability proposed algorithms.

#	Change Type	Main CI to be Considered as a Starting Point	Related Algorithm
01	**A GL-Business Service Related Change**	A specific identified GL-Business Service	ALGORITHM SOS-II: GL-BUSINESS SERVICE RELATED KNOWLEDGE RETRIEVAL
02	**A GL- Business Process Related Change.**	A specific identified GL-Business Process	ALGORITHM SOS-III: GL-BUSINESS PROCESS RELATED KNOWLEDGE RETRIEVAL– SOS CONTEXT
03	**A GL-UOW Related Change**	A specific GL-UOW	ALGORITHM SOS-IV: GL-UOW_RELATED_CHANGE
04	**A GL-Generate Relation Related Change**	A specific GL-Generate Relation	ALGORITHM SOS-V: GENERATE_RELATION_RELATED_CHANGE
05	**A Constituent Business Area Related Change**	A specific Constituent Business Area	ALGORITHM SOS-VI: CONSTITUENT BUSINESS AREA RELATED KNOWLEDGE RETRIEVAL
06	**A LL-Business Service Related Change**	A specific LL-Business Service	ALGORITHM SOS-VII: LL-BUSINESS SERVICE RELATED KNOWLEDGE RETRIEVAL
07	**A LL- Business Process Related Change.**	A specific LL-Business Process	ALGORITHM VIII: LL-BUSINESS PROCESS RELATED KNOWLEDGE RETRIEVAL- SOS CONTEXT
08	**A LL-UOW Related Change**	A specific LL-UOW	ALGORITHM SOS-IX: LL-UOW_RELATED_CHANGE
09	**A LL-Generate Relation Related Change**	A specific LL-Generate Relation	ALGORITHM SOS-X: LL-GENERATE_RELATION_RELATED_CHANGE
10	**A LL-Task Related Change.**	A specific LL-BPM-Task	ALGORITHM SOS-XI: LL-TASK RELATED KNOWLEDGE RETRIEVAL-LL-SBPMN
11	**A LL-Pool Related Change**	A specific LL-BPM-Pool	ALGORITHM SOS-XII: LL-POOL RELATED KNOWLEDGE RETRIEVAL-LL-SBPMN
12	**A LL-SW Service Related Change**	A specific LL-Software Service	ALGORITHM SOS-XIII: LL-SWS RELATED KNOWLEDGE RETRIEVAL-SOS CONTEXT
13	**A LL-Constitute Information Systems Related Change**	A specific LL-Constituent Information System	ALGORITHM SOS-XIV: LL-CONSTITUENT INFORMATION SYSTEM RELATED KNOWLEDGE RETRIEVAL-SOS CONTEXT

ALGORITHM SOS-II: GL-BUSINESS SERVICE RELATED KNOWLEDGE RETRIEVAL

INPUT: a CI as Starting Point.
OUTPUT: A set of identified impacted elements and needed authorities related to the identified CI.

BEGIN

GL_BS = **Starting Point**

GL-BS-Name-ID-Version = **Retrieve** the '**Name_ID_Version**' of the identified **GL-BS**
GL-Business-Area = **Retrieve** the '**GL-BA**' Related to the identified **GL-BS**
LL-Business-Area = **Retrieve** the '**LL-BA**' Related to the identified **GL-Business-Area**

GL-BS-Owners [ ] = **Retrieve** the '**Owner (s)**' of the identified **GL-BS**
GL-BS-Managers [ ] = **Retrieve** the '**Manager (s)**' of the identified **GL-BS**
GL-BS-Engineers [ ] = **Retrieve** the '**Engineer (s)**' of the identified **GL-BS**
GL-BS-Evaluators [ ] = **Retrieve** the '**Evaluator (s)**' of the identified **GL-BS**
GL-BS-Releasers [ ] = **Retrieve** the '**Releaser (s)**' of the identified **GL-BS**
GL-BS-Deployers [ ] = **Retrieve** the '**Deployer (s)**' of the identified **GL-BS**

GL-Supporting-BPA-Model-Segment = **Retrieve** the '**GL-BPA-Segment**' that supports the identified **GL-BS**
GL-SoS-BPA-Model = **Retrieve** the '**GL-BPA-Model**' that encapsulates the identified **GL-Supporting-BPA-Model-Segment**
GL-SoS-BPA = **Retrieve** the '**GL-BPA**' that encapsulates the identified **GL-SoS-BPA-Model**

GL-SoS-BPA-Owners [ ] = **Retrieve** the '**Owner (s)**' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Managers [ ] = **Retrieve** the '**Manager (s)**' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Engineers [ ] = **Retrieve** the '**Engineer (s)**' of the identified **GL-SoS-BPA**
GL-SoS-BPA Evaluators [ ] = **Retrieve** the '**Evaluator (s)**' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Releasers [ ] = **Retrieve** the '**Releaser (s)**' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Deployers [ ] = **Retrieve** the '**Deployer (s)**' of the identified **GL-SoS-BPA**

Encapsulated-GL-Business-Processes: E-GL-BPs [ ] = **Retrieve** the '**GL-Business Processes**' that are part of the identified **GL-Supporting-BPA-Model-Segment**

Encapsulated-GL-Relations: E-GL-Rels [ ] = **Retrieve** the '**Relations**' that are part of the identified **GL-Supporting-BPA-Model-Segment**

For each identified GL-Business_Process: GL-BPi **From** the E-GL-BPs [ ] **Do**

GL-Model-Segments [ ] = **Retrieve** the '**GL-BPA-Model-Segments**' that encapsulate the identified **GL-Bpi**

Figure 7. 6: Part of algorithm II designed to guide knowledge retrieval from the SoS component in relation to GL-Business Service.

Table 7. 13: Part of the developed SQWRL-based knowledge retrieval capabilities to enable retrieving knowledge from the SoS context view ontology.

SQWRL-based Statement To Retrieve Knowledge Related to a Specific GL-Business Service
GL-BS-01: For a specific GL-Business Service, retrieve its related ID_Name_Version, GL-Business Area and LL-Business Areas.
GL_Business_Service (Specific GL-Business Service) ^ Has_ID_Name_Version (Specific GL-Business Service, ?related_id_name_version) ^ Has_Related_GL_BA(Specific GL-Business Service, ?related_gl_business_area) ^ Has_Related_LL_BA(?related_gl_business_area, ?related_ll_business_area) -> sqwrl:select(Specific GL-Business Service, ?related_id_name_version, ?related_gl_business_area, ?related_ll_business_area)
GL-BS-02: For a specific GL-Business Service, retrieve its related ChM-Driven Roles.
GL_Business_Service(Specific GL-Business Service) ^ Has_Owner(Specific GL-Business Service, ?gl_bs_related_owner) ^ Has_Manager(Specific GL-Business Service, ?gl_bs_related_manager) ^ Has_Engineer(Specific GL-Business Service, ?gl_bs_related_engineer) ^ Has_Evaluator(Specific GL-Business Service, ?gl_bs_related_evaluator) ^ Has_Builder(Specific GL-Business Service, ?gl_bs_related_builder) ^ Has_Tester(Specific GL-Business Service, ?gl_bs_related_tester) ^ Has_Releaser(Specific GL-Business Service, ?gl_bs_related_releaser) ^ Has_Deployer(Specific GL-Business Service, ?gl_bs_related_deployer) -> sqwrl:select(Specific GL-Business Service, ?gl_bs_related_owner, ?gl_bs_related_manager, ?gl_bs_related_engineer, ?gl_bs_related_evaluator, ?gl_bs_related_builder, ?gl_bs_related_tester, ?gl_bs_related_releaser, ?gl_bs_related_deployer)
GL-BS-03: For a specific GL-BS, retrieve its related supporting GL BPA-Model-Segment, BPA-Model, and BPA.
GL_Business_Service(Specific GL-Business Service) ^ GL_BPA_Model_Segment(?related_bpa_mSegment) ^ GL_BPA_Model(?related_bpa_model) ^ GL_BPA(?related_bpa) ^ Has_Related_GL_BPAMSegment(Specific GL-Business Service, ?related_bpa_mSegment) ^ BPAMSegment_IsPartOf_BPAModel(?related_mSegment, ?related_bpa_model) ^ BPAModel_IsPartOf_BPA(?related_bpa_model, ?related_bpa) -> sqwrl:selectDistinct (Specific GL-Business Service, ?related_bpa_mSegment, ?related_bpa_model, ?related_bpa)

7.3 Fourth-DSRM-Increment's Second Stage: Demonstration of the OntoSoS.BPA.ChM Framework Based on the Alignment and Knowledge Retrieval Component

During this stage, the artefacts developed in the previous phases were instantiated and demonstrated. Three sub-stages of instantiation were conducted during the demonstration stage; (i) instantiating the developed artefacts related to the ChM component; (ii) instantiating the developed artefacts related to the SoS context view component; and (iii) instantiating the knowledge retrieval capabilities.

7.3.1 Demonstrating the ChM Component Related Developed Artefacts

This sub-stage considered the instantiation and demonstration of artefacts developed in the previous phases and are related to the ChM component. Table 7.14 presents an overview of the ChM aspects instantiated in this stage.

Table 7. 14: Overview of the conducted demonstration activities related to the ChM component.

#	Considered Demonstration Activity	Brief Description
1	**Demonstrating the ChM stages, decision gates and their interrelationships**	▪ The developed ChM stages flow conceptual meta-model (presented in Figure 7.3) was used to instantiate the ChM stages flow ontological meta-model (developed in Phase 3) with instances related to ChM stages, decision gates and their interrelationships (Figure 7.3).
2	**Demonstrating the linkages between the identified ChM stages and their related ChM processes**	▪ The linkages identified between the ChM stages' instances and their related ChM processes' instances (i.e. 'ChMStage_Entails_ AbstractChMProcesses' and 'AbstractChMProcess_Has_Encapsulating_ ChMStage') were instantiated.
3	**Demonstrating the dependency relationships identified for the Riva-driven ChM processes**	▪ The identified object properties related to support the semantic enrichment of the dependency relationships identified for ChM processes were instantiated based on the investigation conducted in Phase1-Sub-Phase 1.
4	**Demonstrating the ChM stages coverage of the CTAG-KHCC main ChM Phases**	▪ Demonstrating how the identified instances for the ChM stages cover real-world ChM main phases identified for the CTAG-KHCC ChM framework. ▪ The coverage check shows the key ChM phases appear in the CTAG-KHCC related ChM policies and procedures. In addition, it shows what ChM stages identified within the ChM framework component covers the CTAG-KHCC ChM phases.

Figures 7.7 and 7.8, and Table 7.15 show examples of the conducted demonstration activities.

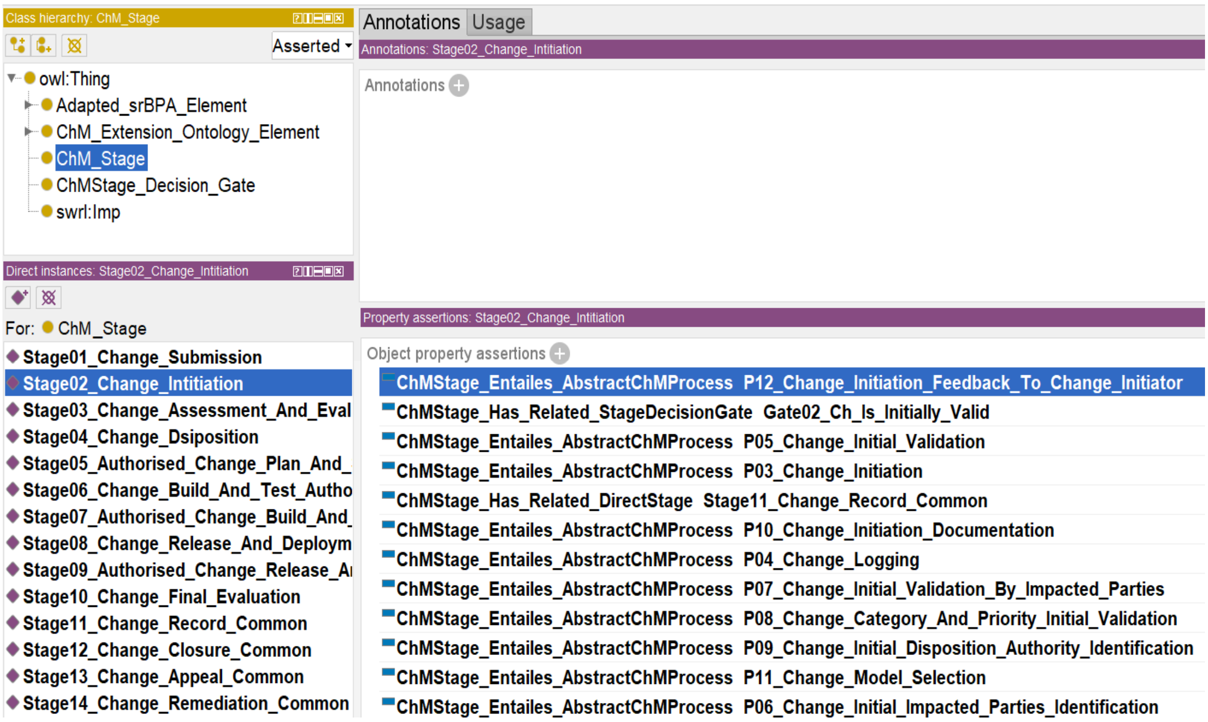


Figure 7. 7: An example of instantiating the ontological ChM stages meta-model.

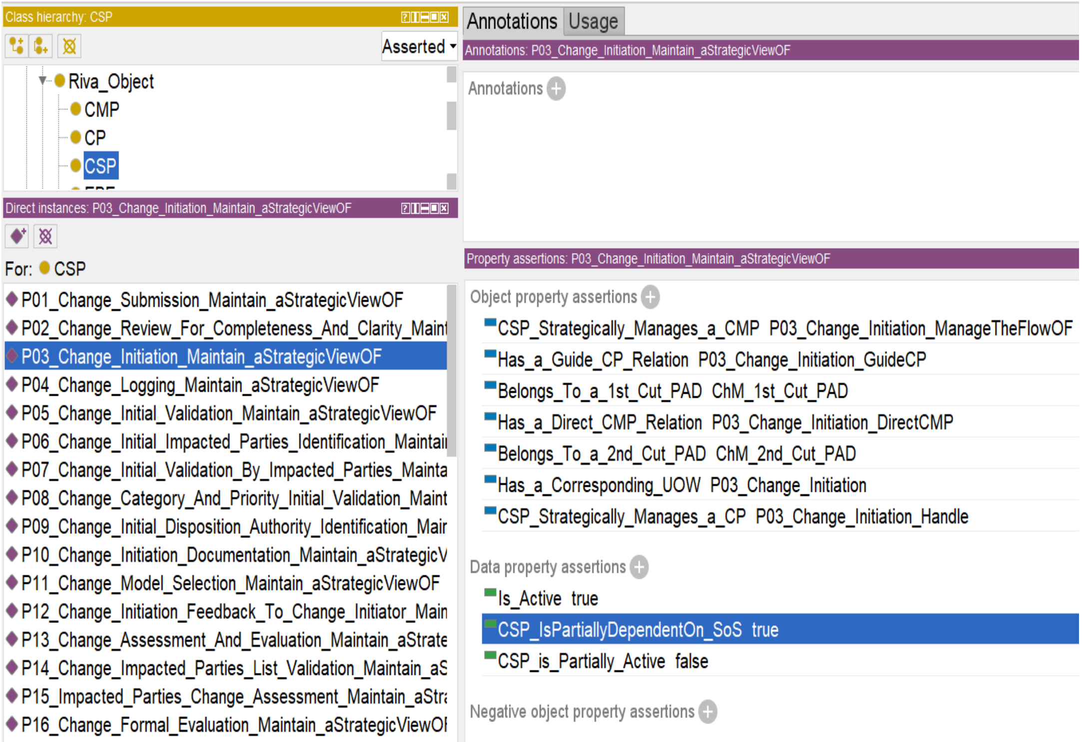


Figure 7. 8: An example of instantiating the dependency relationships for the BPA-driven ChM processes.

Table 7. 15: Demonstrating the coverage of the CTAG-KHCC ChM main phases by the identified ChM stages.

KHCC-ChM Key Phase	Corresponding ChM Stage
Change Initiation	Stage01-Change Submission
Document Change Details	Stage02-Change Initiation
Impact Analysis	Stage03-Change Assessment and Evaluation
Approval	Stage04-Change Disposition
Test/Monitoring	Stage07-Authorised Change Build and Test
Validation	Stage10-Change Final Evaluation

As can be noticed from Table 7.15, the CTAG-KHCC identified six main ChM phases to be considered for the application of their ChM framework. Whereas the ChM component proposes 14 main ChM stages to be considered for the ChM application. Reviewing the proposed ChM stages with domain experts at the CTAG-KHCC, the ChM component was found more comprehensive than the existing adopted CTAG-KHCC ChM framework. Also, it was realised that the identified ChM stages are usable and applicable to real-world settings. However, further investigation using more case studies is suggested to support such a conclusion.

7.3.2 Demonstrating the SoS Context View Component Related Developed Artefacts

In Phase1-Sub-Phase 4, ChM-driven roles were identified to enrich the SoS context component with knowledge about the stakeholders that are related to the identified SoS main CIs. Accordingly, in Phase4.2-Sub-Phase 1, the SoS context view meta-model was updated with ontological elements that support the semantic enrichment of the ChM-driven roles and their linkages to the main SoS CIs. This demonstration sub-stage focused on instantiating the CTAG-KHCC SoS context view ontological model with the related ChM-driven roles instances.

Having investigated the SoS context view elements (e.g. business services, BPAs and BPMs) within the CTAG-KHCC context, the only ChM-driven roles that were found formally and explicitly defined are the CI-Owners and Managers. Therefore, artificial data were used in order to instantiate the ChM-driven roles for the main CTAG-KHCC SoS elements. Figures 7.9 shows an example of the instantiated ChM-driven roles.

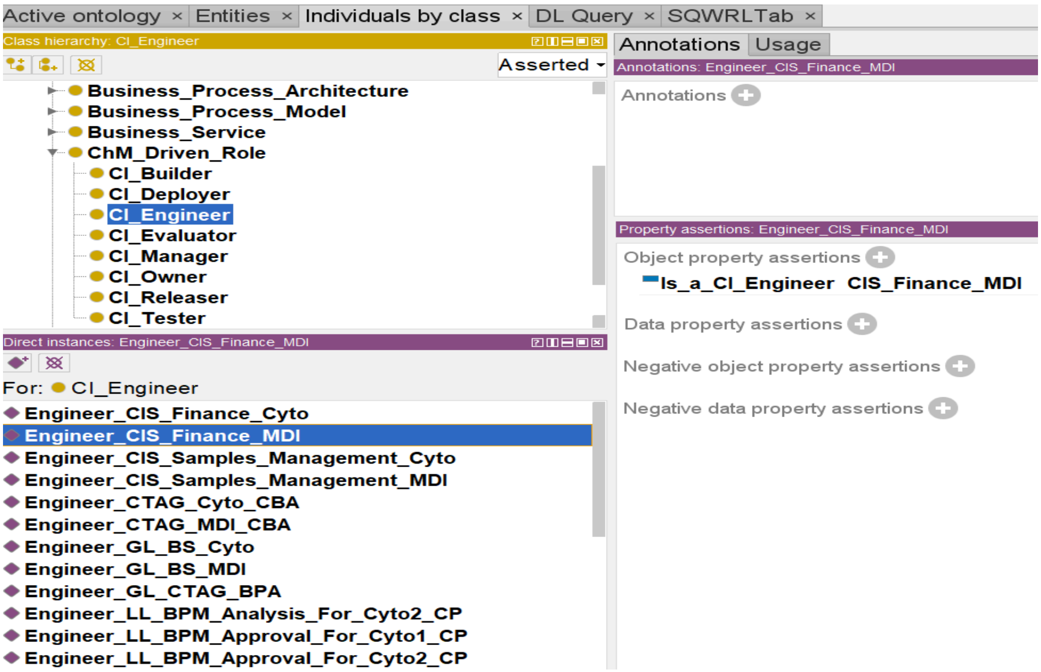


Figure 7. 9: An example of instantiating ChM-driven roles for the CTAG-KHCC SoS component.

7.3.3 Demonstrating the Algorithmic and SQWRL-based Knowledge Retrieval Capabilities

In Phase 4.1-Sub-Phase 4 and Phase 4.2-Sub-Phase 3 algorithmic and SQWRL-based capabilities were developed to retrieve knowledge about the ChM aspects from the ChM component and about change related implications and stakeholders from the SoS component. In this phase, competency questions-based test cases (Gruninger and Fox, 1995). were used to demonstrate the ability of the developed knowledge retrieval capabilities in retrieving knowledge from the ChM and SoS framework components for the CTAG-KHCC SoS arrangement.

7.3.3.1 Demonstrating the Knowledge Retrieval Capabilities Based on Using the ChM Framework Component

A number of query-based capabilities to retrieve knowledge about ChM aspects were pre-defined and categorised into three categories. These categories can be used by the ChM stakeholders to identify the kind of knowledge they are able to retrieve from the ChM component, and which knowledge retrieval capabilities to use. The three identified main query-based capabilities categories were:

1) Queries to retrieve knowledge about the ChM stages in general.
2) Queries to retrieve knowledge about a specific ChM stage.
3) Queries to retrieve knowledge about a specific ChM process.

Driven by these identified categories, competency question-based test cases were used to demonstrate (in this stage) and evaluate (in the next stage) the use of the knowledge retrieval capabilities based on utilising the ChM framework component. Tables 7.16 presents examples of the used test cases. Further examples can be found in Appendix K.

Table 7. 16: Part of the competency questions-based test cases for the demonstration of the ChM knowledge retrieval capabilities.

ChM Competency Questions-Based Test Cases – Category 2		
CQ18: For the 'Change Initiation Stage", what are the entailed abstract ChM processes?		
Expected Output		**Retrieved?**
Main ChM Stage	**Entailed Abstract ChM Process**	✓
Stage02_Change_ Initiation	P03_Change_Initiation	✓
Stage02_Change_ Initiation	P04_Change_Logging	✓
Stage02_Change_ Initiation	P05_Change_Initial_Validation	✓
Stage02_Change_ Initiation	P06_Change_Initial_ Impacted_Paries_Identification	✓
Stage02_Change_ Initiation	P07_Change_Initial_Validation_ By_Impacted_Parites	✓
Stage02_Change_ Initiation	P08_Change_Category_And_ Priority_Initial_Validation	✓
Stage02_Change_ Initiation	P09_Change_Initial_Disposition_ Authority_Identification	✓
Stage02_Change_ Initiation	P10_Change_Initiation_ Documentation	✓
Stage02_Change_ Initiation	P11_Change_Model_Selection	✓
Stage02_Change_ Initiation	P12_Change_Initation_ Feedback_To_Change_Initiator	✓

ChM Competency Questions-Based Test Cases – Category 3		
CQ36: For the abstract ChM process 'P01_Change_Request_Submission', what are its related detected Terminologies?		
Expected Output		**Retrieved?**
ChM Process	**Detect Terminology**	✓
P01_Change_Request_Submission	Change Request (INCOSE 2015; BS EN 9223-104:2018; IEEE 828:2012)	✓
P01_Change_Request_Submission	Change Request Preparation and Submission (CCRM Guide 2012)	✓
P01_Change_Request_Submission	Request For Change (EIA-649B, 2011; IEEE std. 15288:2015)	✓
P01_Change_Request_Submission	Change Proposal (BS ISO 10007:2017; JSP 886:2015)	✓
P01_Change_Request_Submission	Request For Change Submission (ITIL, 2011; SCM Handbook, 2015)	✓
P01_Change_Request_Submission	Engineering Change Proposal Submission (MIL0STD-3046:2013)	✓

7.3.3.2 Demonstrating the Knowledge Retrieval Capabilities based on using the SoS framework component

A number of query-based capabilities to retrieve knowledge about change related candidate implications and stakeholders needed for ChM processes application based on the identified ChM types and their related traceability routes were pre-defined and categorised into 13 categories. These categories can be used by the ChM stakeholders to identify the kind of knowledge they are able to retrieve from the SoS component and which knowledge retrieval capabilities to use. The 13 identified main query-based capabilities categories were:

1) Queries to retrieve knowledge related to a specific GL-Business Service.
2) Queries to retrieve knowledge related to a specific GL-Business Process.
3) Queries to retrieve knowledge related to a specific GL-UOW.
4) Queries to retrieve knowledge related to a specific GL-Generate Relation.
5) Queries to retrieve knowledge related to a specific Constituent Business Area.
6) Queries to retrieve knowledge related to a specific LL-Business Service.
7) Queries to retrieve knowledge related to a specific LL-Business Process.
8) Queries to retrieve knowledge related to a specific LL-UOW.
9) Queries to retrieve knowledge related to a specific LL-Generate Relation.
10) Queries to retrieve knowledge related to a specific LL-BPM-Task.
11) Queries to retrieve knowledge related to a specific LL-BPM-Pool.
12) Queries to retrieve knowledge related to a specific LL-SW-Service.
13) Queries to retrieve knowledge related to a specific LL-Constituent Information System.

Driven by these identified categories, competency questions-based test cases were used to demonstrate (in this stage) and evaluate (in the next stage) the use of the knowledge retrieval capabilities based on utilising the SoS framework component. Figure 7.10 presents a filled change type form that is used to identify the traceability starting point (i.e. 'GL_Analysis_For_Cyto2_CP'). Based on that, the related knowledge retrieval category (i.e. Queries to retrieve knowledge about a specific GL-Business Process) was identified. Furthermore, Table 7.17 presents examples of the used competency questions-based test cases to demonstrate the used knowledge retrieval capabilities. Further examples can be found in Appendix L.

Change Type Form (CTF)

Related Change Request ID:	(0000)
Change Type Form Submitter:	Dr Abdelghani Tbakhi
Validity Check Date and Time:	03-11-2019, 9:30 am

Change Level	**SoS Global Level**
Change Main Type	**A GL-Business Process Related Change**
Element Name	**GL_Analisis_For_Cyto2_CP**

Figure 7. 10: An Example of using a change type form.

Table 7. 17: Part of the competency questions-based test cases for the demonstration of the SoS knowledge retrieval capabilities, GL-BP category.

Retrieving Knowledge About A Specific GL-Business Process Test Case			
CQ1: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related Name_ID_Version, GL-BPA-Model-Segment, GL-BPA-Model, GL-BPA, GL-Business Area and LL-Business Area?			
Elements	Instance	Retrieved?	
		Yes	No
GL-BP Related Name_ID_Version	Analysis_For_Cyto2_CP_01.00	✓	
GL-BP Related GL-BPA-Model –Segments	GL_MSegment_Cyto	✓	
GL-BP Related GL-BPA-Models	GL_CTAG_2nd_Cut_PAD	✓	
GL-BP Related GL-BPA	GL_CTAG_BPA	✓	
GL-BP Related GL-Business Area	CTAG_GL_Busines_Area	✓	
GL-BP Related LL-Business Area	CTAG_LL_Business_Area	✓	
GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'			
CQ17: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Business Process and its related LL-Business Process Model? In addition, what are the BPMN-based Task, Gates, and Events that are related to the identified LL-Business Process Model?			
Elements	Instance	Retrieved?	
		Yes	No
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP	✓	
LL-BP Related LL-BPM	LL_BPM_Analysis_for_Cyto2_CP	✓	
LL-BPM-Graphical Elements	MT_LogInIntoLogSheet_Cyto2 UT_DoRequestedAnalysis_Cyto2 UT_ReviewTheSlidesByAnotherCytoTechnologist_Cyto2 MT_EnsureSpecimentIDAndIntegrity_Cyto2 ST_SendPaperReportToPatholgistForThirdReview_Cyto2 ST_SendRequestedAnalysisForProcessingToTechnologist_Cyto2 ST_SendApprovedReportToMedicalDirectorForApproval_Cyto2 UT_PrepareTheSlides_Cyto2 RT_ReceiveAnalysisRequestByCytoTechnologist_Cyto2 UT_ScanApprovedReportToVistaCPRS_Cyto2 RT_ReceiveApprovalFromPathologistByCytoTech_Cyto2 ST_InformMainPhysicianDirectlyAboutRejection_Cyto2 MT_GenerateReportByCytoTechnologist_Cyto2	✓	
GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'			
CQ20: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are Constituent Information Systems that support the identified LL-SW-Services alongside their related ChM-driven Roles?			
Elements	Instance	Retrieved?	
		Yes	No
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2	✓	
LL-SW-Services-Related Constituent Information Systems (CISs)	CIS_Samples_Management_Cyto	✓	
LL-CIs-Owners	CIS_Samples_Management_Cyto_Owner	✓	
LL-CIs-Managers	CIS_Samples_Management_Cyto_Manager	✓	
LL-CIs-Engineers	CIS_Samples_Management_Cyto_Engineer	✓	
LL-CIs-Evaluators	CIS_Samples_Management_Cyto_Evaluator	✓	
LL-CIs-Builders	CIS_Samples_Management_Cyto	✓	
LL- CIs-Testers	CIS_Samples_Management_Cyto	✓	
LL-CIs-Releasers	CIS_Samples_Management_Cyto	✓	
LL-CIs-Deployers	CIS_Samples_Management_Cyto	✓	

7.4 Fourth-DSRM-Increment's Third Stage: Evaluation of the OntoSoS.BPA.ChM Framework Based on the Alignment and Knowledge Retrieval Component

In this chapter, the increment development of the OntoSoS.BPA.ChM framework by developing the alignment and knowledge retrieval component led to updating the ChM and SoS components. In addition, algorithmic and SQWRL-based capabilities were developed to derive and retrieve knowledge from the updated ChM and SoS components, where such knowledge is used to enrich the awareness of ChM stakeholders generally and especially the ones that operate in a SoS context.

In this DSRM stage, the artefacts developed during the previous phases were verified and validated. After that, aspects related to the effectiveness of the OntoSoS.BPA.ChM framework were assessed.

7.4.1 The Evaluation Roadmap

Table 7.18 presents the parts of the evaluation framework (discussed in **Chapter 3**) adopted for the intended evaluation of the developed artefacts. The table presents an abstract description of the objectives of the evaluation and lists the adopted evaluation types, criteria and approaches, which are discussed more thoroughly in the following sections.

Table 7. 18: Parts of the evaluation framework adopted for the evaluation stage of the fourth-DSRM- increment.

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="6">(Fourth-DSRM-Increment)
(Part-1)

Evaluating the developed ChM stages flow ontological model, the dependency relationships for the BPA-driven ChM Processes and the linkages identified between the newly developed ChM stages and the BPA-driven ChM processes, which were driven by the development of the alignment and knowledge retrieval component:

(1) To inform the adherence of the developed semantically-enriched ChM elements to the ontology-based representation using OWL-specifications.

(2) To further verify the correctness of the newly developed semantically-enriched ChM elements by checking their completeness and redundancy.

(3) To inform the validity of the newly developed semantically-enriched meta-models in representing the identified ChM instances.</td><td colspan="2">Verification</td><td></td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td>Completeness</td><td>Redundancy</td><td>Checklist-based Walkthroughs (By the researcher)</td></tr>
<tr><td colspan="2">Validation</td><td></td></tr>
<tr><td>Correctness</td><td>Completeness</td><td>Checklist-based Walkthroughs (By the researcher or by domain experts)</td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="6">(Fourth-DSRM-Increment)
(Part-2)

Evaluating the developed ChM-driven roles which were driven by the development of the alignment and knowledge retrieval component:

(1) To inform the adherence of the developed semantically-enriched ChM-driven roles elements to the ontology-based representation using OWL-specifications.

(2) To further verify the correctness of the newly developed semantically-enriched ChM-driven roles elements by checking their completeness and redundancy.

(3) To inform the validity of the newly developed semantically-enriched ChM-driven roles elements in representing the identified ChM Roles instances.</td><td colspan="2">Verification</td><td></td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td>Completeness</td><td>Redundancy</td><td>Checklist-based Walkthroughs (By the researcher)</td></tr>
<tr><td colspan="2">Validation</td><td></td></tr>
<tr><td>Correctness</td><td>Completeness</td><td>Checklist-based Walkthroughs (By the researcher or by domain experts)</td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
</table>

Table 7.18: Parts of the evaluation framework adopted for the evaluation stage of the fourth-DSRM-increment, "Continued".

<table>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="6">(Fourth-DSRM-Increment)
(Part-3)

Evaluating the developed algorithmic and SQWRL –based knowledge retrieval capabilities:

(1) To inform the adherence of the developed SQWRL-based capabilities to the ontology-based representation using OWL and SQWRL specifications.

(2) To further verify the correctness of the developed algorithms and their supporting SQWRL-based capabilities by checking their completeness.

(3) To inform the validity of the developed algorithms and their supporting SQWRL-based capabilities.</td><td colspan="2">Verification</td><td></td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><td colspan="2">Completeness</td><td>Checklist-based Walkthroughs
(By the researcher)</td></tr>
<tr><td colspan="2">Validation</td><td></td></tr>
<tr><td>Correctness</td><td>Completeness</td><td>Checklist-based Walkthroughs
(By the researcher with support of domain experts)</td></tr>
<tr><td colspan="2">Consistency</td><td>Protégé Reasoner</td></tr>
<tr><th>Objective of Evaluation</th><th colspan="2">Type and Criteria of Evaluation</th><th>Evaluation Technique</th></tr>
<tr><td rowspan="4">(Fourth-DSRM-Increment)
(Part-4)

Evaluating the Effectiveness of the overall OntoSoS.BPA.ChM Framework:

(1) To inform the appropriateness and novelty of the OntoSoS.BPA.ChM Framework.

(2) To inform the induced improvements of using the OntoSoS.BPA.ChM Framework in real-world settings.</td><td colspan="2">Effectiveness</td><td></td></tr>
<tr><td colspan="2">Fulfilment of the research framework functional characteristics</td><td>A Checklist-based Walkthrough
By the researcher</td></tr>
<tr><td colspan="2">Novelty</td><td rowspan="2">A Checklist-based Walkthrough supported by a Semi-structured Interview
(By the researcher with the support of domain experts)</td></tr>
<tr><td colspan="2">Usefulness</td></tr>
</table>

7.4.2 The Evaluation of the Newly-Developed ChM Elements and Their Integration into the ChM Framework Component

To support the development of the alignment and knowledge retrieval component, further ChM ontological elements were designed, developed, instantiated and added to the ChM component, i.e. ChM stages, their related flow and decision gates, ChM processes dependency relationships and the linkages between the identified ChM stages and related BPA-driven ChM processes. This stage of evaluation focused on the verification and validation of these developed elements and their integration into the ChM component.

7.4.2.1 The Verification of the ChM Framework Component Related Artefacts

In this category of evaluation, the correctness of the developed ChM elements and their integration into the ChM component were verified before their instantiation. This was done by checking their consistency, completeness and redundancy. Table 7.19 provides a description of these criteria as adopted by the research.

Table 7. 19: The adopted verification criteria to verify the newly-developed ChM component related elements.

Verification Criteria	Description
Consistency	▪ The semantic enrichment of the newly developed ChM elements (i.e. the ChM stages, their flow and related decision gates, the dependency relationships of the BPA-driven ChM processes on the SoS context and the Linkages between the ChM stages and their related BPA-driven ChM processes) adhere to the rules and syntax of the OWL-specifications used to create it (i.e. no contradictory items or constrains are detected or inferred).
Completeness	▪ The updated ChM meta-model represents all the newly identified ChM elements.
Redundancy	▪ Each construct of the newly semantically enriched ChM elements contributes knowledge to the ChM meta-model.

Accordingly, Table 7.20 presents the used techniques for verification, linked to the verification criteria. The table also provides a brief description of the used verification techniques.

Table 7. 20: The adopted verification techniques for the evaluation of the newly developed ChM elements and their integration into the ChM framework component.

Verification Criteria	Verification Technique	Brief Description
Consistency	Protégé Reasoner	▪ Checking the consistency of the semantically-enriched ChM constructs and their relationships within the ChM ontology can be done using a reasoner that supports an ontology development tool. For this research, the Protégé reasoner -i.e. Pellet – was used to check the consistency of the integrated BPA-driven meta-model for ChM after it was updated with the newly identified ChM constructs and relationships. ▪ If no consistency is detected by the Protégé reasoner it could be realised that the ontology-based meta-model is consistent. ▪ This check was carried out by running the Protégé reasoner.
Completeness	Checklist-based Walkthroughs	▪ The semantically-enriched ChM component should represent the concepts and relations that appear in the proposed ChM stages flow conceptual model (represented in Figure 7.3). Accordingly, a checklist was designed and used to check if all the elements of the conceptual meta-model were represented by the ChM framework. ▪ Further checklists were used to inspect that all of the dependency relations identified for the BPA-driven ChM processes (discussed in Section 7.2.1) in addition to the linkages identified between the developed ChM stages and their related BPA-driven ChM processes (discussed in 7.2.4) were represented in the semantically-enriched ChM component. ▪ These checklists were carried out by the researcher.
Redundancy	Checklist-based Walkthroughs	▪ The checklists were also used to check that each of the newly identified ChM constructs contributes knowledge to the semantically-enriched ChM component (i.e. to check that there is no redundant knowledge provided by the newly semantically enriched ChM elements). ▪ These checks were carried out by the researcher.

Figure 7.5 and Tables 7.21 and 7.22 show examples of the conducted verification aspects.

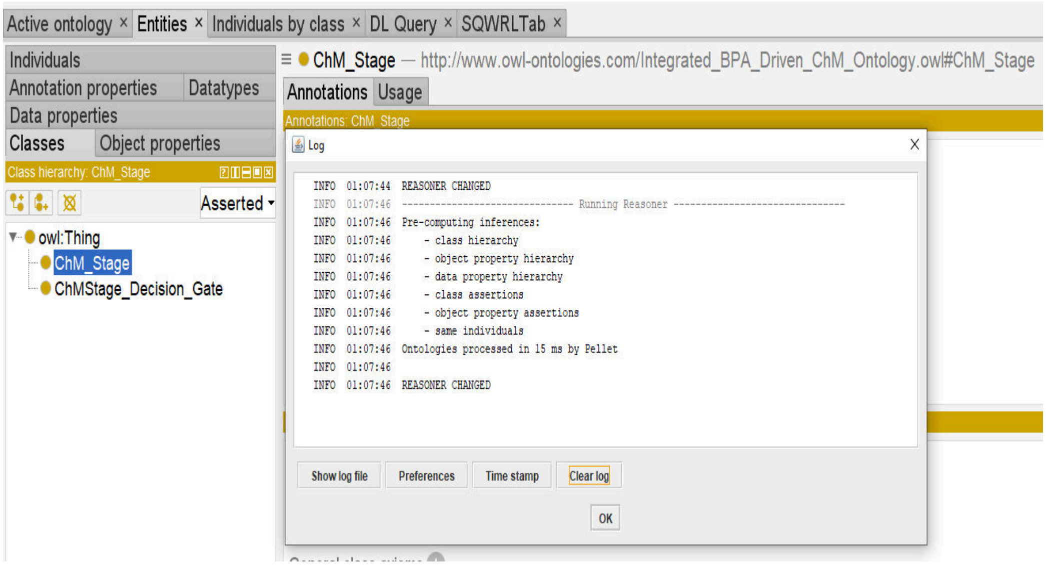


Figure 7. 11: An example of running the Protégé Reasoner to check the consistency of the ChM stages meta-model.

Table 7. 21: Part of the checklist-based walkthrough to check the correctness, completeness and redundancy of the developed ChM stages flow meta-model.

ChM Stages Conceptual Model Aspect	Representing ChM Stages Flow Ontology Element	Represented? (Correctness, Completeness)		Redundant?		Remarks
		Yes	No	Yes	No	
ChM Stage	ChM_Stage : Construct	✓			✓	
ChM Decision Gate	ChMStage_Decision_Gate : Construct	✓			✓	
A relationship between a ChM Stage and a Decision Gate connected to it	ChMSatge_Has_Related_StageDecisionGate : Object Property	✓			✓	
A relationship between a ChM Stage and other ChM Stage directly connected to it	ChMStage_Has_Related_DirectStage : Object Property	✓			✓	
A relationship between a Decision Gate and a ChM Stage that is connected to it as a result of positive check	Next_Stage_IF_Positive : Object Property	✓			✓	
A relationship between a Decision Gate and a ChM Stage that is connected to it as a result of negative check	Next_Stage_IF_Negative : Object Property	✓			✓	
The inverse of the relationship between a ChM stage and its related ChM Decision Gate	StageGate_Has_Related_ChMStage : Object Property	✓			✓	An inverse object property to make the relation explicit

Table 7. 22: Part of the checklist-based walkthrough to check the correctness, completeness and redundancy of the developed ChM dependency relationships related ontological elements.

Dependency Relationship	Representing Ontology Element	Represented? (Correctness, Completeness)		Redundant?		Remarks
		Yes	No	Yes	No	
Dependency Relationship related to the ChM Case Process	CP_IsDependentOn_SoS : Data Property [Boolean]	✓			✓	
Dependency Relationship related to the ChM Case Management Process	CMP_IsDependentOn_SoS : Data Property [Boolean]	✓			✓	
Dependency Relationship related to the ChM Case Strategy Process	CSP_IsPartiallyDependentOn_SoS : Data Property [Boolean]	✓			✓	

Having conducted the verification for the developed ChM ontological aspects, the Protégé reasoner detected no inconsistencies. All the identified elements were represented. However, redundancy was only found for the used inverse object properties. Although there is a form of redundancy detected here, keeping the use of these specific properties makes knowledge more specific and explicit.

7.4.2.2 The Validation of the ChM Framework component Related Artefacts

In this category of evaluation, the correctness of the conceptual ChM flowchart elements (Figure 7.3) was validated. After that, the correctness, completeness and consistency of the ChM ontological elements developed in this chapter were assessed after instantiation (resulting from conducting the demonstration stage). Table 7.23 provides a description of these criteria as adopted by the research.

Table 7. 23: The adopted validation criteria for the evaluation of the newly-developed ChM elements and their integration into the ChM framework component.

Validation Criteria	Description
Correctness	▪ The elements captured in the developed ChM stages conceptual flowchart are correct from a ChM point of view. ▪ The instances of the newly-identified ChM constructs and relationships are correctly represented in the integrated BPA-driven ontology for ChM.
Completeness	▪ All the instances captured for the newly-identified ChM constructs and relationships are represented in the integrated BPA-driven ontology for ChM.
Consistency	▪ After instantiation, no contradictory items are detected in the integrated BPA-driven ontology for ChM.

Accordingly, Table 7.24 lists the used validation techniques, linked to the adopted validation criteria. The table also provides a brief description of the used validation techniques.

Table 7. 24: The adopted validation techniques for the evaluation of the newly-developed ChM elements and their integration into the ChM framework component.

Validation Criteria	Validation Technique	Brief Description
Correctness	Checklist- based Walkthroughs	▪ A Checklist was designed and used to check that the identified elements in the modelled ChM stages conceptual flowchart were correct from a ChM point of view ▪ This check was carried out by domain experts.
		▪ Checklists were designed and used to check that the ChM instances identified for the newly developed and semantically-enriched ChM constructs and relationships were correctly represented within the semantically-enriched ChM component. ▪ These checks were carried out by the researcher.
Completeness	Checklist- based Walkthroughs	▪ The Checklists were also used to check that all the ChM instances identified for the newly-developed and semantically-enriched ChM constructs and relationships were correctly represented within the semantically-enriched ChM component. ▪ These checks were carried out by the researcher.
Consistency	Protégé Reasoner	▪ The Protégé reasoner (i.e. Pellet) was used to check that after instantiating the newly-developed and semantically-enriched ChM constructs and relationships, no contradictory items were detected. ▪ This check was carried out by running the Protégé reasoner.

Tables 7.25 to 7.27 show examples of the conducted validation aspects.

Table 7. 25: Part of the checklist-based walkthrough conducted for the validation of the developed ChM stages conceptual flowchart elements.

#	ChM Stages Conceptual Model Element	Correct?		Remarks
		Yes	No	
1	ChM Stage			
2	01-Change Submission	✓		
3	02-Change Initiation	✓		
4	03-Change Assessment and Evaluation	✓		
5	04-Change Disposition	✓		
6	05-Authorised Change Plan and Schedule	✓		
7	06-Change Build and Test Authorisation	✓		
8	07-Authorised Change Build and Test	✓		
9	08-Change Release and Deployment Authorisation	✓		
10	09-Authorised Change Release and Deployment	✓		
11	10-Change Final Evaluation	✓		
12	11- Change Record-Common	✓		
13	12-Change Closure-Common	✓		
14	13-Change Appeal-Common	✓		
15	14-Change Remediation-Common	✓		
16	ChM Stage Decision Gate			
17	Gat01-Change Is Complete and Clear	✓		
18	Gate02-Change Is Initially Valid	✓		

Table 7. 26: Part of the checklist-based walkthrough conducted for the validation of the instantiated ontological elements related to the ChM processes dependency relationships.

ID	Riva-based ChM Unit of Work (UOW)	Related Case Process (CP)	Related Case Management Process (CMP)	Related Case Strategy Process (CSP)	Correctly Represented?		Completely Represented?	
					Yes	No	Yes	No
1	Change Request (CR) Submission	No	No	No	✓		✓	
2	Change Request Review for Completeness and Clarity	No	No	No	✓		✓	
3	Change Initiation	Yes	No	Yes	✓		✓	
4	Change Logging	No	No	No	✓		✓	
5	Change Initial Validation	Yes	No	Yes	✓		✓	
6	Initial Impacted Parties Identification	Yes	No	Yes	✓		✓	
7	Change Initial Validation	Yes	No	Yes	✓		✓	

Table 7. 27: Part of the checklist-based walkthrough conducted for the validation of the instantiated ontological elements related to the linkages between the ChM stages and ChM processes.

#	ChM Stages	Related BPA-driven ChM Process	The Relations Are Correctly Represented?		The Relations Are Completely Represented?		Remarks
			Yes	No	Yes	No	
1	Change Submission	P01	✓		✓		
		P02	✓		✓		
2	Change Initiation	P03	✓		✓		
		P04	✓		✓		
		P05	✓		✓		
		P06	✓		✓		
		P07	✓		✓		
		P08	✓		✓		
		P09	✓		✓		

Having conducted the validation, the developed ChM stages conceptual flow chart was found valid from a ChM point of view. In addition, all the identified ChM instances were found correctly and completely represented. Moreover, after instantiation, the reasoner detected no inconsistencies.

7.4.3 The Evaluation of the Newly-Developed SoS Elements and Their Integration into the SoS Component

This stage of evaluation focused on the verification and validation of the newly-developed SoS-CIs related ChM-driven roles and their integration into the SoS context view framework component.

7.4.3.1 The Verification of the SoS Framework Component Related Artefacts

In this category of evaluation, the correctness of the newly developed SoS-CIs related ChM-driven roles and their integration into the SoS component were verified before their instantiation. This was done by checking their consistency, completeness and redundancy. Table 7.28 provides a description of these criteria as adopted by the research.

Table 7. 28: The adopted verification criteria for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component.

Verification Criteria	Description
Consistency	▪ The ontological elements developed to support the semantic enrichment of the identified ChM-driven roles and their linkages to the SoS main elements adhere to the rules and syntax of the OWL-specifications used to create it (i.e. no contradictory items or constrains are detected or inferred).
Completeness	▪ The updated abstract SoS context view ontological meta-model represents all the constructs and object properties related to the ChM-driven roles and the linkages to their related SoS elements.
Redundancy	▪ Each construct of the identified semantically-enriched ChM-driven roles contributes knowledge to the SoS meta-model.

Accordingly, Table 7.29 presents the used techniques for verification, linked to the verification criteria. The table also provides a brief description of the used verification techniques.

Table 7. 29: The adopted verification techniques for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component.

Verification Criteria	Verification Technique	Brief Description
Consistency	Protégé Reasoner	▪ The Protégé reasoner -i.e. Pellet – was used to check the consistency of the integrated SoS context view meta-model after it was updated with the newly identified ChM-driven roles constructs and related relationships. ▪ This check was carried out by running the Protégé reasoner.

Table 7.29: The adopted verification techniques for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component, "Continued".

Verification Criteria	Verification Technique	Brief Description
Completeness	Checklist- based Walkthroughs	▪ The updated semantically-enriched SoS context view component should represent the ChM-driven roles constructs and their relationships to the main SoS elements (discussed in Section 7.2.4.2). Accordingly, a checklist was designed and used to check if all the ChM-driven roles related constructs and relationships were represented by the semantically-enriched SoS component. ▪ This check was carried out by the researcher.
Redundancy	Checklist- based Walkthroughs	▪ The checklist was also used to check that the semantically-enriched ChM-driven roles related constructs contributes knowledge to the semantically-enriched ChM component (i.e. to check that there is no redundant knowledge provided by the newly semantically-enriched elements). ▪ This check was carried out by the researcher.

Figure 7.12 and Table 7.30 show examples of the conducted verification aspects.

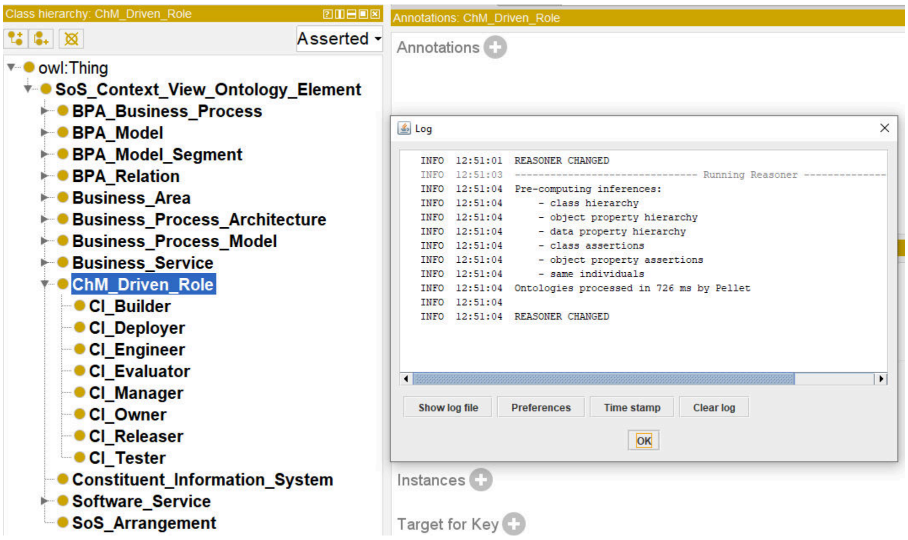


Figure 7. 12: An example of running the Protégé Reasoner to check the consistency of the ontological elements related to the ChM-driven roles.

Table 7. 30: Part of the checklist-based walkthrough conducted for the verification of the ontological elements related to the identified ChM-driven roles.

Proposed ChM-driven Role	Representing Ontological Element	Correctly & Completely Represented?		Redundant?		Remark
		Yes	No	Yes	No	
ChM-Driven Role	ChM_Driven_Role : Class	✓			✓	
CI Owner	CI_Owner : Sub-Class	✓			✓	
CI Manager	CI_Manager : Sub-Class	✓			✓	
CI Engineer	CI_Engineer : Sub-Class	✓			✓	
CI Evaluator	CI_Evaluator : Sub-Class	✓			✓	
CI Builder	CI_Builder : Sub-Class	✓			✓	
CI Tester	CI_Tester : Sub-Class	✓			✓	
CI Releaser	CI_Releaser : Sub-Class	✓			✓	
CI Deployer	CI_Deployer : Sub-Class	✓			✓	

Having conducted the verification for the ontological elements related to the ChM-driven roles, the reasoner detected no inconsistencies. All the identified ChM-driven roles and their linkages to related SoS elements were represented. However, redundancy was only found for the used inverse object properties. Although there is a form of redundancy detected here, keeping the use of these specific properties make knowledge more specific and explicit.

7.4.4.2 THE VALIDATION OF THE SOS FRAMEWORK COMPONENT RELATED ARTEFACTS

In this category of evaluation, the correctness of the identified SoS-CIs related ChM-driven roles was validated with domain experts. After that, the correctness, completeness and consistency of the ChM-driven roles instantiation (resulting from conducting the demonstration stage) were assessed. Table 7.31 provides a description of these criteria as adopted by the research.

Table 7. 31: The adopted validation criteria for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component.

Validation Criteria	Description
Correctness	▪ The identified ChM-driven roles are correct from a ChM point of view. ▪ The instances identified for the ChM-driven roles and their linkages to the main SoS elements are correctly represented in the integrated SoS context view ontology.
Completeness	▪ All the instances identified for the ChM-driven roles and their linkages to the main SoS elements are represented in the integrated SoS context view ontology.
Consistency	▪ After instantiation, no contradictory items are detected in the integrated SoS context view ontology.

Accordingly, Table 7.32 presents the used validation techniques, linked to the adopted validation criteria. The table also provides a brief description of the used validation techniques.

Table 7. 32: The adopted validation techniques for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component.

Validation Criteria	Validation Technique	Brief Description
Correctness	Checklist-based Walkthroughs	▪ A checklist was designed and used to validate the correctness of the identified ChM-driven roles from a ChM point of view. ▪ This check was carried out by domain experts.
		▪ A checklist was designed and used to check that the CTAG-KHCC instances identified for the newly-developed and semantically-enriched ChM-driven roles related constructs and relationships were correctly represented in the semantically-enriched CTAG-KHCC SoS component. ▪ This check was carried out by the researcher.
Completeness	Checklist-based Walkthroughs	▪ The checklist was also used to check that all of the CTAG-KHCC instances identified for the newly-developed and semantically-enriched ChM-driven roles related constructs and relationships were represented in the semantically-enriched CTAG-KHCC SoS component. ▪ This check was carried out by the researcher.
Consistency	Protégé Reasoner	▪ The Protégé reasoner (i.e. Pellet) was used to check that after instantiating the newly-developed and semantically-enriched CTAG-KHCC ChM-driven roles related constructs and relationships, no contradictory items were detected. ▪ This check was carried out by running the Protégé reasoner.

Table 7.33 shows an example of the conducted validation aspects.

Table 7. 33: Part of the checklist-based walkthrough for the evaluation of the newly-developed ChM-driven roles and their integration into the SoS framework component.

#	CTAG Configuration Item	ChM-driven Role	Check		Remarks
			Correctly Represented?	Completely Represented?	
1	LL_SwS_For_Specimen_Cyto1	CI_Owner	✓	✓	
		CI_Manager	✓	✓	
		CI_Engineer	✓	✓	
		CI_Evaluator	✓	✓	
		CI_Builder	✓	✓	
		CI_Tester	✓	✓	
		CI_Releaser	✓	✓	
		CI_Deployer	✓	✓	
2	LL_SwS_For_Sample_Rejection_FC3	CI_Owner	✓	✓	
		CI_Manager	✓	✓	
		CI_Engineer	✓	✓	
		CI_Evaluator	✓	✓	
		CI_Builder	✓	✓	
		CI_Tester	✓	✓	
		CI_Releaser	✓	✓	
		CI_Deployer	✓	✓	
3	LL_SwS_For_PreCollection_BMT	CI_Owner	✓	✓	
		CI_Manager	✓	✓	
		CI_Engineer	✓	✓	
		CI_Evaluator	✓	✓	
		CI_Builder	✓	✓	
		CI_Tester	✓	✓	
		CI_Releaser	✓	✓	
		CI_Deployer	✓	✓	

Having conducted the validation, the identified ChM-driven roles were found correct from a ChM point of view. Furthermore, all the identified instances for the CTAG-KHCC ChM-driven roles and their linkages to the related SoS elements were found correctly and completely represented. In addition, the reasoner detected no inconsistencies after instantiating the ChM-driven roles.

7.4.4 The Evaluation of the Algorithmic and SQWRL -based Knowledge Retrieval Capabilities

This stage of evaluation focused on the verification and validation of the developed knowledge retrieval algorithms and their supporting SQWRL-based capabilities.

7.4.4.1 The Verification of the Algorithmic and SQWRL-Based Knowledge Retrieval Capabilities

In this category of evaluation, the correctness of the developed algorithms and their supporting SQWRL-based capabilities were verified before their instantiation. This was done by checking their completeness and consistency. Table 7.34 provides a description of these criteria as adopted by the research.

Table 7. 34: The adopted verification criteria for the evaluation of the developed algorithmic and SQWRL-based capabilities.

Verification Criteria	Description
Completeness	▪ The developed knowledge retrieval algorithms and their supporting SQWRL-based capabilities cover all the identified ChM aspects in addition to the identified traceability routes of SoS candidate implications and related ChM-driven roles.
Consistency	▪ The developed Knowledge retrieval capabilities adhere to the rules and syntax of the SQWRL-specifications used to create it.

Accordingly, Table 7.35 presents the used techniques for verification, linked to the verification criteria. The table also provides a brief description of the used verification techniques.

Table 7. 35: The adopted verification techniques for the evaluation of the developed algorithmic and SQWRL-based capabilities.

Verification Criteria	Verification Technique	Brief Description
Completeness	Checklist-based Walkthroughs	▪ A checklist was designed and used to check that all the identified ChM aspects were covered by the designed algorithms. ▪ A checklist was designed and used to check that all the SoS elements identified in the traceability routes and the related ChM-driven roles were covered by the designed algorithms. ▪ The checklists were further used to check that the developed supporting SQWRL-based capabilities cover all the ChM related aspects, implications traceability routes and ChM-driven roles. ▪ These checks were carried out by the researcher.
Consistency	Rule-based Reasoner	▪ For each developed SQWRL-based capability, an OWL2-RL reasoner was used to check its adherence to the rules and syntax of the SQWRL-specifications used to create it. ▪ These checks were carried out by running the OWL-2-RL reasoner adopted in Protégé.

Tables 7.36 and 7.37 in addition to Figure 7.13 show examples of the conducted validation aspects.

Table 7. 36: Checklist-based walkthrough conducted for the verification of the knowledge retrieval capabilities related to the identified ChM aspects.

#	Represented ChM Aspect	Covered by The Designed Algorithms?		Covered by The Supporting SQWRL-based Capabilities?		Remark
		Yes	No	Yes	No	
1	The main ChM Stages	✓		✓		
2	ChM Stages that are directly related to a main ChM Stage	✓		✓		
3	ChM Decision Gates Related to a main ChM Stage	✓		✓		
4	Next ChM Stages If a Decision Gate is positive	✓		✓		
5	Next ChM Stages If a Decision Gate is negative	✓		✓		
6	Abstract ChM Processes entailed in a ChM Stage	✓		✓		
7	Outgoing Dynamic Relationships related to an Abstract ChM Process	✓		✓		
8	Rive-driven Case Process (CP) related to an Abstract ChM Process	✓		✓		
9	Rive-driven Case Management Processes (CMP) related to an Abstract ChM Process	✓		✓		
10	Rive-driven Case Strategy Processes (CSP) related to an Abstract ChM Process	✓		✓		
11	Unit Of Work related to an Abstract ChM Process	✓		✓		
12	Process Architecture Diagrams related to a CP, CMP or CSP	✓		✓		
13	Synonyms related to an Abstract ChM Process	✓		✓		
14	ChM Documents related to an Abstract ChM Process	✓		✓		
15	Synonyms related to a ChM Document	✓		✓		
16	ChM Roles related to an Abstract ChM Process	✓		✓		
17	Synonyms related to a ChM Role	✓		✓		
18	Is_Active value related to a CP, CMP or CSP	✓		✓		
19	Dependency Relationship Related to a CP, CMP or CSP	✓		✓		
20	Riva-driven Request Relations related to a CP alongside their Is_Active values, sources and destinations	✓		✓		
21	Riva-driven Start Relations related to a CP alongside their Is_Active values, sources and destinations	✓		✓		
22	Riva-driven Deliver Relations related to a CP alongside their Is_Active values, sources and destinations	✓		✓		
23	Riva-driven Start Relation related to a CMP alongside its Is_Active value, source and destination	✓		✓		
24	Riva-driven Guide_CP Relation related to a CSP alongside its Is_Active value, source and destination	✓		✓		
25	Riva-driven Direct_CMP Relation related to a CSP alongside its Is_Active value, source and destination	✓		✓		

Table 7. 37: Part of the checklist-based walkthrough conducted for the verification of the knowledge retrieval capabilities related to the identified SoS aspects.

#	Change Traceability Starting Point	Candidate Implications Traceability Route For Related Cis and ChM-driven Stakeholders Identification	Covered by The Designed Algorithms?		Covered by The Supporting SQWRL-based Capabilities?		Remark
			Yes	No	Yes	No	
1	GL-Business Service	Related ChM-driven Roles	✓		✓		
		Related GL-BPA Segment	✓		✓		
		Related GL-BPs	✓		✓		
		Related GL-Relations	✓		✓		
		Related GL-BPA and its related entailed elements	✓		✓		
		Related GL-BPA's ChM-driven Roles	✓		✓		
		Related GL-Business Area	✓		✓		
		Related LL-Business Area	✓		✓		
		Related Constituent Business Areas	✓		✓		
		Related Constituent Business Areas' ChM-driven Roles	✓		✓		
		Related LL-BPs	✓		✓		
		Related LL-BPA Segment	✓		✓		
		Related LL-Relations	✓		✓		
		Related LL-Business Services	✓		✓		
		Related LL-Business Services' ChM-driven Roles	✓		✓		
		Related LL-BPA and its related entailed elements	✓		✓		
		Related LL-BPA's ChM-driven Roles	✓		✓		
		Related LL-BPMs	✓		✓		
		Related LL-BPMs' ChM-driven Roles	✓		✓		
		Related LL-BPMs' Tasks	✓		✓		
		Related LL-BPMs' Users	✓		✓		
		Related LL-SW-Services	✓		✓		
		Related LL-SW-Services' ChM-driven Roles	✓		✓		
		Related LL-Constituent ISs	✓		✓		
		Related LL-Constituent ISs' ChM-driven Roles	✓		✓		

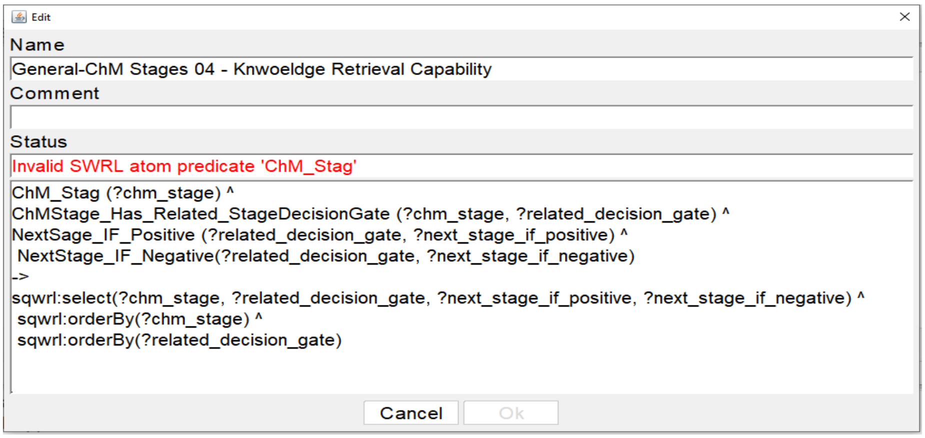


Figure 7. 13: An example of using the Rule-based Reasoner to check the consistency of the developed SQWRL-based capabilities.

Having conducted the verification for the developed knowledge retrieval capabilities, all the intended ChM and SoS aspects were found covered. In addition, each of the developed capabilities was found consistent with the used SQWRL-based specifications.

7.4.4.2 The Validation of the Knowledge Retrieval Capabilities

In this category of evaluation, the developed SQWRL–based knowledge retrieval capabilities were validated by checking its behavioural correctness and completeness. Table 7.38 provides a description of these criteria as adopted by the research.

Table 7. 38: The adopted validation criteria for the evaluation of the developed knowledge retrieval capabilities.

Validation Criteria	Description
Behavioural Correctness	▪ The anticipated ChM and SoS instances are correctly retrieved.
Behavioural Completeness	▪ All of the anticipated ChM and SoS instances are retrieved.

Accordingly, Table 7.39 presents the used techniques for validation, linked to the validation criteria. The table also provides a brief description of the used validation techniques.

Table 7. 39: The adopted validation techniques for the evaluation of the developed knowledge retrieval capabilities.

Validation Criteria	Validation Technique	Brief Description
Behavioural Correctness	Competency Questions and Checklist-based Walkthroughs	▪ Competency questions-based test cases alongside checklist-based walkthroughs were designed and used to check that the retrieved knowledge about the ChM and SoS instances were correct compared to the anticipated output. ▪ These checks were carried out by the researcher based on using the OWL2-RL reasoner within Protégé. ▪ Parts of the conducted checks were validated by domain experts at the CTAG-KHCC.
Behavioural Completeness	Competency Questions and Checklist-based Walkthroughs	▪ Competency questions-based test cases alongside checklist-based walkthroughs were designed and used to check that the retrieved knowledge about the ChM and SoS instances cover all the elements of the anticipated output. ▪ These checks were carried out by the researcher based on using the OWL2-RL reasoner within Protégé. ▪ Parts of the conducted checks were validated by domain experts at the CTAG-KHCC.

Tables 7.40 and 7.41 show examples of the conducted validation aspects.

Table 7. 40: Part of the conducted competency questions-based test cases for the validation of the knowledge retrieval capabilities related to the identified ChM aspects.

Retrieving Knowledge About General ChM Stages Test Case				
CQ4: What are the main ChM stages related to manage a normal change request, their related decision gates and the next ChM stages following the decision gates?				
Expected Output				**Retrieved?**
Main ChM Stage	**Related Decision Gate**	**Next Stage If Positive**	**Next Stage IF Negative**	✓
Stage01	Gate01	Stage02	Stage12	✓
Stage02	Gate02	Stage03	Stage12	✓
Stage03	Gate03	Stage04	Stage12	✓
Stage04	Gate04	Stage05	Stage12	✓
Stage05	No Decision Gate	N/A	N/A	✓
Stage06	Gate05	Stage06	Stage05	✓
Stage06	Gate05	Stage06	Stage12	✓
Stage07	No Decision Gate	N/A	N/A	✓
Stage08	Gate06	Stage09	Stage07	✓
Stage08	Gate06	Stage09	Stage12	✓
Stage08	Gate06	Stage09	Stage14	✓
Stage09	No Decision Gate	N/A	N/A	✓
Stage10	Gate07	Stage12	Stage07	✓
Stage10	Gate07	Stage12	Stage14	✓
Stage11	No Decision Gate	N/A	N/A	✓
Stage12	No Decision Gate	N/A	N/A	✓
Stage13	No Decision Gate	N/A	N/A	✓
Stage14	No Decision Gate	N/A	N/A	✓

Table 7. 41: Part of the conducted competency questions-based test cases for the validation of the knowledge retrieval capabilities related to the identified SoS aspects.

Retrieving Knowledge About A Specific GL-Business Process Test Case			
CQ1: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related Name_ID_Version, GL-BPA-Model-Segment, GL-BPA-Model, GL-BPA, GL-Business Area and LL-Business Area?			
Elements	Instance	Retrieved?	
		Yes	No
GL-BP Related Name_ID_Version	Analysis_For_Cyto2_CP_01.00	✓	
GL-BP Related GL-BPA-Model –Segments	GL_MSegment_Cyto	✓	
GL-BP Related GL-BPA-Models	GL_CTAG_2nd_Cut_PAD	✓	
GL-BP Related GL-BPA	GL_CTAG_BPA	✓	
GL-BP Related GL-Business Area	CTAG_GL_Busines_Area	✓	
GL-BP Related LL-Business Area	CTAG_LL_Business_Area	✓	

Retrieving Knowledge About A Specific GL-Business Process Test Case			
CQ6: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related Riva-based GL- Case Process (CP), Case Management Process (CMP), Case Strategy Process (CSP), Unit Of Work, and 1st-and-2nd-Cut Diagrams? In addition, what are the Is_Active Values related to the identified CP, CMP and CSP?			
Element	Instance	Retrieved?	
		Yes	No
GL-BP Related GL-CP	Analysis_for_Cyto2_Handle_GLBPA	✓	
GL-CP Is_Active Value	True	✓	
GL-BP Related GL-CMP	Analysis_for_Cyto2_ManageTheFlowOf_GLBPA	✓	
GL-CMP Is_Active Value	False	✓	
GL-BP Related GL-CSP	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA	✓	
GL-CSP Is_Active Value	False	✓	
GL-BP Related GL-UOW	Analysis_for_Cyto2_GLBPA	✓	
GL-BP Related GL-1st-Cut-PAD	CTAG_PA_1st_Cut_Diagram_1_GLBPA	✓	
GL-BP Related GL-2nd-Cut-PAD	CTAG_PA_2nd_Cut_Diagram_1_GLBPA	✓	

Retrieving Knowledge About A Specific GL-Business Process Test Case			
CQ22: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are the RPA-Clusters related to the identified LL-SW-Services and the RPA-Clusters encapsulated Capabilities?			
Element	Instance	Retrieved?	
		Yes	No
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2	✓	
SW-Service Related RPA-Clusters	C3_Cyto_Analysis	✓	
RPA-Clusters Related Capabilities	MT_LogInIntoLogSheet_Cyto2 UT_DoRequestedAnalysis_Cyto2 UT_ReviewTheSlidesByAnotherCytoTechnologist_Cyto2 MT_EnsureSpecimentIDAndIntegrity_Cyto2 ST_SendPaperReportToPatholgistForThirdReview_Cyto2 ST_SendRequestedAnalysisForProcessingToTechnologist_Cyto2 ST_SendApprovedReportToMedicalDirectorForApproval_Cyto2 UT_PrepareTheSlides_Cyto2 RT_ReceiveAnalysisRequestByCytoTechnologist_Cyto2 UT_ScanApprovedReportToVistaCPRS_Cyto2 RT_ReceiveApprovalFromPathologistByCytoTech_Cyto2 ST_InformMainPhysicianDirectlyAboutRejection_Cyto2 MT_GenerateReportByCytoTechnologist_Cyto2	✓	

Having conducted the validation, the behaviours of the developed SQWRL-based knowledge retrieval capabilities were found correct and complete.

7.4.5 EVALUATING THE EFFECTIVENESS OF THE ONTOSOS.BPA.CHM FRAMEWORK

After completing the development of the OntoSoS.BPA.ChM framework as well as its verification and validation, this evaluation stage focused on assessing the effectiveness of the research framework in improving the application of ChM in a SoS context. The key basis for realising the improved effectiveness is to check the framework fulfilment of the research gaps identified in Section 2.7. Subsequently, evaluation criteria, i.e. fulfilment of the framework functional characteristics, novelty and usefulness, which are derived from the identified research gaps, were assessed to support realising how the framework addresses the research gaps and therefore improves the effectiveness of ChM application in a SoS context. Table 7.42 provides a description of these criteria as adopted by the research.

Table 7. 42: The adopted effectiveness criteria for the evaluation of the OntoSoS.BPA.ChM framework.

Verification Criteria	Description
Fulfilment of Functional Characteristics	▪ The OntoSoS.BPA.ChM framework meets the functional characteristics (driven from the research gaps in Section 2.7) that derived its development.
Novelty	▪ Compared to existing ChM frameworks, the OntoSoS.BPA.ChM framework contributes innovatively to the ChM and SoS domains by bridging the gaps' aspects identified in Section 2.7.
Usefulness	▪ The OntoSoS.BPA.ChM framework induce improvements to ChM application in SoS context based on the bridged identified gaps' aspects.

Accordingly, Table 7.43 presents the techniques used for the assessment of the OntoSoS.BPA.ChM effectiveness, linked to the adopted effectiveness assessment criteria. The table also provides a brief description of the used assessment techniques.

Table 7. 43: The adopted effectiveness assessment techniques for the OntoSoS.BPA.ChM framework.

Assessment Criteria	Assessment Technique	Brief Description
Fulfilment of Functional Characteristics	Checklist-based Walkthrough	▪ A checklist-based walkthrough was designed and used to inform the fulfilment of the high-level functional characteristics (identified in Section 2.7) by the research framework and its constituent components. ▪ This check was carried out by the researcher.
Novelty	Comparison & Checklist-based Semi-Structured Interview	▪ Novelty aspects were driven from the research gaps and the functional characteristics identified in Section 2.7. ▪ The OntoSoS.BPA.ChM was compared with the CTAG-KHCC ChM framework, as a proof of concept, to emphasis the novelty aspects of the research framework against real-world setting. Furthermore, a checklist-based semi-structured interview to validate the conducted comparison with domain experts at the CTAG-KHCC was carried out.
Usefulness	Checklist-based Questionnaire through Semi-Structured Interview	▪ After the framework had been applied to the CTAG-KHCC case study and checked against the CTAG-KHCC ChM framework. The usefulness of adopting the OntoSoS.BPA.ChM framework was informed. Subsequently, a number of induced improvements, that were established based on the addressing the research gaps and their related driven functional characteristics, were checked and validated by the CTAG-KHCC domain experts through semi-structured interviews.

Tables 7.44 and 7.45 show parts of the conducted effectiveness assessment aspects.

Table 7. 44: Checklist-based walkthrough conducted to check the framework fulfilment of the functional characteristics identified to drive the framework development.

Research Gap	Driven High-Level Functional Characteristic	The fulfilling Framework Component
Research Gap 1	1. The framework should use new approaches to capture problem domains related to ChM and SoS.	▪ The ChM Component ▪ The SoS Context View Component
	2. The framework should provide an innovative solution to support ChM application in SoS context.	▪ The ChM Component ▪ The SoS Context View Component ▪ The Knowledge Retrieval Component
Research Gap 2	3. The framework should provide generalised models that represent ChM aspects related to ChM processes and their interrelationships.	▪ The ChM Component
	4. The framework should capture the different terminologies related to the identified ChM concepts.	▪ The ChM Component
	5. The framework should provide a means that enables a shared understanding of and common agreement on the different ChM aspects related to the identified ChM processes in a heterogenetic environment.	▪ The ChM Component ▪ The Knowledge Retrieval Component
Research Gap 3	6. The framework should explicitly, and formally model generalised aspects related to ChM processes.	▪ The ChM Component
	7. The framework should provide dedicated means to enable realising the modelled ChM aspects.	▪ The ChM Component ▪ The Knowledge Retrieval Component
Research Gap 4	8. The framework should explicitly and formally model the main elements of an SoS arrangement and the linkages between them driven by global-local levels alignment and BITA perspectives.	▪ The SoS Context View Component
	9. The framework should adapt the 'configuration item' concept to further include SoS main business aspects.	▪ The SoS Context View Component ▪ The Knowledge Retrieval Component
Research Gap 5	10. The framework should explicitly and formally model the linkages between the SoS-elements and the related stakeholders needed for ChM application.	▪ The SoS Context View Component
	11. The framework should provide dedicated means to enable realising the candidate implications and stakeholders related to a change request in both the global and local SoS levels independently of other configuration management functional areas and SoS authorities.	▪ The SoS Context View Component ▪ The Knowledge Retrieval Component

Table 7. 45: Part of the comparison-based walkthrough to check the novelty of the OntoSoS.BPA.ChM framework.

Comparison Aspect	The CTAG ChM Framework	The OntoSoS.BPA.ChM Framework	Domain Expert Feedback		
			Agree	Partially Agree	Disagree
ChM Aspects Conceptualisation	▪ Text-based description. ▪ Lacks model-based Conceptualisation. ▪ Implicit conceptualisation (in the mind of stakeholders based on how they interpret the related ChM Policy).	▪ BPA-driven flowchart conceptual model for the main ChM Stages and related Decision Gates. ▪ BPA-driven models for the ChM Processes and the Relationships between them. ▪ Explicit conceptualisation of the ChM domain aspects.	✓		
Remark:					
ChM Aspects Formal Specification	▪ Lacks formal specification.	▪ Formal OWL-based specification.	✓		
Remark:					
Knowledge Representation of ChM Processes	▪ Lacks knowledge representation of the ChM processes.	▪ Ontology-based and BPA-driven knowledge representation of ChM processes.	✓		
Remark:					
ChM Processes Management Levels Support	▪ No explicit process centric support for the different management level.	▪ Operational Level (The identification of ChM case processes). ▪ Tactical Level (The identification of ChM case management processes). ▪ Strategical Level (The identification of ChM Case Strategy Processes).	✓		
Remark:					
Knowledge Representation of Relationships between ChM Processes	▪ Lacks knowledge representation of relationships between the ChM processes. ▪ Implicit interpretation of relationships by the ChM stakeholders	▪ Explicit, Ontology-based and BPA-driven knowledge representation of ChM relationships. ▪ Dynamic relationships identified.	✓		
Remark:					
Knowledge Representation of ChM Semantic Heterogeneity	▪ The CTAG global level ChM framework uses its own terminologies, which is limited to adopting the ITIL ChM framework terminologies. ▪ No explicit identification of synonyms related to the used ChM processes, documents and roles. ▪ Lacks knowledge representation of the synonyms related to the used ChM processes, documents and roles.	▪ Explicit, Ontology-based and BPA-driven synonyms identified for the ChM processes, documents and roles based on the investigation of 12 standards, guidelines and practices in the software and systems engineering domains.	✓		
Remark:					

Table 7.45: Part of the comparison-based walkthrough to check the novelty of the OntoSoS.BPA.ChM framework, "Continued".

<table>
<tr><th rowspan="2">Comparison Aspect</th><th rowspan="2">The CTAG ChM Framework</th><th rowspan="2">The OntoSoS.BPA.ChM Framework</th><th colspan="3">Domain Expert Feedback</th></tr>
<tr><th>Agree</th><th>Partially Agree</th><th>Disagree</th></tr>
<tr><td>The Configuration Item Scope</td><td>▪ Mainly, IT-driven CIs.
▪ No explicit consideration of Business-driven CIs.
▪ CIs are defined precisely to include:
o Hardware.
o Software or Applications.
o LAN/WAN.
o Network or Server Hardware or Software.
o IT-environments that CTAG-KHCC relies on to conduct normal business operations.</td><td>▪ CIs includes:
o Business-driven related aspects (e.g. Business Services and Business Processes)
o IT-driven aspects (i.e. Software Services and the Constituent Information Systems that support the Business-related aspects).</td><td>✓</td><td></td><td></td></tr>
<tr><td>Knowledge Representation of the SoS Elements and the Linkages between them based on Global-Local Levels Alignment.</td><td>▪ Lacks explicit and formal identification of the SoS context Global and Local elements that need to be considered by the ChM framework in order to maintain Global-Local Levels Alignment.</td><td>▪ Explicit, Ontology-based and BPA-driven knowledge representation of SoS context Global and Local levels' elements and the linkages between them.</td><td>✓</td><td></td><td></td></tr>
<tr><td colspan="6">Remark:</td></tr>
<tr><td>Knowledge Representation of the SoS Elements and the Linkages between them based on Business-IT Alignment.</td><td>▪ Lacks explicit and formal identification of the SoS context business elements, the supporting constituent information systems and the linkages between them that need to be considered by the ChM framework in order to maintain Business-IT Alignment.</td><td>▪ Explicit, Ontology-based and BPA-driven knowledge representation of the SoS business elements, the supporting constituent information systems and the linkages between them.</td><td>✓</td><td></td><td></td></tr>
<tr><td colspan="6">Remark:</td></tr>
<tr><td>Knowledge Representation of the SoS elements related Stakeholders and the Linkages between them based on ChM point of view.</td><td>▪ Lacks explicit and formal identification of the SoS stakeholders that are related to the identified SoS elements alongside the linkages between them based on a ChM point of view.</td><td>▪ Explicit and Ontology-based knowledge representation of the SoS elements, their related stakeholders and the linkages between them driven by a ChM point of view.</td><td>✓</td><td></td><td></td></tr>
<tr><td colspan="6">Remark:</td></tr>
<tr><td>Discovering Candidate Implications Related to a Change Request</td><td>▪ The CTAG ChM framework depends on independent configuration management functional areas and SoS authorities to provide the ChM framework with sufficient initial impact analysis from technical and business point of views.
▪ No dedicated knowledge base nor direct capabilities are available to support the CTAG ChM framework in tracing and realising the candidate implications related to a change request
▪ No dedicated knowledge base nor direct capabilities are available to provide the ChM frameworks with a benchmark that can be used to validate the assessments acquired from the different independent parties.</td><td>▪ Dedicated knowledge base and direct capabilities are available to support/enable tracing and realising the candidate implications related to a change request independently of the impact assessment authorities or configuration management functional areas.
▪ Dedicated knowledge base and direct capabilities are available to provide the ChM framework with a benchmark that can be used to validate the assessments acquired from the different parties.</td><td>✓</td><td></td><td></td></tr>
<tr><td colspan="6">Remark:</td></tr>
<tr><td>Discovering CIs related Stakeholders Needed During the Management of a Change Request</td><td>▪ The CTAG ChM framework has a high dependency on independent configuration management functional areas and SoS authorities to provide the ChM framework with sufficient linkages between the CIs and their related stakeholders.
▪ No dedicated knowledge base nor direct capabilities are available by the ChM frameworks to enable tracing and realising the candidate stakeholders related to a change request.
▪ No dedicated knowledge base nor direct capabilities are available to provide a ChM framework with a benchmark that can be used to validate the stakeholders identified related to a change request, which are acquired from the different independent parties.</td><td>▪ Dedicated knowledge base and direct capabilities are available by the ChM framework to enable tracing and realising the candidate stakeholders related to a change request independently of the assessment authorities or Configuration Management functional areas.
▪ Dedicated knowledge base and direct capabilities are available to provide the ChM framework with a benchmark that can be used to validate the stakeholders identified related to a change request, which are acquired from different independent parties.</td><td>✓</td><td></td><td></td></tr>
</table>

Having assessed the effectiveness of the OntoSoS.BPA.ChM framework, the functional characteristics derived from the research gaps to drive the development of the research framework were found fulfilled by the OntoSoS.BPA.ChM framework and its constituent components. As a proof of concept, aspects that were derived from the research gaps and their related high-level functional characteristics were checked against the ChM framework adopted in the CTAG-KHCC in order to inform the novelty of the developed framework in a real-world setting. After validating the conducted comparison with domain experts at the CTAG-KHCC, they agreed that the research framework provides novel contributions to the domains of ChM and SoS. These contributions are mainly driven by the explicit and formal specifications of the generalised conceptualisations alongside the knowledge retrieval capabilities that the research framework provides for the ChM and SoS aspects in order to support the application of ChM in a SoS context.

Furthermore, driven by the contributions that the OntoSoS.BPA.ChM framework provides, a number of induced improvements to the ChM application in the CTAG-KHCC SoS context were realised and agreed on by the CTAG-KHCC domain experts. These induced improvements include the following:

The use of the OntoSoS.BPA.ChM framework in the CTAG-KHCC context:

a) enriches the awareness of the CTAG-ChM stakeholders -who operate at different levels of the arrangement- of the ChM main stages, related decision gates and ChM processes, in addition to the ChM processes related interrelationships, dependency relationships on SoS elements, documents and roles. Besides, it enriches their awareness of the deferent terminologies detected for the identified ChM processes, documents and roles;
b) provides a clearer and more comprehensive understanding of the different ChM aspects needed to manage a change in the CTAG-KHCC arrangement compared to the currently adopted ChM framework and related devised policies;
c) reduces the SoS heterogeneity impact on reaching a shared understanding of and agreement on the different ChM aspects amongst the CTAG-KHCC ChM stakeholders and further when communicating with external stakeholders (e.g. developers and providers);
d) improves revising the current CTAG-KHCC ChM policies and procedures to be clearer and more comprehensive. Also, it improves aligning the CTAG-KHCC ChM framework with more ChM standards and guidelines available in the systems and software engineering domains.
e) provides a more comprehensive traceability of change related candidate implications and stakeholders compared to the current adopted ChM framework.
f) improves the effectiveness (i.e. the accuracy and completeness to achieving goals) of the processes related to ChM impact analysis and coordination in addition to reducing the dependency of the processes related to the change initiation stage on other independent configuration management functional areas and SoS technical authorities.
g) provides the CTAG-KHCC ChM-stakeholders with knowledge that can be used as a benchmark to validate the initial traceability of change related implications and stakeholders that were acquired by the independent validation parties.
h) facilitates the detection of conflicts related to a submitted change between the participating constituent business areas.
i) provides the CTAG-KHCC ChM-stakeholders with knowledge that more effectively support aligning the CTAG global-and-local levels and the CTAG business aspects with their supporting constituent information systems compared to the current adopted ChM framework.

To emphasise, based on the previously noticed induced improvements, the CTAG-KHCC domain experts agreed that this research provides a generalised framework that can be adopted by the different levels of a CTAG-SoS arrangement. Furthermore, they agreed that using the OntoSoS.BPA.ChM to support ChM for the CTAG-SoS arrangement improves the effectiveness of the ChM application in the CTAG-SoS context. However, further case studies were suggested to be carried out in order to support the generalisation of the framework contributions.

7.5 Chapter Summary And Discussion

This chapter focused on the development of the alignment and knowledge retrieval component (the third and final key research framework component) by conducting the adopted Fourth-DSRM-Increment. During the design and development stage, aspects related to the development of the 'alignment and knowledge retrieval' component were identified then the component was built. The identified aspects include: (i) The ChM stages flow model; (ii) the dependency relations of the ChM processes on the SoS context elements; (iii) the main CIs and change types that need to be considered for the application of the OntoSoS.BPA.ChM framework; (iv) the ChM-driven roles that need to be considered for the application of the OntoSoS.BPA.ChM framework; (v) the knowledge related aspects that need to be considered for the knowledge retrieval capabilities; and (vi) the change implications traceability as well as ChM-driven roles identification routes. Accordingly, a phased-approach that is comprised of three main phases was adopted and carried out.

In the demonstration stage, the resultant artefacts were instantiated and put into work within a real-world context, using the CTAG-KHCC case study. For example, test cases derived from the CTAG-KHCC context were used to demonstrate retrieving knowledge from the ChM and SoS components. After the demonstration, the increment concludes with the evaluation stage, in which identified evaluation aspects were applied to assess the design and utility of the developed artefacts and the effectiveness of the OntoSoS.BPA.ChM framework. Protégé integrated reasoner, checklist-based walkthroughs, competency question-based test cases and semi-structured interviews were used to support the evaluation process.

Besides its key role in answering RQ1, the ChM framework component has enabled the semantic identification and representation of ChM processes related relationships that inform the dependency of ChM processes on SoS context, to be linked to the identified Riva-driven ChM processes (Sections 7.2.1, 7.2.4 and 7.3.1). It has also enabled the semantic identification and representation of ChM-driven roles (configuration items related authorities) to be linked to the main elements identified in the SoS context view component (Sections 7.2.1, 7.2.4 and 7.3.2). Furthermore, having the ChM framework component has facilitated the design and development of algorithmic and SQWRL-based capabilities that have enabled retrieving knowledge in relation to the identified and represented ChM aspects (Sections 7.2.2, 7.2.4, and 7.3.3).

On the other hand, besides its key role in answering RQ2, the SoS framework component has enabled revisiting the 'configuration item' concept and adapting its scope for the application of ChM in a SoS context (Section 7.2.1). Also, it has enabled revisiting the change types that need to be considered for the application of ChM in a SoS context (Section 7.2.1). Furthermore, having the SoS elements and the linkages between them captured and represented by the SoS context view component has enabled the identification of traceability routes for the comprehensive identification of candidate change implications, including the adapted CIs and its related stakeholders (Section 7.2.2). Moreover, it has enabled the identification of linkages between the SoS elements and related authorities needed during the application of ChM in a SoS context. Finally, having the SoS framework component has facilitated the design and development of algorithmic and SQWRL-based capabilities that have enabled retrieving knowledge in relation to the identified configuration items in addition to their related authorities, change types and change implications traceability routes (Sections 7.2.2, 7.2.4, and 7.3.3).

Adopting a DSRM-based process enabled the incremental and rigour development of the research documents to answer the identified RQs. After the 'Alignment and Knowledge Retrieval Framework Component' was developed based on utilising the ChM and SoS framework components, its applicability and validity were demonstrated using a sufficient and representative real-world case study (i.e. CTAG-KHCC) with support of domain experts (Sections 7.3 and 7.4).

Accordingly, the OntoSoS.BPA.ChM framework has demonstrated its effectiveness in addressing the identified research gaps when applied to the selected representative case study. In particular, (i) a novel approach was used to capture related aspects of the ChM and SoS problem domains using new conceptual models (e.g. BPA models for ChM and BPA-driven models for SoS context) and then to introduce an innovative solution (semantically-enriched BPA-driven ChM framework) to support ChM application in a SoS context; (ii) the heterogeneity impact of SoS arrangements on achieving a common agreement on the different ChM aspects related to managing a change request has been minimised by providing generalised BPA-driven and semantically enriched models that aligns between twelve ChM standards and guidelines and resolves semantic heterogeneity between them; (iii) the enrichment of ChM stakeholders awareness of different ChM aspects related to ChM processes and the relationships between them has been enabled using knowledge-retrieval capabilities that are based on explicit and formal representations of the related ChM aspects; (iv) better support of maintaining SoS global-local levels alignment and BITA during ChM application has been facilitated by capturing key related SoS elements and linkages between them using a semantically-enriched and BPA-driven approach; and (iv) compared to traditional ChM frameworks, the OntoSoS.BPA.ChM framework has minimised the dependency of ChM functional area on other separate configuration management functional areas by providing dedicated means that enable more comprehensive traceability of candidate change implications and more effective identification of configuration items and stakeholders related to a change request.

By completing this chapter, the development, demonstration and evaluation of the whole research framework were accomplished. This chapter mainly addressed **RQ3** and **RQ4** in addition to bridging first and fifth research gaps identified in Section 2.7. As has been informed by using the CTAG-KHCC case study, the alignment and knowledge retrieval component alongside the ChM and SoS framework components have provided the ChM framework with dedicated means that facilitate retrieving knowledge in relation to the identified ChM and SoS aspects in order to be shared and agreed on amongst the SoS-ChM stakeholders. They have also provided the ChM framework with dedicated means that enable achieving comprehensive BIT-driven traceability of change related implications and effective identification of configuration items related authorities, leading to an increased ChM functional area independence of other configuration management functional areas in a SoS context, which has contributed to facilitating and improving the application of ChM in a SoS context. Table 7.46 maps between the main research questions and the thesis chapters where they were addressed.

Table 7. 46: The current status of addressing the identified RQs by the thesis chapters.

Research Question	Chapter 4	Chapter 5	Chapter 6	Chapter 7
RQ1	✓✗	✓		
RQ2			✓	
RQ3				✓
RQ4				✓

CHAPTER 8

CONCLUSIONS AND FUTURE WORK

8.1 INTRODUCTION

Having investigated the ChM and SoS domains in Chapter 2, several research gaps that affect the application of ChM in a SoS context were identified (Section 2.7). Accordingly, this research is aimed at addressing these gaps through the adoption of a design science research process to investigate the use of a semantically-enriched BPA-driven approach to improve the effectiveness of ChM application in a SoS context.

Through the previous chapters, the OntoSoS.BPA.ChM framework and its constituent components were developed, demonstrated and evaluated, culminating in the research conclusions detailed in this final chapter. Accordingly, this chapter is organised as follows: Section 8.2 informs the fulfilment of the research gaps and proposition. Section 8.3 presents an overview of the research contributions. Finally, Section 8.4 concludes the chapter by highlighting future research directions.

8.2 FULFILMENT OF RESEARCH GAPS AND PROPOSITION

Table 8.1 provides a summative illustration of how the identified Research Questions (RQs) and Research Gaps (RGs) were answered and bridged within the research work, respectively. The table highlights that all the identified RQs and RGs were fulfilled by the research outcomes resulting from carrying out Chapters 4, 5, 6 and 7 of the thesis through the adopted DSRM increments.

A novel approach was used in this research to capture related aspects of the ChM and SoS problem domains by developing new generalised BPA-driven conceptual models for the ChM functional area and SoS operational context. In addition, innovative artefactual solutions (the semantically-enriched BPA-driven ChM, SoS context view, and alignment and knowledge retrieval framework components) were established and introduced to bridge the identified gaps (Section 2.7) and improve ChM application in a SoS context.

Furthermore, the heterogeneity impact of SoS arrangements on achieving a shared understanding of and common agreement on the different ChM aspects related to managing a change request has been minimised. This was accomplished by developing a generalised semantically-enriched and object-based BPA-driven model for the ChM functional area. It is the first published BPA-driven model for the ChM functional area that aligns between different well-known ChM standards, practices and guidelines associated with the systems and software engineering domains. Having used an object-based BPA-driven approach to develop the ChM

Table 8. 1: Summative traceability of addressing the research questions and gaps.

Thesis Chapters	DSRM Increments	Main Outcomes	Research Hypothesis								
			RQ1	RQ2	RQ3	RQ4	RG1	RG2	RG3	RG4	RG5
Ch. 4	**First-DSRM-Increment**	▪ Generalised BPA-driven models for the ChM functional area.	✓				✓	✓	✓		
Ch. 5	**Second-DSRM-Increment's First-Sub-Increment**	▪ Semantically-enriched BPA model for the ChM functional area.	✓				✓	✓	✓		
	Second-DSRM-Increment's Second-Sub-Increment	▪ Extended Semantically-enriched BPA-driven ChM model.	✓				✓	✓	✓		
Ch. 6	**Third-DSRM-Increment**	▪ Generalised Semantically-enriched BPA-driven model for the SoS operational context.		✓			✓			✓	
Ch. 7	**Fourth-DSRM-Increment**	▪ Semantically-enriched BPA-driven ChM stages flow model.	✓				✓	✓	✓		
		▪ Semantically-enriched ChM processes dependency relationships.	✓				✓	✓	✓		
		▪ Semantically-enriched ChM-driven roles linked to Identified SoS Elements.		✓			✓			✓	✓
		▪ Adapted configuration item concept to include business-driven aspects.			✓		✓			✓	✓
		▪ Query-based ChM knowledge retrieval capabilities.			✓		✓		✓		
		▪ Query-based SoS knowledge retrieval capabilities.			✓		✓				✓
		▪ Informing the effectiveness of the research framework.				✓	✓	✓	✓	✓	✓

models enabled the provision of a stable, clear and abstract understanding of the ChM core processes and the relationships between them. Besides, having used a semantically-enriched approach enabled resolving semantic heterogeneity and supporting semantic interoperability. Also, it enabled representing the models by a machine-readable format that supports knowledge reasoning and retrieval (Chapter 4 and 5), which facilitates sharing and agreeing on ChM aspects.

Driven by the developed BPA-driven models for the ChM functional area, the enrichment of ChM stakeholders' awareness of different ChM aspects related to ChM processes and relationships between them has been enabled. This was done through the provision of novel, generalised, explicit and formal representation of the related ChM aspects, which is based on using a semantically-enriched BPA-driven approach. Furthermore, it was enabled by the provision of knowledge retrieval capabilities that utilise the developed ChM model to retrieve and empower ChM-stakeholders with knowledge about the identified ChM processes. As mentioned in Chapter 2, the literature lacks ChM frameworks that provide a generalised, explicit and formal representation of the ChM aspects. Also, it lacks ChM frameworks that provide ChM knowledge retrieval capabilities based on using formal and explicit models to enrich the awareness of ChM stakeholders of the different related ChM aspects. However, the ChM framework component developed in this research, alongside its related knowledge retrieval capabilities, address these recognised gaps.

Additionally, key related SoS elements and linkages between them were formally captured using a semantically-enriched and BPA-driven model. This, in turn, has provided a better support of maintaining SoS global-local levels alignment and BITA during ChM application compared to the current ChM frameworks, which do not formally and explicitly consider the SoS elements and the linkages between them. The developed SoS context view model provides a novel, generalised, explicit and formal representation that covers a part of the knowledge found absent from the ChM and SoS domains and is needed to support ChM application in a SoS context. By its own, it can be instantiated for any given SoS arrangement with identified BPAs and BPMs, which facilitates sharing and agreeing on knowledge related to the operational context of a given SoS arrangement amongst SoS stakeholders. Linked to the ChM framework, it establishes the grounds for achieving comprehensive traceability of change related implications on a SoS arrangement and an effective identification of related stakeholders.

Finally, the developed ChM and SoS framework components provide knowledge bases that can be used to enrich the awareness of the concerned SoS-ChM stakeholders. Based on that, the 'alignment and knowledge retrieval framework component' was designed and developed, which, alongside the ChM and SoS knowledge bases, provide the research framework with dedicated formal means that facilitate retrieving purposeful knowledge in relation to the identified ChM and SoS aspects in order to be shared and agreed on amongst the SoS and ChM stakeholders. Also, they provide the research framework with dedicated formal means that enable achieving comprehensive BIT-driven traceability of change related implications and effective identification of configuration items related authorities. This, in turn, minimises the dependency, found in the literature, of the ChM functional area on other CM functional areas and SoS authorities to provide ChM stakeholders with knowledge related to change impact analysis and related authorities identification.

When formulating the research questions in Section 1.3 based on the established research proposition, a top-down approach was taken in order to address all relevant components of the research proposition. Subsequently, to accept the research proposition during this research, a bottom-up approach has been taken. Having answered all the research questions one by one through the research, bridging the identified research gaps and establishing the effectiveness of the developed research framework in improving the application of ChM in a SoS context, it is made sure that all relevant components of the research proposition have been fulfilled. Accordingly, the research proposition is found satisfactory addressed. However, one key limitation has been identified with influence on accepting the research proposition, which is: only one comprehensive case study was considered for the demonstration of the framework's effectiveness in addressing the research gaps. This limitation seems acceptable since a sufficient, representative, complex and real-world case study has been utilised. However, additional case studies are suggested to be conducted in order to increase confidence in the generalisation of the research outcomes.

8.3 An Overview of Research Contributions

The primary knowledge contribution of this research is **minimising the identified research gaps** by developing a BPA-driven and semantically-enriched ChM framework to support ChM application in a SoS context. Further accomplished contributions are summarised as follows:

➢ **Direct Research Contributions In Addressing the Research Gaps:**

1) The OntoSoS.BPA.ChM Framework:

A semantically-enriched BPA-driven ChM framework developed to support the application of ChM in a SoS context and improve its effectiveness. The OntoSoS.BPA.ChM is a novel framework that contributes novel knowledge to both the ChM and SoS domains. The framework provides generalised ChM knowledge that can be shared and agreed on amongst the different SoS-ChM stakeholders, leading to reducing the SoS heterogeneity impact on ChM application. Furthermore, it supports SoS global-local levels alignment and BITA during ChM application by providing comprehensive traceability of change related candidate implications and effective authorities identification.

2) The First Generalised BPA for ChM Functional Area:

It is an object-based Riva-driven BPA that can be applied to both monolithic and SoS contexts. It provides a generalised conceptual explicit representation of ChM core processes and the dynamic relationships between them. The developed BPA is aligned with the generic business nature of ChM functional area and the main ChM managerial levels in any organisation (i.e. operational, tactical and strategical levels). The BPA also aligns well-known existing ChM standards, guidelines and practices in software and systems engineering domains.

3) The First Semantically-enriched Generalised BPA model for ChM Functional Area:

It is an ontology-based Riva-driven BPA model that can be adopted for monolithic and SoS contexts. This includes coherent semantic representation of ChM concepts, relationships, constraints and axioms related to the developed BPA for ChM alongside resolving semantic heterogeneities detected for the identified ChM-UOWs. Such a model provides a machine-readable and explicit ChM knowledge that facilitates sharing, understanding and agreeing on ChM processes and the relationships between them amongst different ChM stakeholders in traditional and SoS contexts.

4) Extension of the Semantically-enriched ChM-BPA:

A novel semantically-enriched, BPA-driven and generalised model that extends the developed ontology-based BPA for ChM to include: generalised main ChM stages, their related flow and decision gates; the developed ChM-BPA models' elements; BPA-driven ChM documents, roles and dependency relationships identified for the ChM processes; and linkages between the identified elements.

This artefact contributes to the domain of ChM with novel knowledge that has not been provided explicitly and formally by the current existing ChM frameworks. It is applicable to traditional and SoS contexts. Having such knowledge enables the enrichment of ChM stakeholders' awareness of different generalised entailed ChM aspects, which contributes to facilitating and improving the effectiveness of ChM processes application.

5) Generalised Semantically-enriched BPA-driven Meta-model for SoS Context:

The meta-model provides a novel, generalised, explicit and formal representation of main elements related to a SoS arrangement operational context and the linkages between them. It can be instantiated for any given SoS arrangement that has its related BPA models and BPMs available. Furthermore, it covers a part of the knowledge that found absent in the ChM and SoS domains, which supports maintaining SoS global-local level alignment and BITA during ChM application in a SoS context. Moreover, it enables achieving comprehensive traceability of change related implications and effective identification of related stakeholders in a SoS context.

6) Extension of the Configuration Item (CI) Concept:

Instead of being limited to IT-related components or assets, in this research, the concept 'CI' is adapted to refer to 'a SoS context view-driven element identified within the SoS global or local levels, where a change applied to it might have a notable impact on the Global-Local levels alignment and/or BITA, and it needs to be under the control of ChM'. Adapting the CI concept facilitates the provision of ChM knowledge that supports achieving more comprehensive traceability of change-related implications than traditional ChM frameworks and therefore improving global-local levels alignment and BITA during ChM application.

7) Knowledge Retrieval Capabilities:

Possession of the ChM and SoS context view semantically-enriched BPA-driven models allows provision of dedicated means (i.e. knowledge base and knowledge retrieval capabilities) to enable ChM stakeholders realisation of aspects related to ChM application (stages, processes, relationship, etc.) and the traceability of candidate implications and candidate stakeholders related to a change request in both the global and local SoS levels. This is enabled to be done independently of other configuration management processes and SoS authorities, which traditional ChM frameworks do not provide.

- Indirect Research Contributions to Knowledge:

1) Extension and Enhancements to the Riva-based BPA Modelling Approach (Ould, 2005):

Having investigated the Riva-based BPA modelling approach (Ould, 2005) -that is used to model core business processes and the dynamic relationships for any given functional area- two limitations were identified; (i) the Riva approach relies on carrying out brainstorming sessions with specific stakeholders identified within a specific organisational boundary to elicit the main organising concepts that form the grounds for the BPA models (i.e. EBEs); and (ii) the Riva approach lacks the representation of the CSP concept and certain aspects related to modelling its relationships with its associated processes (i.e. CP and CMP). Accordingly, this research has adapted the Riva BPA modelling approach to drive anticipated BPA models from different sources of knowledge. Furthermore, notations and heuristics that extend the representation of the CSP concept have been proposed.

The use of the adapted Riva BPA modelling approach is not limited to this research only; it can be used for any research that considers the development of a more comprehensive and generalised BPA-models than the ones resulted from adopting the original Riva BPA modelling approach.

2) Extension and Enhancements to the srBPA Ontological meta-model and its Instantiation (Yousef and Odeh, 2014):

The srBPA ontology (Yousef, 2010) was developed to semantically enrich the original Riva-driven BPA models. Conversely, as the Riva BPA modelling approach has been adapted for this research, the srBPA ontology has also been adapted to entail the newly identified Riva BPA modelling aspects. The original srBPA semantic models were extended to include semantic representation of the CSP concept and its related relationships. The semantic-based rules, originally employed to instantiate the srBPA meta-model, were also adapted as well. In addition, the srBPA meta-model was extended to entail ontological elements that support the semantic-enrichment of synonyms that are captured for identified UOWs instances.

The use of the adapted srBPA ontology is not limited to this research only, the adapted ontology and its instantiation process can be used for any research that considers the development of semantically-enriched BPA-models resulted from using the adapted Riva BPA modelling approach proposed by this research.

8.4 Future Research Directions

This section proposes further future directions that are anticipated to contribute to this research.

1) Applying the research OntoSoS.BPA.ChM framework to other case studies.

The OntoSoS.BPA.ChM framework was instantiated and applied successfully through this research to the CTAG-KHCC case study. In future, the OntoSoS.BPA.ChM framework is anticipated to be applied to other case studies. This will test and validate its effectiveness and applicability beyond the CTAG-KHCC domain.

2) Linking the OntoSoS.BPA.ChM framework with goals, policies and strategies of SoS arrangements

The SoS context view meta-model developed to address the aim of the OntoSoS.BPA.ChM framework is limited to representing business-driven aspects with a focus on global-local levels alignment and BITA. However, the identified elements are not associated with goals, policies and strategies of a SoS arrangement. Such associations are proposed to be covered in future, thereby, ensuring the attainment of more comprehensive traceability of change candidate implications.

3) Expanding the scope of the research framework by developing other related CM functional areas models and linking them to the ChM models

In addition to the ChM functional area, the configuration management domain entails other related areas (e.g. version management, release management and system building). To expand the developed framework, explicit formal BPA-driven models for other configuration management functional areas are recommended for development and then association to the ChM component of the OntoSoS.BPA.ChM framework.

4) Expanding the scope of the research framework to include conflict management processes with reference to conflict detection and resolution aspects

The framework provides knowledge that can be used to detect change conflicts amongst the constituent business areas and information systems that participate in a SoS arrangement. However, the research scope does not extend to the application of conflict management activities. Therefore, it is recommended to apply conflict detection and resolution mechanisms within the OntoSoS.BPA.ChM framework.

5) A reference ontology for ChM

The ChM ontological models were mainly derived from the software and systems engineering domains. To promote for reusing the ChM ontological models in multiple application contexts, a reference ontological model for ChM is suggested to be developed based on the current established ChM models.

6) Using the ChM-BPA models to drive the development of ChM role activity diagrams.

This research focused on the development of generalised ChM-BPA models based on investigating twelve ChM standards, practices and guidelines. Future studies are proposed to develop ChM-role activity diagrams driven by the ChM knowledge provided by this research, especially by the developed ChM-BPA models.

7) Automating the instantiation of the SoS context meta-models.

This research used a semi-automated approach to instantiate the developed SoS context view meta-models, including the instantiation of related adapted srBPA and sBPMN ontologies. Recommendations for future work include examining associated automation of the instantiation related to the SoS context view meta-models based on using application programming interfaces alongside serialised BPAs and BPMNs-based models.

8) Utilising Key Performance Indicators (KPIs)

To visualise statistics that will aid in enhancing the OntoSoS.BPA.ChM framework's application and its support of ChM applications in the context of SoS, a list of KPIs proposed to be designed and used.

9) **Developing a formal diagramming tool for modelling the Riva-based BPA models including its adapted aspects.**

To depict Riva-driven BPA models, generic drawing tools can be employed. However, there is a clear absence of tools that support automatic or semi-automatic derivation of the Riva-driven BPA conceptual models from its identified UOWs. Furthermore, the literature lacks drawing tools that provide formal serialisation (e.g. XML serialisation) capabilities dedicated for the Riva-driven BPA notations. As future work, such a tool is proposed to be considered for development.

REFERENCES

Abdalla, G. (2017) Establishment of an ontology for Systems-of-Systems. MSc dissertation, Department of Computer Science and Computational Mathematics, Universidade de São Paulo ICMC-USP, Brazil.

Abramowicz, W., Filipowska, A., Kaczmarek, M. and Kaczmarek, T. (2011) Semantically enhanced business process modeling notation. In: Semantic Technologies for Business and Information Systems Engineering: Concepts and Applications. DOI:10.4018/978-1-60960-126-3.ch013.

Ackoff, R.L. (1971) Towards a System of Systems Concepts. Management Science. 17 (11), pp. 661–671. DOI:10.1287/mnsc.17.11.661.

Ahmad, M. (2015) Semantic derivation of enterprise information architecture from Riva-based business process architecture. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Ali, U. and Kidd, C. (2014) Barriers to effective configuration management application in a project context: An empirical investigation. International Journal of Project Management. 32 (3), pp. 508–518. DOI: 10.1016/j.ijproman.2013.06.005.

De Almeida Monte-Mor, J. and Da Cunha, A.M. (2014) GALO: A semantic method for software configuration management ITNG 2014 - Proceedings of the 11th International Conference on Information Technology: New Generations. pp. 33–39. DOI:10.1109/ITNG.2014.66.

Ambrosio, A.P., Santos, D.C. De, Lucena, F.N. De and Silva, J.C.D. (2004) Software Engineering Documentation: An Ontology-Based Approach In proceedings of Web Media and LA-Web. pp. 38–40.

Antoniou, G., Groth, P., Harmelen, F. van and Hoekstra, R. (2012) A Semantic Web Primer. 3rd edition. London, England: MIT Press.

Arantes, L.D.O., Falbo, R.D.A. and Guizzardi, G. (2007) Evolving a Software Configuration Management Ontology in Proceedings of the 2nd Workshop on Ontologies and Metamodeling Software and Data Engineering.

Aversano, L., Grasso, C. and Tortorella, M. (2013) A literature review of business/IT alignment strategies. Lecture Notes in Business Information Processing. 141, pp. 471–488. DOI:10.1007/978-3-642-40654-6_28.

AXELOS (2011) ITIL Service Transition Stuart Rance, Colin Rudd, Shirley Lacy, Ashely Hanna, and Et Al. (eds.). 2011th edition. UK: TSO (The Stationery Office). ISBN: 9780113313068.

Axelsson, J. (2019) Experiences of Using Linked Data and Ontologies for Operational Data Sharing in Systems-of-Systems. In: 13th Annual IEEE International Systems Conference SysCon 2019. 2019 Orlando, Florida, United States: IEEE.

Beeson, I., Green, S. and Kamm, R. (2013) Comparative process architectures in two higher education institutions. International Journal of Organisational Design and Engineering. 3 (1), pp. 35. DOI:10.1504/ijode.2013.053667.

Beeson, I., Green, S. and Kamm, R. (2009) Process Architectures in Higher Education. In: UK Academy for Information Systems Conference Proceedings 2009.11. Available from: https://aisel.aisnet.org/ukais2009/11.

Bell, J. and Opie, C. (2003) Learning from Research: Getting More from Your Data. 1st edition. Buckingham, UK: Open University Press. ISBN: 09578234.

Bellomo, S. and Smith, J.D. (2008) Attributes of effective configuration management for systems of systems. In: 2008 2nd Annual IEEE Systems Conference Proceedings, SysCon 2008. 2008 Montreal, Que., Canada: IEEE. pp. 177–184. DOI:10.1109/SYSTEMS.2008.4519006.

Benali, H., Ben Saoud, N.B. and Ben Ahmed, M. (2014) Context-based ontology to describe System-of-Systems Interoperability. In: Proceedings of IEEE/ACS International Conference on Computer Systems and Applications, AICCSA. November 2014 Doha, Qatar: IEEE/ACS. pp. 64–71. DOI:10.1109/AICCSA.2014.7073180.

Bendix, L. (2003) Software Configuration Management Problems and Solutions to Software Variability Management. In: ICSE-2003 Workshop on Software Variability Management. 2003 Portland, Oregon: IEEE Computer Society. pp. 1–3.

Berners-Lee, T., Hendler, J. and Lassila, O. (2001) The Semantic Web. Scientific American. 284 (5), pp. 34–43.

Berry, B. (1964) Cities as systems within systems of cities. Papers and Proceedings of the Regional Science Association. 13 (1), pp. 149–163.

BKCASE Editorial Board (2019) The Guide to the Systems Engineering Body of Knowledge (SEBoK), v. 2.0 [online] (2.0) pp. 1–1035. Available from: www.sebokwiki.org.

Boardman, J., Pallas, S., Sauser, B. and Verma, D. (2006) Report on Systems of Systems Engineering, Final Report for the Office of the Secretary of Defence.

Boulding, K. (1956) General Systems Theory–The Skeleton of Science. Management Science. 2 (3), pp. 197–208. DOI: E:CO Vol. 6 No. 1/2, Fall 2004, pp. 127-139.

Brickley, D. and Guha, R.V. (2014) RDF Schema 1.1, W3C Recommendations. Available from: https://www.w3.org/TR/rdf-schema/ [Accessed 9 September 2019].

Brouse, P. (2008) Configuration Management. In: Systems Engineering And Management For Sustainable Development, Volume 1 Andrew P. Oxford, UK: Encyclopaedia of Life Support Systems (EOLSS). pp. 214–243.

Calhau, R.F. and De Almeida Falbo, R. (2012) A configuration management task ontology for semantic integration Proceedings of the ACM Symposium on Applied Computing, pp. 348–353.

Chen, P. and Clothier, J. (2003) Advancing systems engineering for systems-of-systems challenges. Systems Engineering. 6 (3), pp. 170–183.

Claramunt, C., Levashkin, S. and Bertolotto, M. (2011) GeoSpatial Semantics: 4th International Conference, GeoS 2011, Brest, France, May 12-13, 2011, Proceedings. Christophe Claramunt, Sergei Levashkin, and Michela Bertolotto (eds.). Berlin Heidelberg: Springer-Verlag Berlin Heidelberg.

Cleven, A., Gubler, P. and Hüner, K.M. (2009) Design alternatives for the evaluation of design science research artifacts. In: Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology, DESRIST ’09. 2009 Philadelphia, Pennsylvania, USA. DOI: 10.1145/1555619.1555645.

Cropley, D.H. (2004) 4.6.2 A Knowledge Management Approach to Change Management in Systems-of-Systems. In: INCOSE International Symposium. 2004 Toulouse, France: International Council on Systems Engineering. pp. 837–847. DOI:10.1002/j.2334-5837.2004.tb00537.x.

Crosar, D. and Sleeman, D. (2006) Reusing JessTab rules in Protege. Knowledge-Based Systems. 19 (5), pp. 291–297. DOI: http://dx.doi.org/10.1016/j.knosys.2005.11.010.

Dahmann, J. (2014) System of Systems Pain Points. INCOSE International Symposium. 24 (1), pp. 108–121.

Dahmann, J., Rebovich, G., Lane, J., Lowry, R. and Baldwin, K. (2011) An implementers’ view of systems engineering for systems of systems. In: IEEE (ed.). An implementers’ view of systems engineering for systems of systems. November 2011, London: IEEE. pp. 212–217.

DANSE Consortium (2012a) Characterization of SoS [online] (Deliverable 4.1, Ver. 1.0). Available from: https://danse-ip.eu/home/pdf/danse_d4.1_characterization_of_sos.pdf.

DANSE Consortium (2012b) Gap Analysis of Existing Modeling Formalisms [online] (6.1). Available from: http://www.danse-ip.eu/home/pdf/danse_d6.1_gap_analysis_of_existing_modeling_formalisms.pdf.

Dijkman, R., Vanderfeesten, I. and Reijers, H. (2011) The road to a business process architecture: an overview of approaches and their use. The Nederlands: Eindhoven University of Technology.

Dijkman, R., Vanderfeesten, I. and Reijers, H.A. (2016) Business process architectures: overview, comparison and framework. Enterprise Information Systems. 10 (2), pp. 129–158. DOI:10.1080/17517575.2014.928951.

Dobrica, L. and Niemelá, E. (2002) A survey on software architecture analysis methods. IEEE Transactions on Software Engineering. 28 (7), pp. 638–653. DOI:10.1109/TSE.2002.1019479.

DoD (2019) Chapter 3 - Systems Engineering. Available from: https://www.dau.edu/tools/dag [Accessed 12 September 2019].

DoD (2001) MIL-HDBK-61A(SE): Configuration Management Guidance [online]. Available from: http://www.acqnotes.com/Attachments/MIL-HDBK-61A (SE)Configuration Management Guidance.pdf.

DoD (2013) MIL-STD-3046(ARMY): DEPARTMENT OF DEFENSE INTERIM STANDARD PRACTICE CONFIGURATION MANAGEMENT. DOI: AMSC 9275.

Dogan, H., Barot, V., Henshaw, M., Siemieniuch, C. and Sinclair, M. (2014) Systems of systems engineering thesaurus approach: from concept to realisation. International Journal of System of Systems Engineering (IJSSE). 5 (3), pp. 228–247. DOI:10.1504/IJSSE.2014.065751.

Dong, M., Yang, D. and Su, L. (2011) Ontology-based service product configuration system modeling and development. Expert Systems with Applications. 38 (9), pp. 11770–11786. DOI:10.1016/j.eswa.2011.03.064.

Estublier, J. (2000) Software configuration management: A roadmap. In: Proceedings of the Conference on the Future of Software Engineering, ICSE 2000 [online]. 2000 Limerick, Ireland: ACM. pp. 279–289.

Fauzi, M., Sanim, S., Bannerman, P.L. and Staples, M. (2010) Software Configuration Management in Global Software Development: A systematic map. In: Proceedings - Asia-Pacific Software Engineering Conference, APSEC 2010. 2010 Sydney, Australia: IEEE. pp. 404–413. DOI:10.1109/APSEC.2010.53.

Ferreira, S. and Tejeda, J. (2014) An Ontology for Unmanned and Autonomous Systems of Systems Test and Evaluation. INCOSE International Symposium. 21 (1), pp. 1082–1091. DOI: https://doi.org/10.1002/j.2334-5837.2011.tb01267.x.

Flick, Ui. (2015) Introducing Research Methodology: A Beginner's Guide to Doing a Research Project. 2nd edition. London, England: Sage Publication Ltd.

Floridi, L. (2004) The Blackwell Guide to the Philosophy of Computing and Information. Oxford, UK: Blackwell Publishing Ltd.

Gandhi, S.J., Gorod, A. and Sauser, B. (2012) A systemic approach to managing risks of SoS. IEEE Aerospace and Electronic Systems Magazine. 27 (5), pp. 23–27. DOI:10.1109/MAES.2012.6226691.

Gašević, D., Djurić, D. and Devedžić, V. (2009) Model driven engineering and ontology development. Berlin Heidelberg: Springer-Verlag Berlin Heidelberg.

Gorard, S. (2013) Research design creating robust approaches for the social sciences. Katie Metsler (ed.). 1st edition. London: Sage Publication Ltd.

Gorod, A., Sauser, B. and Boardman, J. (2008) System-of-systems engineering management: A review of modern history and a path forward. IEEE Systems Journal. 2 (4), pp. 484–499. DOI:10.1109/JSYST.2008.2007163.

Gorod, A., White, B., Ireland, V., Gandhi, S.J. and Sauser, B. (2014) Modern History of System of Systems, Enterprises, and Complex Systems. In: Case Studies in System of Systems, Enterprise Systems, and Complex Systems Engineering (Complex and Enterprise Systems Engineering) 1st edition. Florida, USA: CRC Press. pp. 3–33.

Gruber, T.R. (1993) A Translation Approach to Portable Ontology Specifications. Knowledge acquisition. 5 (2), pp. 199–220.

Gruninger, M. and Fox, M.S. (1995) The Role of Competency Questions in Enterprise Engineering. In: Rolstadas, A., ed. Benchmarking — Theory and Practice. US: Springer, pp.22-31.

Guarino, N., Oberle, D. and Staab, S. (2009) What Is an Ontology? In: S. Stabb and R. Struder (eds.). Handbook on Ontologies, International Handbooks on Information Systems. 2nd edition. Berlin, Heidelberg: Springer, Berlin, Heidelberg. pp. 1–17. DOI:https://doi.org/10.1007/978-3-540-92673-3-0.

Hammad, R. (2018) A Hybrid E-learning Framework: Process-based, Semantically-Enriched And Service Oriented. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Harmon, P. (2003) Business process change: a manager's guide to improving, redesigning, and automating processes. San Francisco, Calif; London: Morgan Kaufmann.

Havey, M. (2005) Essential Business Process Modeling. 1st edition. California, USA: O'Reilly Media Inc.

He, Y., Zhang, J., Yue, L.Q., Li, Z.M. and Tang, L.J. (2014) Based on ontology methodology to model and evaluate System of Systems (SoS). In: Proceedings of the 9th International Conference on System of Systems Engineering: The Socio-Technical Perspective, SoSE 2014. 2014 Adelaide, Australia: IEEE. pp. 101–106. DOI:10.1109/SYSOSE.2014.6892471.

Hepp, M. and Roman, D., 2007. An ontology framework for semantic business process management. In: Proceedings of Wirtschaftsinformatik, February 28–March 2, Karlsruhe,1–18.

Herselman, M. and Botha, A. (2015) Evaluating an Artifact in Design Science Research. In: ACM International Conference Proceeding Series. 2015 Stellenbosch, South Africa. pp. 21. DOI:10.1145/2815782.2815806.

Hevner, A. and Chatterjee, S. (2010) Design Research in Information Systems, Theory and Practice. New York, USA: Springer.

Hevner, A.R., March, S.T., Park, J. and Ram, S. (2004) Design science in information systems research. MIS Quarterly: Management Information Systems. 28 (1), pp. 75–105.

Horridge, M., Knublauch, H., Rector, A., Stevens, R., Wroe, C., Jupp, S., Moulton, G., Stevens, R., Drummond, N., Jupp, S., Moulton, G. and Brandt, S. (2011) A Practical Guide to Building OWL Ontologies Using Protege 4 and CO-ODE Tools Matrix [online]. Available from: http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorial P4_v1_3.pdf.

Horrocks, I., Patel-Schneider, P.F., Boley, H., Tabet, S., Grosof, B., Dean, M., Horrocks, I., Patel-schneider, P.F., Boley, H., Tabet, S., Grosof, B. and Dean, M. (2004) SWRL : A Semantic Web Rule Language Combining OWL and RuleML. Available from: http://www.w3.org/Submission/SWRL/.

INCOSE (2015) Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. D. Walden, G. Roderler, K. Forsberg, R. Hamelin, and T. Shortell (eds.). 4th edition. San Diego, CA, USA: John Wiley & Sons, Inc., Hoboken, New Jersey.

ISO/IEC/IEEE (2019) 21841-2019 - ISO/IEC/IEEE International Standard - Systems and software engineering -- Taxonomy of systems of systems p.pp. 1–10. DOI:10.1109/IEEESTD.2019.8766998.

ISO/IEC/IEEE (2015) ISO/IEC/IEEE 15288: 2015 Systems and Software Engineering - System Life Cycle Processes BSI Standards 2015. pp. 1–122.

ISO (2003) ISO 10007:2003 - Quality management systems- Guidelines for configuration management, Second Edition [online] 3. Available from: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=36644.

ISO (2017) ISO 10007:2017- Quality management — Guidelines for configuration management. DOI:ISO 10007:2017(E).

Jacob, F. (1976) The logic of life: a history of heredity. New York, USA: Vintage Books.

Jensen, C.T., Charters, I., Amsden, J., Darlington, S., Owen, M., Herness, E. and Irassar, P. (2008) Leveraging SOA, BPM and EA for strategic business and IT alignment IBM White Paper. pp. 1–28.

Juristo, N. and Morant, J.L. (1998) Common framework for the evaluation process of KBS and conventional software. Knowledge-Based Systems. 11 (2), pp. 145–159. DOI:10.1016/S0950-7051(98)00047-1.

Khan, Z. (2009) Bridging the Gap between Business Process Models and Service-Oriented Architectures with reference to the Grid Environment. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Khan, Z., Ludlow, D. and Caceres, S. (2013) Evaluating a collaborative IT-based research and development project. Evaluation and program planning. 40 pp. 27–41. DOI:10.1016/j.evalprogplan.2013.04.004.

Klein, J., Cohen, S. and Kazman, R. (2013) Common Software Platforms in System-of-Systems Architectures: The State of the Practice.

Kossmann, M. (2010) OntoREM: An Ontology-Driven Requirements Engineering Methodology Applied in the Aerospace Industry. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Kotov, V. (1997) Systems of systems as communicating structures. HP Laboratories Technical Report. (97–124), pp. 1–15.

Langford, G. and Langford, T. (2017) The making of a system of systems: Ontology reveals the true nature of emergence. In: 12th System of Systems Engineering Conference, SoSE 2017. June 2017, Hawaii, USA: IEEE. pp. 1–5. DOI:10.1109/SYSOSE.2017.7994936.

Larsson, M. and Crnkovic, I. (1999) New challenges for configuration management. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) System Configuration Management. Switzerland: Springer. pp. 232–243. DOI:10.1007/3-540-48253-9_17.

Leon, A. (2015) Software Configuration Management Handbook. 3rd edition. London, UK: Artech Houde.

Lindkvist, C., Stasis, A. and Whyte, J. (2013) Configuration management in complex engineering projects. Procedia CIRP. 11 pp. 173–176. DOI:10.1016/j.procir.2013.07.046.

Livari, J. and Venable, J. (2009) Action Research and Design Science Research - Seemingly similar but decisively dissimilar. In: 17th European Conference on Information Systems (ECIS 2009). 2009 Verona, Italy. pp. 1642–1653.

Luftman, J. and Brier, T. (1999) Achieving and sustaining business-IT alignment. California Management Review. 42 (1), pp. 109–122. DOI:10.2307/41166021.

Madni, A.M. and Sievers, M. (2014) System of systems integration: Key considerations and challenges. Systems Engineering. 17 (3), pp. 330–347. DOI:10.1002/sys.21272.

Maier, M. (1998) Architecting Principles for Systems-of-Systems. Systems Engineering: The Journal of the International Council on Systems Engineering. 1 (4), pp. 267–284. DOI:10.1002/(SICI)1520-6858.

Maier, M.W. (2005) Research Challenges for Systems-of-Systems. In: [online]. IEEE. pp. 3149–3154.

Malinova, M., Leopold, H. and Mendling, J. (2013) An Empirical Investigation on the Design of Process Architectures. In: 11th International Conference on Wirtschaftsinformatik (WI2013). 2013 Leipzig, Germany. pp. 1197–1211.

Manthorpe, W.H.J. (1996) The emerging joint system of systems: A systems engineering challenge and opportunity for APL. Johns Hopkins APL Technical Digest (Applied Physics Laboratory). 17 (3), pp. 305–313.

March, S. and Smith, G. (1995) Design and natural science research on information technology. Decision Support Systems. 15 (4), pp. 251–266.

McBride, B. (2004) The Resource Description Framework (RDF) and its Vocabulary Description Language RDFS. In: S. Staab and R. Studer (eds.). Handbook on Ontologies. International Handbooks on Information Systems 1st edition. Berlin Heidelberg: Springer, Berlin, Heidelberg. pp. 51–65. DOI:10.1007/978-3-540-24750-0_3.

MITRE (2014) Systems Engineering Guide. [online]. USA: The MITRE Corporation. Available From: https://www.mitre.org/publications.

Motik, B., Sattler, U. and Studer, R. (2004) Query answering for OWL-DL with rules. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 3298 pp. 549–563.

Munir, K., Odeh, M. and McClatchey, R. (2012) Ontology-driven relational query formulation using the semantic and assertional capabilities of OWL-DL. Knowledge-Based Systems. 35 pp. 144–159. DOI:10.1016/j.knosys.2012.04.020.

Musen, M.A. (2015) The Protégé project: A look back and a look forward. AI Matters. Association of Computing Machinery Specific Interest Group in Artificial Intelligence [online]. 1 (4), pp. 4–12. Available from: http://protege.stanford.edudoi:DOI: 10.1145/2557001.25757003.

Nielsen, C.B., Larsen, P.G., Fitzgerald, J., Woodcock, J. and Peleska, J. (2015) Systems of systems engineering: Basic concepts, model-based techniques, and research directions. ACM Computing Surveys. 48 (2), pp. 18. DOI:10.1145/2794381.

Northrop, L., Feiler, P., Gabriel, R.P., Goodenough, J. and Al., E. (2006) Ultra-large-scale systems - The Software Challenge of the Future Companion to the 21st ACM SIGPLAN conference on Object-oriented programming systems, languages, and applications - OOPSLA '06.

Novakouski, M., Lewis, G.A., Anderson, W.B. and Davenport, J. (2012) Best Practices for Artifact Versioning in Service-Oriented Systems Best Practices for Artifact Versioning in Service-Oriented Systems (Technical Note-CMU/SEI-2011-TN-009).

Noy, N. and Mcguinness, D. (2001) Ontology Development 101: A Guide to Creating Your First Ontology. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.

O'Connor, M. and Das, A. (2009) SQWRL: A query language for OWL. In: Rinke Hoekstra and Peter Patel-Schneider (eds.). Proceedings of OWL: Experiences and Directions (OWLED 2009), Sixth International Workshop Chantilly [online]. 2009 Virginia, USA. Available from: http://www/webont.org/owled/2009.

Odeh, Y. (2015) GQ-BPAOntoSOA: A goal- and object-based semantic framework for deriving software services from an organisation's goals and Riva business process architecture. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Odeh, Y., Tbaishat, D., Al-Okaily, A., Khudirat, S., Al-Smadi, O., Hejazi, A., Sharma, S., Tbakhi, A. and Odeh, M. (2018) Informing Business Process Models Adherence to Protocols via Business Process Modelling: The Case of Cell Therapy and Applied Genomics in Cancer Care. In: Proceedings - 2018 1st International Conference on Cancer Care Informatics, CCI 2018. 2018 Amman, Jordan. pp. 82–99. DOI:10.1109/CANCERCARE.2018.8618205.

ODUSD(A&T) SSE (2008) Systems Engineering Guide for Systems of Systems Technology [online] 36 (Version 1.0). Available from: http://www.acq.osd.mil/se/docs/SE-Guide-for-SoS.pdfdoi:10.1109/EMR.2008.4778760.

Orlando, J.P., Rívolli, A., Hassanpour, S., O'Connor, M.J., Das, A. and Moreira, D.A. (2012) SWRL rule editor: A web application as rich as desktop business rule editors. In: ICEIS 2012 - Proceedings of the 14th International Conference on Enterprise Information Systems. 2012 Poland. pp. 258–263.

Ormrod, D., Turnbull, B. and O'Sullivan, K. (2016) System of systems cyber effects simulation ontology. In: Proceedings - Winter Simulation Conference. December 2016, Washington, DC, USA: IEEE. pp. 2475–2486. DOI:10.1109/WSC.2015.7408358.

Ould, M.A. (2005) Business process management: a rigorous approach. 1st edition. Swindon: British Computer Society.

Pan, J.Z. (2009) Resource Description Framework. In: Handbook on Ontologies, International Handbooks on Information Systems. 2nd edition. Springer, Berlin, Heidelberg. pp. 71–91. DOI: https://doi.org/10.1007/978-3-540-92673-3_0.

Peffers, K., Rothenberger, M., Tuunanen, T. and Vaezi, R. (2012) Design science research evaluation. In: Proceedings of the 7th international conference on Design Science Research in Information Systems: advances in theory and practice. 2012 Las Vegas, NV, USA. pp. 398–410. DOI:10.1007/978-3-642-29863-9_29.

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), pp. 45–77. DOI:10.2753/MIS0742-1222240302.

Peisl, R. (2012) The Process Architect: The Smart Role In Business Process Management. IBM Corp. pp. 1-62. Available from: https://www.redbooks.ibm.com/redpapers/pdfs/redp4567.pdf.

Popper, S.W., Bankes, S.C., Callaway, R. and DeLaurentis, D. (2004) System-of-Systems Symposium: Report on a Summer Conversation Potomac Institute for Policy Studies, Arlington, VA. pp. 21–22.

Prat, N., Comyn-Wattiau, I. and Akoka, J. (2015) A Taxonomy of Evaluation Methods for Information Systems Artifacts. Journal of Management Information Systems. 32 (3), pp. 229–267. DOI:10.1080/07421222.2015.1099390.

Prat, N., Comyn-Wattiau, I. and Akoka, J. (2014) Artifact evaluation in information systems design science research - A holistic view. In: Proceedings - Pacific Asia Conference on Information Systems, PACIS 2014. 2014 Chengdu, China. pp. 23.

Pries-Heje, J., Baskerville, R. and Venable, J. (2008) Strategies for design science research evaluation. In: Association for Information Systems (ed.). 16th European Conference on Information Systems, ECIS 2008. 2008 Galway, Ireland. pp. 1-13. Paper 87.

Prud'hommeaux, E. and Seaborne, A. (2008) SPARQL Query Language for RDF. Available from: https://www.w3.org/TR/rdf-sparql-query/.

PTC (2011) Addressing the Change and Configuration Management Imperative how to overcome your five toughest challenges process can cut up to. Best Practice White Paper. Available from: https://www.isa.org/standards-and-publications/isa-publications/intech-magazine/white-papers/.

Ranka, S., Banerjee, A., Biswas, K.K., Dua, S., Mishra, P., Moona, R., Poon, S.-H. and Wang, C.-L. (2010) Contemporary Computing: Third International Conference, IC3 2010, Noida, India, August 9-11, 2010. Proceedings. S. Ranka, A. Banerjee, K.K. Biswas, S. Dua, P. Mishra, R. Moona, S.-H. Poon, and C.-L. (Eds.) Wang (eds.). Berlin, Germany: Springer-Verlag Berlin Heidelberg.

Raygan, R.E. (2008) Configuration management in a system-of-systems environment delivering IT services. In: IEEE International Engineering Management Conference, Europe (IEMC-Europe-2008). 2008 Estoril, Portugal: IEEE. pp. 330–335.

SAE International (2011) EIA-649-B: Technical Report: Configuration Management Standard SAE International.

Sage, A. and Cuppan, C. (2001) On the Systems Engineering and Management of Systems of Systems and Federations of Systems. Information Knowledge Systems Management. 2 (4), pp. 325–345.

Samhan, A., Odeh, M., Sa, J. and Kossmann, M. (2016) OntoSoS.CM: A business process architecture driven and semantically enriched change management framework for systems of systems engineering. In: ISSE 2016 - 2016 International Symposium on Systems Engineering - Proceedings Papers. 2016 DOI:10.1109/SysEng.2016.7753178.

Saunders, M., Lewis, P. and Thronhill, A. (2009) Research methods for business students. 5th edition. Harlow, Essex, England: Pearson Education Ltd.

Sekine, J., Suenage, T., Yano, J., Nakagawa, K. and Yamamoto, S. (2009) A Business Process-IT Alignment Method for Business Intelligence. In: T. Halpin (ed.). Enterprise, Business-Process and Information Systems Modeling. BPMDS 2009, EMMSAD 2009. Lecture Notes in Business Information Processing, vol 29. Berlin Heidelberg: Springer, Berlin, Heidelberg. pp. 46–57. DOI: https://doi.org/10.1007/978-3-642-01862-6_5.

Siegel, J. (2014) Model Driven Architecture (MDA): MDA Guide Revised.

Silvius, A.J.G. (2007) Business & IT alignment in theory and practice. In: Proceedings of the Annual Hawaii International Conference on System Sciences 2007. IEEE. pp. 211b-211b. DOI:10.1109/HICSS.2007.119.

Simon, H. (1996) The Science of Artificial. 3rd edition. London, England: MIT Press.

Slimani, T. (2015) Ontology development: A comparing study on tools, languages and formalisms. Indian Journal of Science and Technology. 8 (24), pp. 1–12. DOI:10.17485/ijst/2015/v8i34/54249.

Smith, B. (2002) Ontology and Information Systems. Science [online]. (1964), pp. 1–97. Available from: http://ontology.buffalo.edu/ontology_long.pdf.

Smith, M., Welty, C. and McGuinness, D. (2004) OWL web ontology language overview. Available from: https://www.w3.org/TR/owl-guide/ [Accessed 29 August 2019].

Sommerville, I. (2016) Software Engineering (10th edition). 10th edition. Essex, England: Pearson Education Limited.

Sonnenberg, C. and Brocke, J. vom (2012) Evaluations in the Science of the Artificial – Reconsidering the Build-Evaluate Pattern in Design Science Research. In: DESRIST: International Conference on Design Science Research in Information Systems. 2012 Las Vegas, NV, USA: Springer, Berlin, Heidelberg. pp. 381–397. DOI: https://doi.org/10.1007/978-3-642-29863-9_28.

Soomro, K. (2016) HyDRA - Hybrid Workflow Design Recommender Architecture. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Sun, Y. and Couch, A. (2008) Complexity of system configuration management. In: Jan Bergstra and Mark Burgess (eds.). Handbook of Network and System Administration. Switzerland: ELSEVIER B.V. pp. 623–651. DOI:10.1016/B978-044452198-9.50025-2.

Tarrani, M. (2012) Configuration, Change, and Release Management Policies and Procedures Guide [online]. Available from: http://www.processdox.com/ConfigChangeReleaseMgmt.pdf [Accessed 7 December 2016].

Taye, M. (2010) Understanding Semantic Web and Ontologies: Theory and Applications. Journal of Computing. 2 (6).

Tbaishat, D., Odeh, Y., Tbakhi, A. and Odeh, M. (2018) Deriving Object-based Business Process Architectures Using Role-based Business Process Models: A Reverse-Engineering Approach Applied to the Cell Therapy and Applied Genomics in a Cancer Care Organisation. In: Proceedings - 2018 1st International Conference on Cancer Care Informatics, CCI 2018. 2018 Amman, Jordan. pp. 119–124. DOI:10.1109/CANCERCARE.2018.8618214.

Toledo-Pereyra, L.H. (2012) Research Design. Journal of Investigative Surgery [online]. 25 (5), pp. 279–280. Available from: https://doi.org/10.3109/08941939.2012.723954%0 DOI:10.3109/08941939.2012.723954.

Vaishnavi, V. and Kuechler, W. (2004) Design Research in Information Systems.

Venable, J., Pries-Heje, J. and Baskerville, R. (2012) A comprehensive framework for evaluation in design science research. In: DESRIST 2012. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Vo; 7286. 2012 Las Vegas, NV, USA: Springer, Berlin, Heidelberg. pp. 423–438. DOI:10.1007/978-3-642-29863-9_31.

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), pp. 77–89.

W3C OWL Working Group (2012) OWL 2 Web Ontology Language Document Overview (Second Edition). Available from: https://www.w3.org/TR/owl2-overview/ [Accessed 9 September 2019].

Whitgift, D. (1991) Methods and tools for software configuration management. Journal of Software Maintenance: Research and Practice. 6 (2), pp. 102–103. DOI:10.1002/smr.4360060207.

Xu, Y., Malisetty, M.K. and Round, M. (2013) Configuration management in aerospace industry. Procedia CIRP. 11 pp. 183–186. DOI:10.1016/j.procir.2013.07.052.

Yang, L., Cormican, K. and Yu, M. (2019) Ontology-based systems engineering: A state-of-the-art review. Computers in Industry. 111 pp. 148–171. DOI: https://doi.org/10.1016/ j.compind.2019.05.003.

Yin, R. (2014) Case Study Research Design and Methods. 5th edition. California, USA: Sage Publication Ltd.

Ying, L., Lijun, X. and Wei, S. (2009) Key Issues for Implementing Configuration Management. In: International Symposium on Web Information Systems and Applications (WISA 2009). 2009 Nanchang, China: Academy Publisher. pp. 347–350.

Youn, S. and McLeod, D. (2006) Ontology Development Tools for Ontology-Based Knowledge Management. In: Mehdi Khosrow-Pour (ed.). Encyclopaedia of E-Commerce, E-Government, and Mobile Commerce. IGI Global. pp. 858–864. DOI:10.4018/978-1-59140-799-7.ch138.

Yousef, R. (2010) BPAOntoSOA: a semantically enriched framework for deriving SOA candidate software services from Riva-based business process architecture. PhD thesis, Software Engineering Research Group, the University of the West of England, Bristol, United Kingdom.

Yousef, R. and Odeh, M. (2014) The srBPA Ontology: Semantic Representation of the Riva Business Process Architecture. International Journal of Computer Science Issues (IJCSI). 11 (2), pp. 84.

Zeller, A. and Snelting, G. (1997) Unified Versioning through Feature Logic. ACM Transactions on Software Engineering and Methodology. 6 (4), pp. 398–441

Zhang, M., Chen, H. and Luo, A. (2018) A Systematic Review of Business-IT Alignment Research with Enterprise Architecture. IEEE Access. 6 pp. 18933–18944. DOI:10.1109/ ACCESS.2018.2819185.

Appendices

APPENDIX - A: IDENTIFIED CHM- EBES AND UOWS LISTS

TIL (AXELOS, 2011)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Proposal	67	An EBE	Not UOW, (input)
Change Creation	69	An EBE	**A UOW**
Change	69	An EBE	= RFC Submission
Request for Change (RFC)	69	An EBE	= RFC Submission
Change Request (CR)	69	An EBE	= RFC Submission
Raising an RFC	69	Not an EBE (a/an)	Not a UOW
Request For Change Submission	71	An EBE	**A UOW**
Change Request Initiator	69	Not an EBE, (Role out of scope)	Not a UOW
Individual, (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Organisation (As a request initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Business Unit, (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Problem Management Staff (initiator)	69	Not an EBE, (Role out of scope)	Not a UOW
Major change	69	An EBE	A type of a Change
Change Proposal	69	An EBE	A type of a Change Request
Change Record	70 65	An EBE	Not a UOW, (Output)
Change Document	71	An EBE	= Change Record
Configuration Management System (CMS)	71	An EBE	Not a UOW, (Lifetime)
CMS Information Update	71	An EBE	**A UOW**
Change Logging	71	An EBE	= RFC logging
RFC Logging	71	An EBE	**A UOW**
Change Documentation (from documenting)	71	An EBE	**A UOW**
Change Recordation	69, 71	An EBE	= RFC Documentation
RFC Form	71	An EBE	Not a UOW (An output from the process)
Paper-based RFC Form	71	A DBE	A type of an RFC Form
Email-based RFC Form	71	A DBE	A type of an RFC Form
Web-based RFC Form	71	A DBE	A type of an RFC Form
ID number Allocation to CR	71	An EBE	In RFC Logging
Problem Report	71	An EBE	Not a UOW, (lifetime)
Change Documentation Update	71	An EBE	= Change Documentation
Trigger number Allocation to CR	73	An EBE	In RFC Logging
Integrated Service Management Tool	73	A DBE	Not a UOW, (Lifetime)
Change Management Log	73	An EBE	Not a UOW, (Part of the CMS)
RFC Review	73	An EBE	**A UOW**
RFC Validation	73	An EBE	= RFC Review
Change Management Authority	73	An EBE	Not a UOW, (a Role)
RFC Rejection	73	An EBE	Part of the RFC Review
RFC Approval	73	An EBE	Part of the RFC Review
Feedback to the change Initiator	73	An EBE	**A UOW**
Change Management Log Update	73	An EBE	In CMS Information Update
Change Assessment and Evaluation	73	An EBE	**A UOW**
Work Order	71	A DBE	Not a UOW, (output)
Assessment Work Orders Issuance	71	A DBE	**A DUOW**
Significant Change	73	An EBE	A Type of a Change

Formal Change Evaluation	73	An EBE	**A UOW**
Formal Evaluation Request	73	An EBE	= Formal Change Evaluation
Formal Evaluation Request	73	An EBE	Not a UOW, (output)
Evaluation Plan	73/17	An EBE	Not UOW, (lifetime)
Change Authority	73	An EBE	Not a UOW, (Role)
Change Assignment to a Change Authority	74	An EBE	**A UOW**
Impact & Resource Assessment	74	An EBE	**A UOW**
Impact Assessment Form	74	A DBE	Not a UOW, (output)
Impact Assessor	74	An EBE	Not a UOW, (Role)
Stakeholder (As a Change Authority)		An EBE	Not a UOW, (Role)
Change Advisory Board (CAB) (As a Change Authority)	74	An EBE	Not a UOW, (Role)
Emergency CAB (ECAB) (As a Change Authority)	74	An EBE	Not a UOW, (Role)
Risk & Benefits -based Assessment	74	An EBE	**A UOW**
IT perspective Assessment	75	An EBE	In Impact Assessment
Business perspective Assessment	75	An EBE	In Impact Assessment
Change Evaluation Output	75	An EBE	An output of the Evaluation
Category & Urgency Check	76	An EBE	**A UOW**
Change Build & Test Authorisation	78	An EBE	**A UOW**
Change Authority (for disposition and authorising)	78	An EBE	Not a UOW, (Role)
Change authority level Identification	78	An EBE	**A UOW**
Change Authority Authorisation	78	An EBE	**A UOW**
Authorization Hierarchy	78	An EBE	Not a UOW, (lifetime)
Change Authorisation Escalation	78	An EBE	In Change Authority Level Identification
Formal Change Authorisation	78	An EBE	Not a UOW, (output)
Local Authority	78	An EBE	Not a UOW, (Role)
Change Manager	78	An EBE	Not a UOW, (Role)
CAB or ECAB	78	An EBE	Not a UOW, (Role)
IT management board or IT steering group	78	An EBE	Not a UOW, (Role)
Business executive board	78	An EBE	Not a UOW, (Role)
Change Priority Allocation	76	An EBE	**A UOW**
Immediate (priority)	76	An EBE	A Type of a change priority
Urgent (Priority)	76	An EBE	A Type of a change priority
High (priority)	76	An EBE	A Type of a change priority
Medium (priority)	76	An EBE	A Type of a change priority
Low (priority)	76	An EBE	A Type of a change priority
Appeal	79	An EBE	**UOW**
Change Approval	79	An EBE	Part of the Authorisation Process
Change Rejection	79	An EBE	Part of the Authorisation Process
Rejected Change Review and Closure	79	An EBE	**A UOW**
Change Planning & Scheduling	76	An EBE	**A UOW**
Change Management	77	An EBE	Not a UOW, (Role)
Customer (To agree the Schedule and plans)	77	An EBE	Not a UOW, (Role)
Service Level Management (To agree the Schedule and plans)	77	An EBE	Not a UOW, (Role)
Service Desk (To agree the Schedule and plans)	77	An EBE	Not a UOW, (Role)
Service Provider/Management (To agree the Schedule and plans)	77	An EBE	Not a UOW, (Role)
Change Planning	76	An EBE	**A UOW**
Change Scheduling	76	An EBE	**A UOW**
Production and Distribution of a change schedule	77	An EBE	In Change Scheduling

Change projected service outage	77	An EBE	**A UOW**
Production and Distribution of a projected service outage	77	An EBE	In Change PSO
Change plans, schedule and PSO Agreement with other stakeholders	77	An EBE	**A UOW**
Release and Deployment planning	77	An EBE	**A UOW**
Release windows plan	77	An EBE	In Change Planning and Scheduling
Throughput of Change plan	77	An EBE	In Change Planning and Scheduling
Throughput of releases plan	77	An EBE	In Change Planning and Scheduling
Remediation Planning	78, 79	An EBE	**A UOW**
Remediation Assessment	78, 79	An EBE	**A UOW**
Remediation Plan	78	An EBE	(Output of the Remediation Planning)
Mitigation plan	78	An EBE	= Remediation Plan
Change Build Coordination	79	An EBE	**A UOW**
Release and Deployment Management	79	An EBE	Not a UOW, a Role
Authorised Change Submission to Relevant Technical Groups	79	An EBE	**A UOW**
Work Orders	79	DBE	Not a UOW, (Output)
Work Orders Issuance		DBE	In Authorised Change Submission to Technical Groups
Change Build	79	An EBE	**A UOW**
Thorough Test Coordination	79	An EBE	**A UOW**
Change Testing	79	An EBE	**A UOW**
Change Deployment Authorisation	79	An EBE	**A UOW**
Design, Build and Test Evaluation Coordination	79	An EBE	**A UOW**
Design, Build and Test Evaluation Check	79	An EBE	**A UOW**
Interim evaluation report for Build and Test	79	An EBE	Not a UOW, (Output)
Interim evaluation report Review	79	An EBE	**A UOW**
Evaluation Results submission to Change Authority	79	An EBE	**A UOW**
Change Authority (To authorise change deployment)	79	An EBE	Not a UOW, (Role)
Change Release and Deployment Management	79	An EBE	Not a UOW, (Role)
Change deployment Approval	79	An EBE	Part of the deployment authorisation process
Formal Change Deployment Authorisation	79	An EBE	Output of Deployment Authorisation
Change to design or deployment schedule request	79	An EBE	**A UOW**
Change Deployment Coordination	79	An EBE	**A UOW**
Change Deployment as scheduled	79	An EBE	**A UOW**
Change Remediation	79	An EBE	**A UOW**
Change Review	79	An EBE	**A UOW**
Formal Change Evaluation Initiation	79	An EBE	**A UOW**
Change Evaluation Process Management	79	An EBE	Not a UOW, (Role)
Change Check	79	An EBE	**A UOW**
Formal Change Evaluation Process	79	An EBE	Not a UOW, (lifetime)
Formal Change Evaluation Request	79	An EBE	Not a UOW, (Output)
Formal Change Evaluation Report	79	An EBE	Not a UOW, (Output)
-Other types of Change-Verification	79	An EBE	In Change Review

Evaluation of any incidents arising as a result of the change	80	An EBE	Included in the Review Process
verification results Approval	80	An EBE	Part of the Review Process
verification results Rejection	80	An EBE	Part of the Review Process
Post-implementation review	80	An EBE	= Change Review
Spot checking of Change	80	DBE	A Type of a Review
Sampling	80	DBE	A Type of a Review
Change Management	80	An EBE	Not a UOW, (Role)
CAB	80	An EBE	Not a UOW, (Role)
Review results Communication	80	An EBE	**A UOW**
Revised RFC To include follow up actions	80	An EBE	May result based on the review process
Follow up action	80	An EBE	**A UOW**
Submission of revised RFC	80	An EBE	Included in follow up action
Change Record Closure	79	An EBE	**A UOW**
logging system Update	80	An EBE	**A UOW**
Change Management Staff	73	An EBE	Not a UOW, (Role)
Change Log	80	An DBE	Output of managing a change

SW-Engineering Book (Sommerville, 2016)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
System Stakeholder (AS **Change Requester** in the diagram)	747	Not an EBE, (Role)	Not a UOW
Customer (As a CR initiator)	747	Not an EBE	Not a UOW
System Owner (As a CR initiator)	747	Not an EBE	Not a UOW
System User (As a CR initiator)	747	Not an EBE	Not a UOW
Beta Tester (As a CR initiator)	747	Not an EBE	Not a UOW
Marketing Department (As a CR initiator)	747	Not an EBE	Not a UOW
Developer (As a CR initiator)	747	Not an EBE	Not a UOW
Change Request Submission	747	An EBE	**A UOW**
Change Request (CR)	746/ 747	An EBE	Output of CR Submission
Bug Report	747	An EBE	= CR
Additional functionality Request	747	An EBE	= CR
Change Request Form (CRF)	747	A DBE	Not a UOW, (output)
Electronic CRF	747	A DBE	A Type of a CRF
CR Validity Check	748	An EBE	**A UOW**
Validity Checker	748	An EBE	Not a UOW, (Role)
Customer Support (As a CR Validity Checker)	748	An EBE	Not a UOW, (Role)
Application Support (As a CR Validity Checker)	748	An EBE	Not a UOW, (Role)
Member of the Development Team (As a CR Validity Checker)	748	An EBE	Not a UOW, (Role)
CR Rejection	748	An EBE	Part of the RFC Validity Check
Change Request Closure (if not valid)	748	An EBE	**A UOW**
CR Approval	748	An EBE	Part of the RFC Validity Check
CR Logging	748	An EBE	**A UOW**
CRF Update	747	An EBE	**A UOW**
Change Assessment and Costing	748	An EBE	**A UOW**
Change Assessment and Costing Analyser	747	An EBE	Not a UOW, (Role)
Development Team	748	An EBE	Not a UOW, (Role)

As an Analyser			
Maintenance Team As an Analyser	748	An EBE	Not a UOW, (Role)
Change Impact Check	748	An EBE	= Change Impact Analysis
Change Impact Report	748	An EBE	Not a UOW, (output)
Components Identification	748	An EBE	In Change Impact Analysis
Change Implementation Cost	748	An EBE	In Change Cost Analysis
Change Assessment to System Modules	748	An EBE	In Change Impact Analysis
Change Cost Estimation	748	An EBE	= Change Cost Analysis
Change Implementation Analysis	746	An EBE	**A UOW**
Change Impact Analysis	746	An EBE	**A UOW**
Change Cost Analysis	746	An EBE	**A UOW**
Technical Analysis	748	An EBE	In Change Assessment and Costing
Change Control Board (CCB)	748	An EBE	Not a UOW, (Role)
Product Development Group	748	An EBE	Not a UOW, (Role)
Change Assessment and Review (by the CCB)	748	An EBE	**A UOW**
Change Acceptance	748	An EBE	Part of the Change Assessment and Review Process
Change Rejection	748	An EBE	Part of the Change Assessment and Review Process
Accepted change Prioritisation	748	An EBE	**A UOW**
Release Decisions	748	An EBE	Output of Disposition
Rejected Change Closure	749	An EBE	**A UOW**
Accepted Change Submission to the development group	748	An EBE	**A UOW**
Development Group	747/ 748	An EBE	Not a UOW, Role
Change Implementer	747	An EBE	Not a UOW, Role
SW Modification	746	An EBE	**A UOW**
New SW Test	746	An EBE	**A UOW**
CR Closure	746	An EBE	**A UOW**
Derivation History Record of a Component	750	A DBE	Not a UOW, (output)
Component Change Report	750	An EBE	Not a UOW, (output)
SW-CM Handbook (Leon, 2015)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Initiation	86	An EBE	**A UOW**
Request for Change (RFC)	86	An EBE	= RFC Submission
RFC Submission	86	An EBE	**A UOW**
Change Originator	86/87	Not an EBE, (Role)	Not a UOW
Developer (As a Change originator)	86	Not an EBE, (Role)	Not a UOW
Member of the QA team (As a Change originator)	86	Not an EBE, (Role)	Not a UOW
Reviewer (As a Change originator)	86	Not an EBE, (Role)	Not a UOW
User (As a Change originator)	86	Not an EBE, (Role)	Not a UOW
Change Request Form (CRF)	86	A DBE	Not a UOW, (output)
Problem Report (PR)	86	An EBE	= Change Request
Specification Change Notice	86	An EBE	= Change Request
Electronic CRF	87	A DBE	A Type of a CRF
Configuration Management Officer (CMO)	87	An EBE == Receiving Authority	Not a UOW (A Role)
Member of the SCM team == Receiving Authority	87	An EBE	Not a UOW (A Role)
CR Review (for clarity and completeness) (By the receiver)	87	An EBE	**A UOW**

Feedback to the CR originator	87	An EBE	**A UOW**
Tracking number Assignment	87	An EBE	**A UOW**
Initial classification Assignment	87	An EBE	In Change Classification
CR -tracking database / files-Update	87	An EBE	**A UOW**
Approval Authority Hierarchy	88	An EBE	Not UOW, (Lifetime)
Change Classification	88	An EBE	**A UOW**
SCM Plan	88	An EBE	Not UOW, (Lifetime)
Major change	88	An EBE	A Type of change
Minor change	88	An EBE	A Type of change
Change Management Officer	88	An EBE	Not a UOW, (Role)
Receiving authority	88	An EBE	Not a UOW, (Role)
Classification Criteria	88	An EBE	Not UOW, (Lifetime)
Change Evaluation & Analysis	88	An EBE	**A UOW**
Pre-Evaluation Screening	88	An EBE	**A UOW**
Change Management (doing pre-evaluation screening)	88	An EBE	Not a UOW, (Role)
Change Management Officer (doing pre-evaluation screening)	88	An EBE	Not a UOW, (Role)
CR Rejection	88	An EBE	Part of the pre-evaluation screening
CR Approval	88	An EBE	Part of the pre-evaluation screening
Change Impact Analysis	88	An EBE	**A UOW**
Impact to systems functionality	88	An EBE	In Change Impact Analysis
Impact to interfaces	88	An EBE	In Change Impact Analysis
Impact to Utility	88	An EBE	In Change Impact Analysis
Impact to Cost	88	An EBE	In change impact analysis
Impact to Schedule	88	An EBE	In Change Impact Analysis
Impact to Contractual Requirements	88	An EBE	In Change Impact Analysis
Impact on Software Safety	88	An EBE	In Change Impact Analysis
Impact on Software Reliability	88	An EBE	In Change Impact Analysis
Impact on SW Maintainability	88	An EBE	In Change Impact Analysis
Impact on SW Transportability	88	An EBE	In Change Impact Analysis
Impact on SW Efficiency	88	An EBE	In Change Impact Analysis
Software Engineering Staff	88	An EBE	Not a UOW, (Role)
Change Analysis Documentation	88	An EBE	Not a UOW, (Output)
Change Package	88	An EBE	Not a UOW, (Output)
Change Package Update	88	An EBE	**A UOW**
Change Package Submission to the CCB	88	An EBE	**A UOW**
Change Disposition	89	An EBE	**A UOW**
Change Authority Disposition	89	An EBE	**A UOW**
CCB	89	An EBE	Not a UOW, (Role)
Change documentations and Analysis Documents Review	89	An EBE	Part of the Change Disposition Process
Change Approval	89	An EBE	Part of the Change Disposition Process
Change Disapproval	89	An EBE	Part of the Change Disposition Process
Change Deferment	89	An EBE	Part of the Change Disposition Process
Feedback to Originator	89	An EBE	**A UOW**
Change Rejection Feedback to Originator	89	An EBE	An output of the Disposition feedback
Filed Differed CR for later resolution	89	An EBE	An output of the Disposition
CMO	89	An EBE	Not a UOW, (Role)
Project Leader (As an Authority management)	89	An EBE	Not a UOW, (Role)
CR Record Update	89	An EBE	**A UOW**
Analysis Group	89	An EBE	Not a UOW, (Role)
Approved Change Submission to CMO	89	An EBE	**A UOW**

Minutes of Meeting Preparation and Distribution	89	An EBE	**A UOW**
Evaluation Reports	90	An EBE	Not a UOW, an Output
Impact Analysis Reports	90	An EBE	Not a UOW, an Output
Approved Change Submission to the development team	89	An EBE	**A UOW**
Change Implementation	90	An EBE	**A UOW**
Change Authorisation Form	90	An EBE	Not a UOW, (Output)
Change Directive	90	An EBE	Not a UOW, (Output)
Instructions Issuance (Change directives)	90	A DBE	Included in Approved Change submission to the development team
Development Team To implement and test	90	An EBE	Not a UOW, (Role)
Baseline Component	90	An EBE	Not UOW, (Lifetime)
Program Library	90	An EBE	Not UOW, (Lifetime)
Resources Schedule	90	An EBE	**A UOW**
Design Development	90	An EBE	**A UOW**
Items Check out from Configuration library	86	An EBE	**A UOW**
Change Coding	90	An EBE	**A UOW**
Change Testing (Local testing)	90	An EBE	**A UOW**
Associated Documentation Revision	90	An EBE	**A UOW**
New Items Check into the configuration library	86	An EBE	**A UOW**
change implementation information Recordation	90	An EBE	**A UOW**
Change Verification	90	An EBE	**A UOW**
Change Verification at system level	90	An EBE	Included in the verification process
Reviewing Team/Authority	90	An EBE	Not a UOW, (Role)
Regression Test	90	An EBE	Included in the verification process
Implementation Information	90	An EBE	records about the build and testing
Verification evidence Submission to program library	90	An EBE	**A UOW**
Change/Patch History	90	An EBE	records about the build and testing
Change Items Disposition	90	An EBE	**A UOW**
New baseline	90	An EBE	Not a UOW, (Lifetime)
Occurrence Recordation	90	An EBE	**A UOW**
Change history Update	90	An EBE	**A UOW**
Baseline Change Control	91	An EBE	= Baseline Release
Baseline Release	91	An EBE	**A UOW**
Product release	91	An EBE	A Type of a Release
Major release	91	An EBE	A Type of a Release
Minor Release	91	An EBE	A Type of a Release
Customer-specific release	91	An EBE	A Type of a Release
Alpha release	91	An EBE	A Type of a Release
Beta Release	91	An EBE	A Type of a Release
Release Information	91	An EBE	Not UOW, (Output)
Release Authority	91	An EBE	Not a UOW, Role
Change Items promotion to new baseline	86	An EBE	Included in release
New SW Version release	86	An EBE	= baseline release
EIA-649 B – 2011 (SAE International, 2011)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Impacted areas of responsibility	33	An EBE	Not a UOW, Role
Change Initiation	35	An EBE	**A UOW**
Request for Change Management	34	An EBE	= Change Initiation
Change	34	An EBE	= RFC
Request for Change (RFC)	34	An EBE	**A UOW**
Request for Change Document	34/35/ 36	An EBE	An output of the RFC submission

Product	34	An EBE	Not UOW, (Lifetime)
Product Configuration Information	34	An EBE	Not UOW, (Lifetime)
Request for Variance	34	An EBE	A type of FRC
Baseline	34	An EBE	Not UOW, (Lifetime)
Current Baseline	34	An EBE	A Type of Baseline
New Baseline	34	An EBE	A Type of Baseline
Change Justification Provision	35	An EBE	**A UOW**
Configuration Change	35	An EBE	= Change
Preliminary Change Coordination	35	An EBE	**A UOW**
Justification and Assessment Authority	35	An EBE	Not a UOW, (Role)
Affected personnel and interfacing organisations.	35	An EBE	Not a UOW, (Role)
with: Requirers	35	An EBE	Not a UOW, (Role)
with: Designers	35	An EBE	Not a UOW, (Role)
with: Manufacturers	35	An EBE	Not a UOW, (Role)
with: Customers	35	An EBE	Not a UOW, (Role)
with: Safety Providers	35	An EBE	Not a UOW, (Role)
with: Quality Provider	35	An EBE	Not a UOW, (Role)
with: Planning Provider	35	An EBE	Not a UOW, (Role)
with: Scheduling Provider	35	An EBE	Not a UOW, (Role)
with: Cost Provider	35	An EBE	Not a UOW, (Role)
with: Test Provider	35	An EBE	Not a UOW, (Role)
with: Reliability Provider	35	An EBE	Not a UOW, (Role)
with: Maintainability Provider	35	An EBE	Not a UOW, (Role)
With: Producibility Provider	35	An EBE	Not a UOW, (Role)
Preliminary assessment	35	An EBE	Not a UOW, (Output)
Change Benefits Assessment	35	An EBE	Not a UOW, (Output)
Change Risks Assessment	35	An EBE	Not a UOW, (Output)
Change Timing Assessment	35	An EBE	Not a UOW, (Output)
Change Cost Assessment	35	An EBE	Not a UOW, (Output)
Change Resources assessment	35	An EBE	Not a UOW, (Output)
Change Justification	35	An EBE	Not a UOW, (Output)
Change Identification	35	An EBE	**A UOW**
Change Identifier	35	An EBE	In change identification
Identifier Assignment to a RFC	35	An EBE	In change identification
RFC identifier Reflection	36	An EBE	In change identification
Change Classification	36	An EBE	**A UOW**
Classification Criteria	36	An EBE	Not a UOW, lifetime is not under ChM
Change impact Categorisation	36	An EBE	In change classification
Approval Authority Level Identification	36	An EBE	**A UOW**
Approval Authority	36	An EBE	Not a UOW, (Role)
Major Change	36	An EBE	A Type of a Change
Significant Change	36	An EBE	= Major Change
Minor Change	36	An EBE	A Type of a Change
Documented Criteria for the identification of Approval Authority	37	An EBE	Not UOW, (Lifetime)
Change Documentation	37	An EBE	**A UOW**
Request for Change Document	37	An EBE	Not a UOW, (Output)
Implementation Plans	37	An EBE	Included in the RFC Documentation
Delivery Schedules	37	An EBE	Included in the RFC Documentation
Change Coordination	37, 39	An EBE	**A UOW**
Affected party	37, 39	An EBE	Not a UOW, (Role)
Change Evaluation	37, 39	An EBE	**A UOW**
Change Board	38	An EBE	Not a UOW, (Role)

Team	38	An EBE	Not a UOW, (Role)
Committee	38	An EBE	Not a UOW, (Role)
Program Review Board	38	An EBE	Not a UOW, (Role)
Configuration Control Board	38	An EBE	Not a UOW, (Role)
Change Review Board	38	An EBE	Not a UOW, (Role)
Disposition Related Authority	38	An EBE	Not a UOW, (Role)
Assessment Instruction to Impacted Parties	39	An EBE	**A UOW**
Impact Documentation	39	An EBE	**A UOW**
Impacted- products, components, and product configuration information- Identification	39	An EBE	**A UOW**
Implementation schedule Determination	39	An EBE	**A UOW**
Proposed Implementation Cost Development	39	An EBE	**A UOW**
Assessment Output Integration to RFC	39	An EBE	**A UOW**
Basic Change Plan and Schedule Determination	40	An EBE	**A UOW**
Integrated RFC Submission to the approval Authority	39	An EBE	**A UOW**
Integrated RFC	39	An EBE	Not a UOW, (Output)
Requested Change Disposition	37, 39	An EBE	**A UOW**
Change Authority Evaluation and Disposition	39	An EBE	**A UOW**
RFC Approval	39	An EBE	Part of the Requested Change Disposition Process
RFC Deferment	39	An EBE	Part of the Requested Change Disposition Process
RFC Disapproval	39	An EBE	Part of the Requested Change Disposition Process
RFC Scope/Effectivity Review	39	An EBE	Part of the Requested Change Disposition Process
Disposition Results Dissemination to Affected Parties	39	An EBE	**A UOW**
Implementation & Verification Planning	40	An EBE	**A UOW**
Implementation actions direction	39	An DBE	**A DUOW**
Implementation Coordination	40	An EBE	**A UOW**
Approved Change Implementation	39	An EBE	**A UOW**
Detailed Implementation Planning	40	An EBE	**A UOW**
Detailed Verification Planning	41	An EBE	**A UOW**
Product Definition Information Update and Release	40	An EBE	**A UOW**
Operation and Maintenance, and Sales Information Update and Release	40	An EBE	**A UOW**
Build & Test Information Update and Release	40	An EBE	**A UOW**
Correlated Documents Revision	40	An EBE	**A UOW**
Planning and Implementation Authorities	40	An EBE	Not a UOW, Role
Product Definition Information / Product Configuration Information	40	An EBE	Not a UOW, (Output)
Mfg/Prod/Test Instructions Revision	41	An EBE	Included in implementation and verification
Ordering Data Update	41	An EBE	Included in implementation and verification

Operation and Maintenance Information Update	41	An EBE	Included in implementation and verification
Documents Changes Dissemination	40	An EBE	**A UOW**
Change Notice	40	DBE	Included in documents Change dissemination
Formal Verification Coordination	39	An EBE	**A UOW**
Verification and Auditing Authority	50	An EBE	Not a UOW, Role
Consistency Check	50	An EBE	Included in the formal verification process
CCRM (Tarrani, 2012)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Request Initiator	8	An EBE	Not a UOW, (Role)
Configuration Control Manager	8	An EBE	Not a UOW, (Role)
Test Plan	9	An EBE	An output
Process Owner	14/15	An EBE	Not a UOW, Role
Change Request Preparation and Submission	19	An EBE	**A UOW**
Help Desk (As a Request Receiver)	19	An EBE	Not a UOW, (Role)
Change request Fill-in	19	An EBE	In Preparation and Submission
User (As a Request Initiator)	19	Not an EBE, (Role)	Not a UOW
Vendor (As a Request Initiator)	19	Not an EBE, (Role)	Not a UOW
IT Department (As a Request Initiator)	19	Not an EBE, (Role)	Not a UOW
Request Initiator	21	Not an EBE, (Role)	Not a UOW
Help Desk Call	19	A DBE	In Preparation and Submission
Change Priority Identification (by initiator)	19	An EBE	In Preparation and Submission
CRF Submission	19	An EBE	In Preparation and Submission
Change Request	19	An EBE	= Change Preparation and Submission
Change Request Form	8/19	A DBE	Not a UOW, (Output)
Change Request Identification	19	An EBE	**A UOW**
Change Request Logging	20	An EBE	In CR Identification
Control Number Assignment to Change Request	20	An EBE	In CR Identification
Request Priority Validation	21	An EBE	**A UOW**
Feedback to the Initiator	21	An EBE	**A UOW**
Initiation Feedback	21	An EBE	An output of the Initiation
Change reference Provision to the initiator	21	An EBE	= Feedback to the Initiator
Configuration Control Manager (CCM) Initiation resolution	21	An EBE	Not a UOW, (Role)
Assessment Criteria	24	An EBE	Not a UOW
End User-initiated Change Request	23, 47	An EBE	A Type of a Change Request
Vender-initiated Change	23	An EBE	A Type of a Change Request
IT change	23	An EBE	A Type of a Change Request
Request Initiator Supervisor's Approval	45	An EBE	In Preparation and Submission
Change Request Submission to the Configuration Control Manager (CCM)	21	An EBE	In Review Cycle Initiation
Change Request Assessment	22	An EBE	**A UOW**
Configuration Control Manager	23	An EBE	Not a UOW, (Role)
Priority Assignment	23	An EBE	**A UOW**
Review cycle Initiation	23	An EBE	**A UOW**

Subject Matter Experts and Stakeholders Review Cycle	23	An EBE	Not a UOW, A Role
Assessment Findings and Recommendations	22/23	An EBE	Not a UOW, (Output)
Findings and recommendations Compilation	23	An EBE	**A UOW**
Combined Findings and Recommendations	23	An EBE	An output of the Finding Compilation
Findings Submission to a Proper Assessment Entity	23	An EBE	**A UOW**
Assessment Entity CCB/Peer Reviewer/Subject Matter Experts/ Stakeholders	23	An EBE	Not a UOW, A Role
Cost Effectiveness	24	An EBE	Included in the Change Assessment
Technical Requirements	24	An EBE	Included in the Change Assessment
Change impact on company strategic architecture	25	An EBE	Included in the Change Assessment
Change Impact on life cycle management considerations	25	An EBE	Included in the Change Assessment
Change impact on interrelated and/or interdependent systems	25	An EBE	Included in the Change Assessment
Change impact on security	25	An EBE	Included in the Change Assessment
Change impact on data security	25	An EBE	Included in the Change Assessment
Change impact on meeting OLA's and SLA's	25	An EBE	Included in the Change Assessment
Technical, cost or schedule risks	25	An EBE	Included in the Change Assessment
Cost/Benefit and predicted return on investment	25	An EBE	Included in the Change Assessment
Change request Submission to approving Authority	25	An EBE	= Findings Submission to a Proper Assessment Entity
Change Request Cancellation	25	An EBE	**A UOW**
Change Request Approval	26	An EBE	**A UOW**
Change Disposition Decision	26	An EBE	Not a UOW, (Output)
Configuration Control Board (CCB)	27	An EBE	Not a UOW, (Role)
Approval Authority Identification Criteria	27	An EBE	Not a UOW
Change Authority Assessment and Approval	27	An EBE	**A UOW**
Peer review and/or independent verification and validation	25, 27	An EBE	In Change Authority Assessment and Approval
Unanimous agreement of the subject matter experts and stakeholders	25, 27	An EBE	In Change Authority Assessment and Approval
CCB Review	25, 27	An EBE	In Change Authority Assessment and Approval
CR Approval	27	An EBE	Part of the approval process
CR Denial	27	An EBE	Part of the approval process
Denied CR Closure	27	An EBE	**A UOW**
Rejected CR initiator Notification	27	An EBE	**A UOW**
Rejected CR Associated documentation disposal	27	An EBE	**A UOW**
Approved CR Submission to Planning phase	28	An EBE	**A UOW**
Plans/ budget /Schedule Authorization	28	An EBE	**A UOW**
Change Implementation	28	An EBE	**A UOW**
Implementation Planning	29	An EBE	**A UOW**
Personnel Resources plan	29	An EBE	Included in implementation plan
Parts and Materials Plan	30	An EBE	Included in implementation plan

Availability of alternate services Plan	30	An EBE	Included in implementation plan
Action Plan	30	An EBE	Included in implementation plan
Quality Assurance Test Plan	30	An EBE	Included in implementation plan
Release Plans & Criteria	30	An EBE	Included in implementation plan
Statement of work	30	An EBE	Included in implementation plan
Scope Definition	30	An EBE	Included in implementation plan
Dependencies	30	An EBE	Included in implementation plan
Technical cost	30	An EBE	Included in implementation plan
Schedule Risks	30	An EBE	Included in implementation plan
Implementation Scheduling	30	An EBE	**A UOW**
implementation window schedule	30	An EBE	Included in implementation Schedule
Worst-case stop time	30	An EBE	Included in implementation Schedule
Rollback point	30	An EBE	Included in implementation Schedule
Milestones for task completion	30	An EBE	Included in implementation Schedule
Milestones for QA checkpoints	30	An EBE	Included in implementation Schedule
Milestones for release into production	30	An EBE	Included in implementation Schedule
Assignment of Personnel tasks by name	30	An EBE	Included in implementation Schedule
Implementation plans and schedules Review (By approving authorities to approve or not)	30	An EBE	**A UOW**
Implementation Pre-Staging	30, 7 0	An EBE	**A UOW**
Resources availability Confirmation	30	An EBE	Included in implementation Pre-staging
Materials Staging	30	An EBE	Included in implementation Pre-staging
Preparation the system for change execution	30	An EBE	Included in implementation Pre-staging
Testing and Releasing a Change	31	An EBE	Included in implementation Pre-staging
Change Testing	32	An EBE	**A UOW**
IT Member For Implementation	32	An EBE	Not a UOW, Role
IT member For Testing	32	An EBE	Not a UOW, Role
System Owner For Testing	32	An EBE	Not a UOW, Role
Quality Assurance Inspection	70	An EBE	Included in the change test
Pre-Release Activities Plan	71	An EBE	= Testing
Test Approval	32	An EBE	Included in the change test
Signing off	70	An EBE	Included in the change test
Test Rejection	32	An EBE	Included in the change test
Change Release	33	An EBE	**A UOW**
Operational Baseline	33	An EBE	Not UOW, (Lifetime)
Status Accounting procedures Initiation	33, 72	An EBE	**A UOW**
Configuration Database Audit	38	An EBE	Not UOW, (Lifetime)
Change Request Closure	37	An EBE	**A UOW**
Help Desk	38	An EBE	Not a UOW, (Role)
Configuration Document	37	An EBE	Under the CM consideration
Notification	38	An EBE	Not a UOW, (Output)
Systems Engineering Handbook (INCOSE, 2015)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change	124	An EBE	= Request For Change
Change to a baseline	124	An EBE	= Request For Change
Baseline	124	An EBE	Not UOW, (Lifetime)
Change Identification	124	An EBE	**A UOW**
Change recordation	124	An EBE	**A UOW**

Request for Change (RFC)	124	An EBE	Output of Change Request
Request for Variance (RFV)	124	An EBE	A Type of a RFC
Request for Deviation	124	An EBE	A Type of a RFC
Configuration Management Documentation	124	An EBE	Not a UOW, (Lifetime)
Engineering Change Proposal	125	An EBE	= Request For Change
Change Request (requesting a change)	125	An EBE	**A UOW**
Customer (As a Change Requester)	125	Not an EBE, (Role)	Not a UOW
Supplier (As a Change Requester)	125	Not an EBE, (Role)	Not a UOW
Minor Change	125	An EBE	A Type of a Change
A need for change Identification	125	An EBE	In change identification
Engineering Notice	125	An EBE	A type of RFC (for minor Change)
Configuration Item	125	An EBE	Not UOW, (Lifetime)
Configuration Item Requirements	125	An EBE	Not UOW, (Lifetime)
Configuration Item Specifications	125	An EBE	Not UOW, (Lifetime)
Configuration Item Configuration Definition Document	125	An EBE	Not UOW, (Lifetime)
Configuration Item Design	125	An EBE	Not UOW, (Lifetime)
Problem Statement	126	An EBE	Not a UOW, (Output)
Proposal Change Description	126	An EBE	In problem statement
Proposal Change Justification	126	An EBE	In problem statement
Problem Report	127	An EBE	A Type of a RFC
Change Report	127	An EBE	
Specification Change Notice	127	An EBE	A Type of a RFC
Engineering Change Request	126, 127	An EBE	A Type of a RFC
Request for Waiver (Deviation)	127	An EBE	A Type of a RFC
Change Review	124	An EBE	**A UOW**
Change Affect Analysis	125	An EBE	**A UOW**
Change impact on existing plans	125	An EBE	Included in the Change Affect Analysis
Change impact on costs	125	An EBE	Included in the Change Affect Analysis
Change impact on schedule	125	An EBE	Included in the Change Affect Analysis
Impact on technical performance	125	An EBE	Included in the Change Affect Analysis
Impact of not making the change	125	An EBE	Included in the Change Affect Analysis
Change Effectivity Identification	127	An EBE	Included in the Change Affect Analysis
Review Board	127	An EBE	Not a UOW, (Role)
ECP Approval	124, 125	An EBE	**A UOW**
Change Control Board (CCB)	126	An EBE	Not a UOW, (Role)
Review Board	126	An EBE	Not a UOW, (Role)
Overall Review Board	126	An EBE	Not a UOW, (Role)
Satellite or Subordinate Review Boards	126	An EBE	Not a UOW, (Role)
RFC Processing	124	An EBE	**A UOW**
Change processing and Implementation Status Record, Track, and report	126	An EBE	**A UOW**
IEEE std. 15288-2015 (ISO/IEC/IEEE, 2015)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change	41	An EBE	= RFC
Variance	41	An EBE	= A Type of a Change
Deviation	41	An EBE	= A Type of a Change
Waiver	41	An EBE	= A Type of a Change
Concession	41	An EBE	= A Type of a Change

Baseline	41	An EBE	Not a UOW, (Lifetime)
RFC & RFV Identification	41	An EBE	**A UOW**
RFC & RFV Recordation	41	An EBE	**A UOW**
Request for Change (RFC)	41	An EBE	**A UOW**
Request for Variance (RFV)	41	An EBE	= A Type of a RFC
Request for Deviation	41	An EBE	= A Type of a RFC
Request for Waiver	41	An EBE	= A Type of a RFC
Request for Concession	41	An EBE	= A Type of a RFC
RFC & RFV Coordination	41	An EBE	**A UOW**
RFC & RFV Evaluation	41	An EBE	**A UOW**
Impact Assessment of the proposed change	41	An EBE	**A UOW**
Impact Assessment	41	An EBE	An output of the Assessment
Impact on project plans	41	An EBE	Included in the Impact Assessment
Impact on Costs	41	An EBE	Included in the Impact Assessment
Impact on Benefits	41	An EBE	Included in the Impact Assessment
Impact on Risks	41	An EBE	Included in the Impact Assessment
Impact on Quality	41	An EBE	Included in the Impact Assessment
Impact on Schedule	41	An EBE	Included in the Impact Assessment
Request Submission for review and approval	41	An EBE	**A UOW**
Configuration Control Board	41	An EBE	Not a UOW, (Role)
CCB Approval	41	An EBE	**A UOW**
Approved Change Tracking and Management	41	An EBE	**A UOW**
Approved Change_Prioritisation	41	An EBE	**A UOW**
Approved Change Schedule	41	An EBE	**A UOW**
Change and Rationales Recordation	41	An EBE	**A UOW**
Technical Processes Initiation	41	An EBE	**A UOW**
Technical Processes Related Authorities	41	An EBE	Not a UOW, Role
Verification and Validation related Authorities	41	An EBE	Not a UOW, Role
Change Closure	41	An EBE	**A UOW**
BS ISO 10007:2017 (ISO, 2017)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Related Change Documentation	4	An EBE	Not a UOW, (Output)
Change	4	An EBE	= Change Proposal
Waiver	4	An EBE	= Change Proposal
Deviations	4	An EBE	= Change Proposal
Concession	4	An EBE	= Change Proposal
Change Initiation	4	An EBE	**A UOW**
Change Identification	4	An EBE	**A UOW**
Change Documentation	4	An EBE	**A UOW**
Organization (As a Change Initiator)	4	Not an EBE, (Role)	Not a UOW
Customer (As a Change Initiator)	4	Not an EBE, (Role)	Not a UOW
External Provider (As a Change Initiator)	4	Not an EBE, (Role)	Not a UOW
Dispositioning Authority	4	An EBE	Not a UOW, (Role)
Change Proposal	4	An EBE	**A UOW**
Change Proposal Form	4	A DBE	Not a UOW, (Output)
Configuration item	4	An EBE	Not UOW, (Lifetime)
CI revision status	4	An EBE	Included in the Change Proposal
Change Category	4	An EBE	Included in the Change Proposal
Change Reason	4	An EBE	Included in the Change Proposal
Change Processing Status	4	An EBE	Included in the Change Proposal
CRF Identifier Assignment	4	An EBE	Included in the Identification Process
Change Evaluation	5	An EBE	**A UOW**
Evaluation Documentation	5	An EBE	**A UOW**

Technical benefits of the proposed change	5	An EBE	Included in the Change Evaluation
Risks Associated with the Change	5	An EBE	Included in the Change Evaluation
Impact on contract	5	An EBE	Included in the Change Evaluation
Impact on schedule	5	An EBE	Included in the Change Evaluation
Impact on costs	5	An EBE	Included in the Change Evaluation
Impact of not approving the change			
Change Disposition	5	An EBE	**A UOW**
Dispositioning Authority	2, 5	An EBE	Not a UOW, (Role)
Dispositioning Authority Identification	5	An EBE	**A UOW**
Proper documentation of the CR Check	2	An EBE	**A UOW**
Proper Categorisation of CR Check	2	An EBE	**A UOW**
Planned Activities for implementation Check	2	An EBE	**A UOW**
Change Evaluation Review	5	An EBE	**A UOW**
Disposition decision Record	5	An EBE	**A UOW**
Disposition Circulation to Relevant Parties	5	An EBE	**A UOW**
Approved change Implementation	5	An EBE	**A UOW**
Product configuration information Change	5	An EBE	**A UOW**
Relevant interested parties Action	5	An EBE	**A UOW**
Change Verification	5	An EBE	**A UOW**
Verification Recordation	5	An EBE	**A UOW**
Verification Documentation	5	An EBE	Not a UOW, (Output)
JSP 886-2015 (MoD, 2015)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Problem Report	18	An EBE	Not a UOW, (Output)
Change/Modification Proposal	18	An EBE	Not a UOW, (Output)
Documented Change Request	18	An EBE	Not a UOW, (Output)
Change Initiation	19	An EBE	**A UOW**
Change Identification	19	An EBE	**A UOW**
Change Documentation	19	An EBE	**A UOW**
System Engineering Requirements (reason for change)	19	An EBE	Not UOW, (Lifetime)
Product Attributes (altered because of change)	19	An EBE	Not UOW, (Lifetime)
Product Baseline	19	An EBE	Not UOW, (Lifetime)
Contractual standards	19	An EBE, constraints	Not UOW, (Lifetime)
Change Proposal	20	An EBE	**A UOW**
Change Proposal	20	An EBE	Not a UOW, (Output)
Change Proposal Identification	20	An EBE	= Change Identification
Change Proposal Documentation	20	An EBE	= Change Documentation
Change Evaluation	20	An EBE	**A UOW**
Classification Criteria	20	An EBE	Not a UOW
Evaluation Documentation	20	An EBE	**A UOW**
Stakeholders (Involved in the evaluation)	21	An EBE	Not a UOW, (Role)
Impact Assessment	21	An EBE	**A UOW**
Applicability Determination	21	An EBE	**A UOW**
Cost Determination	21	An EBE	**A UOW**
Evaluation Submission to Disposition Authority	21	An EBE	**A UOW**
Design Organisation (conduct assessment	21	An EBE	Not a UOW, (Role)
Authority's Representative (conduct assessment)	21	An EBE	Not a UOW, (Role)
Disposition (Approval/Rejection)	21	An EBE	**A UOW**

Configuration Change Authority (CCB)	21	An EBE	Not a UOW, (Role)
Disposition Authority Decision (Diagram)	21	An EBE	**A UOW**
Subsidiary Committee	21	An EBE	Not a UOW, (Role)
Authority's representatives	21	An EBE	Not a UOW, (Role)
CR Approval	21	An EBE	Part of the disposition process
CR Rejection	21	An EBE	Part of the disposition process
Effectivity Date of CR	21	An EBE	**A UOW**
Change incorporation	21	An EBE	**A UOW**
Implementation & Verification Planning	22	An EBE	**A UOW**
Authorised change Implementation	22	An EBE	**A UOW**
Implementation Plan	22	An EBE	**A UOW**
Verification Plan	22	An EBE	**A UOW**
Product Configuration Information Update	22	An EBE	**A UOW**
Baseline Update	22	An EBE	**A UOW**
Affected support elements Update	22	An EBE	**A UOW**
Retrofit arrangement to existing products	22	An EBE	**A UOW**
Product configuration information Release to relevant stakeholders	22	An EBE	**A UOW**
Change Implementation to actions taken by relevant stakeholders	22	An EBE	**A UOW**
Establishment of records of compliance with authorised change	22	An EBE	**A UOW**
Change Verification	22	An EBE	**A UOW**
Verification Recordation	22	An EBE	**A UOW**
In-service configuration control authority	22	An EBE	Not a UOW, (Role)
Subsidiary committee	22	An EBE	Not a UOW, (Role)
Modified product	22	An EBE	Not UOW, (Lifetime)
Updated Configuration Baseline	22	An EBE	Not UOW, (Lifetime)
BS EN 9223 -104: 2018 (BSI, 2018)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change Request	11	An EBE	Not a UOW, (Output)
Deviation Request	11	An EBE	Not a UOW, (Output)
Request For Concession	11	An EBE	Not a UOW, (Output)
Change	12	An EBE	= Change Request
Technical Change	12	An EBE	A Type of a Change
Deviation	12	An EBE	A Type of a Change
Waiver	12	An EBE	A Type of a Change
Configuration Documentation	12	An EBE	Not UOW, (Lifetime))
Statement of need	12	An EBE	= CR
Change File	13	A DBE	Not a UOW, (Output)
Engineering Change	14	An EBE	A Type of a Change
Change Request	14	An EBE	**A UOW**
Request for Engineering Change	14	An EBE	A Type of a Change Request
Technical Change Request	14	An EBE	A Type of a Change Request
Deviation permit Request	14	An EBE	A Type of a Change Request
Concession Request	14	An EBE	A Type of a Change Request
Concession	14	An EBE	A Type of a Change Request
Request Application	14	An EBE	= CR
Change Initiation		An EBE	**A UOW**
Request Originating Authority	15	An EBE	Not a UOW, Role
Customer (As a Request Initiator)	15	Not an EBE, (Role)	Not a UOW, Role
User (As a Request Initiator)	15	Not an EBE, (Role)	Not a UOW, Role

Supplier (As a Request Initiator)	15	Not an EBE, (Role)	Not a UOW, Role
Sub-contractor (As a Request Initiator)	15	Not an EBE, (Role)	Not a UOW, Role
Change Justification	15	An EBE	Included in the CR
Request Originating Authority	15	Not an EBE, (Role)	Not a UOW
Initial Impact Assessment (by originator)	15	An EBE	Included in the CR
Initial Classification (by originator)	15	An EBE	Included in the CR
Management Authority	15	An EBE	Not a UOW, (Role)
Change Request Assessment Escalation	15	An EBE	In Competent Authority Identification
Change Impact Investigation	16	An EBE	= Change Request Investigation
Bottom up analysis of the product's tree structure	16	An EBE	Included in the Change Request Investigation
Management Authority	16	An EBE	Not a UOW, (Role)
Authority Competency Assessment	16	An EBE	Included in Competent Authority Identification
Investigation results Registration	16	An EBE	**A UOW**
Competent Authority Identification	16	An EBE	**A UOW**
Change Request Investigation	26	An EBE	**A UOW**
Change Technical and Economical Feasibility	26	An EBE	**A UOW**
Change Technical and Economical impacts on the product, manufacturing and logistics	27	An EBE	**A UOW**
Go/No Go decision	27	An EBE	**A UOW**
Request submission	15	An EBE	**A UOW**
Management Authority Tree Structure	15	An EBE	Not UOW, (Lifetime)
Competency Assessment	16	An EBE	In Competent Authority Identification
Decision-Making	16	An EBE	**A UOW**
Suitable Authority Board	16	An EBE	Not a UOW, (Role)
Change Classification	17	An EBE	**A UOW**
Consistency Check	18	An EBE	Part of the Decision-making process
Configuration Item Management Authority	18	An EBE	Not a UOW, (Role)
Decision Report	18	An EBE	Not a UOW, (Output)
Provision of Implementing supporting actions	18	An EBE	In the Decision Report
Supporting Action	18	An EBE	Not UOW, (Lifetime)
Change Responsible Authority	19	An EBE	Role
Design Authority	19	An EBE	Role
Change Detailed Design	27	An EBE	**A UOW**
Change Detailed definition	27	An EBE	**A UOW**
Change impact analysis	27	An EBE	**A UOW**
Definition qualification and change validation	27	An EBE	**A UOW**
Examination of technical, financial and scheduling repercussions	28	An EBE	**A UOW**
Definition file elaboration	28	An EBE	**A UOW**
Change Implementation on product and production process	28	An EBE	**A UOW**
Detailed definition of implementation conditions	28	An EBE	**A UOW**
Modification of the documentation	28	An EBE	**A UOW**
Modification and/or update support systems	28	An EBE	**A UOW**

Establishment of measures associated to the change		An EBE	**A UOW**
configuration status Record and update		An EBE	**A UOW**
MIL-STD-3046: 2013 (DoD, 2013)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Engineering Change Proposal	20	An EBE	= ECP Submission
ECP Document	20	An EBE	Not a UOW, (Output)
Change	20	An EBE	= ECP
Engineering Change	20	An EBE	A Type of a Change
Configuration Documentation	20	An EBE	Not UOW, (Lifetime)
Change Identification	20	An EBE	**A UOW**
Change Justification	20	An EBE	**A UOW**
Change Documentation	20	An EBE	**A UOW**
Change Classification (Initial Classification)	21	An EBE	**A UOW**
Major Change	21	An EBE	A Type of a Change
Minor Change	21	An EBE	A Type of a Change
Change Originator	22	An EBE	Not a UOW, Role
Administrative Change	22	An EBE	A Type of a Change
ECP Submission (by third party originator)	22	An EBE	**A UOW**
Unique Identifier Assignment to an ECP	22	An EBE	In Change Identification
ECP Revision	22	An EBE	**A UOW**
Preliminary ECP	22	An EBE	A Type of an ECP
Formal ECP	22	An EBE	A Type of an ECP
ECP Prioritisation	23	An EBE	**A UOW**
Routine ECP	23	An EBE	In Prioritisation
Urgent ECP	23	An EBE	In Prioritisation
Emergency ECP	23	An EBE	In Prioritisation
Justification Code Assignment to an ECP	24	An EBE	In Change Justification
Request for Variance (RFV)	25	An EBE	A Type of an ECP
RFC Document	25	An EBE	Not a UOW, (Output)
Variance	25	An EBE	A Type of a Change
Deviation	25	An EBE	A Type of a Change
Variance Identification	25	An EBE	A Type of Change Identification
Variance Justification	25	An EBE	A Type of Change Justification
Variance Documentation	25	An EBE	A Type of Change Documentation
RFV Classification	25	An EBE	A Type of Classification
Critical RFV	25	An EBE	A Type of Change Variance
Major RFV	25	An EBE	A Type of Change Variance
Minor RFV	25	An EBE	A Type of Change Variance
RFV Prioritisation	26	An EBE	A Type of Change Prioritisation
Routine RFV	26	An EBE	A Type of Variance priority
Urgent RFV	26	An EBE	A Type of Variance priority
Emergency RFV	26	An EBE	A Type of Variance priority
RFV Revision	26	An EBE	A Type of Change Revision
RFV Submission to Configuration Change Authority	25	An EBE	A Type of ECP Submission to CCA
ECP or RFV Review & Evaluation	20	An EBE	**A UOW**
Resources Identification	20	An EBE	**A UOW**
Supporting Data	22	An EBE	Not a UOW, (Output)
Classification Assignment	21	An EBE	**A UOW**
Priority Assignment	23	An EBE	**A UOW**
Justification code Assignment	24	An EBE	**A UOW**
Supporting Data Analysis	22	An EBE	**A UOW**
ECP Submission	20	An EBE	**A UOW**

To Configuration Change Authority for Disposition			
ECP or RFV Disposition	20	An EBE	**A UOW**
Configuration Change Authority (CCA)	20, 27	An EBE	Not a UOW, (Role)
CR Approval	22	An EBE	Part of the disposition process
CR Disapproval	22	An EBE	Part of the disposition process
CR Originator Notification	22	An EBE	**A UOW**
Notification of Originator	22	An EBE	Output of originator notification
Rational provision to Rejected CR originator	22	An EBE	In CR Originator Notification
Configuration Control Board	26	An EBE	Not a UOW, (Role)
Approved ECP or RFV	27	An EBE	A Type of a Disposition Decision
Approved as Modified ECP or RFV	27	An EBE	A Type of a Disposition Decision
Disapproved ECP or RFV	27	An EBE	A Type of a Disposition Decision
Withdrawn ECP or RFV	27	An EBE	A Type of a Disposition Decision
Replaced by Revision	27	An EBE	A Type of a Disposition Decision
Configuration Management Officer	27	An EBE	A Role
Configuration Control Board Directives	27	An EBE	Not a UOW, (Output)
Approved Change Incorporation into the configuration documentation	20	An EBE	**A UOW**
Approved Change Incorporation into the product configuration	21	An EBE	**A UOW**
Approved Change Incorporation via retrofit into existing product	21	An EBE	**A UOW**
Approved Change Incorporation into sub-contractor configuration when required	21	An EBE	**A UOW**
Approved Change Incorporation into product operational information	21	An EBE	**A UOW**
ECP Archival	21	An EBE	**A UOW**
IEEE Std. 828:2012 (IEEE Computer Society, 2012)			
Candidate EBE	**Page**	**EBE or Not**	**UOW or Not**
Change	14	An EBE	= Change Request
Change Control Infrastructure	14	An EBE	Not UOW, (Lifetime)
Change Control Infrastructure Establishment	14	An EBE	Not UOW, (Lifetime)
Configuration Item	14	An EBE	Not UOW, (Lifetime)
Configuration Baseline	14	An EBE	Not UOW, (Lifetime)
Environment Specification	14	An EBE	Not UOW, (Lifetime)
Tool Specification	14	An EBE	Not UOW, (Lifetime)
Baselined Requirements Specifications	14	An EBE	In Configuration Item
Interface Specifications	14	An EBE	A Configuration Item
Design	14	An EBE	A Configuration Item
Code	14	An EBE	A Configuration Item
Build	14	An EBE	A Configuration Item
Build Data	14	An EBE	A Configuration Item
Database Trigger	14	An EBE	A Configuration Item
Database Schema	14	An EBE	A Configuration Item
SQL Script	14	An EBE	A Configuration Item
Unit Test	14	An EBE	A Configuration Item
Coverage Test	14	An EBE	A Configuration Item
Standards	14	An EBE	A Configuration Item
Change Request	14	An EBE	**A UOW**
Change Disposition	14, 15, 16	An EBE	**A UOW**
CCB Identification	14	An EBE	**A UOW**

Change Disposition Documentation	16	An EBE	**A UOW**
Change Deposition Dissemination	16	An EBE	**A UOW**
Change Evaluation	14, 15	An EBE	**A UOW**
Change Disposition Authority	15	An EBE	Not a UOW (Role)
Change Approval	15	An EBE	In Change Disposition
Change Rejection	15	An EBE	In Change Disposition
Technical Evaluation	15	An EBE	In Change Evaluation
Managerial Evaluation	15	An EBE	In Change Evaluation
Disposition Authority Representative	15	An EBE	Not A UOW (Role)
Stakeholder	15	An EBE	Not A UOW (Role)
Functional Area	15	An EBE	Not A UOW (Role)
Disposition Criteria	15	An EBE	Not a UOW, (Lifetime)
Pre-Established Disposition Criteria	15	An EBE	In Disposition Criteria
Change Request Form	15	A UOW	Not a UOW, (Output)
Change Origin	15	An EBE	In Change Request
Change Final Disposition	15	An EBE	In Change Review
Configuration Management Database	15	An EBE	Not a UOW, (Lifetime)
Change Originator	15	An EBE	Not a UOW (Role)
Impact Analysis	15, 16	An EBE	**A UOW**
Concurrence Conflicts Evaluation	15	An EBE	In Impact Analysis
Change Disposition Rationale	15, 16	An EBE	in Change Disposition
Configuration Management System	15	An EBE	Not a UOW, (Lifetime)
Notification (of the affected parties)	15, 16	An EBE	**A UOW**
Notification	15, 16	An EBE	**An output**
Informative Notification Record	15	An EBE	In Notification
Reversibility (Remediation)	15, 16	An EBE	**A UOW**
Reversibility Information	15, 16	An EBE	Not a UOW, (Output)
Set of Change	15	An EBE	In Impact Analysis
Audit Trial	15	An EBE	**A UOW**
Attribution	16	An EBE	**A UOW**
Change Control Board	16	An EBE	Not a UOW (Role)
Versioning System	16	An EBE	Not a UOW (lifetime)
Documentation	16	An EBE	**A UOW**
Rejected Change Review	16	An EBE	**A UOW**
Approved Change Implementation	16	An EBE	**A UOW**
Approved Change Testing	16	An EBE	**A UOW**
Approved Change Implementation Verification	16	An EBE	**A UOW**
Approved Change Implementation Documentation	16	An EBE	**A UOW**
Approved Change Testing Verification	16	An EBE	**A UOW**
Approved Change Testing Documentation	16	An EBE	**A UOW**
Approved Change Traceability Verification	16	An EBE	**A UOW**
Approved Change Traceability Documentation	16	An EBE	**A UOW**
Backing out unsuccessful Change	16	AN EBE	In Reversibility
Change Commit (Deployment)	46	AN EBE	**A UOW**

APPENDIX - B: IDENTIFIED & LINKED CHM-UOWS

#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	RFC Submission	Change Request Submission	RFC Submission	Request for Change	Change Request Preparation & Submission	Change Request	Request for Change	Change Proposal	Change Proposal	Change Request	ECP Submission	Change Request
2			CR Review									
3	Change Creation		Change Initiation	Change Initiation				Change Initiation	Change Initiation	Change Initiation		
4	RFC Logging	CR Logging	Tracking Number Assignment	Change Identification	CR Identification	Change Identification	RFC & RFV Identification	Change Identification	Change Identification		Change Identification	
5	RFC Review	CR Validity Check	Pre-Evaluation Screening								ECP Revision	
6			Change Classification	Change Classification	Request Priority Validation						Change Classification & Prioritisation	
7				Preliminary Change Coordination								
8				Change Justification Provision							Change Justification	
9				Approval Authority Identification								
10	CMS Information Update		CR Tracking Database Update									
11	Change Documentation Update	CRF Update	CR Files Update	Change Documentation		Change Recordation	RFC & RFV Recordation	Change Documentation	Change Documentation		Change Documentation	Change Documentation
12	Feedback to Change Initiator		Feedback to the CR Originator		Feedback to the Initiator							Notification
13		Change Request Closure										
	Change Analysis & Assessment											
14	Change Assessment & Evaluation	Change Assessment & Costing	Change Evaluation & Analysis	Change Evaluation	Change Request Assessment	Change Review	RFC & RFV Evaluation	Change Evaluation	Change Evaluation	Change Request Investigation	ECP or RFV Review & Evaluation	Change Evaluation
15	Change Assignment to a Change Authority			Change Coordination			RFC & RFV Coordination					

#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
16	Impacted Partied Assessment			Impacted Partied Assessment	Impacted Partied Review							
17	Formal Evaluation Request											
18			Change Package Update	Assessment Output Integration to RFC	Findings and Recommendations Compilation							
19 - 26	Impact & Resource Assessment **(25)**	Change Implementation Analysis **(19)**	Change Impact Analysis	Impacted (Products, Components, and Product Configuration Configurations) Identification	Change Assessment	Change Affect Analysis	Impact Assessment of the Proposed Change	Change Evaluation	Impact Assessment	Technical & Economical Impacts on the Product, Manufacturing and Logistics	Supporting Data Analysis & Resources Identification (needed to review, evaluate, and implement Changes)	Impact Analysis
		Change Impact Analysis **(20)**										
				Proposed Implementation Cost Development					Applicability Determination **(26)**	Technical & Economical Feasibility of the Change		
		Change Cost Analysis **(21)**							Cost Determination			
	Risk & Benefits-based Assessment **(22)**											
	Category & Urgency Check **(23)**				Priority Assignment (Based on Enterprise-wide requirements)						Classification & Priority & Justification Code Assignment	
				Basic Implementation Plan & Schedule Determination **(24)**								
27				Change Impact Documentation				Evaluation Documentation	Evaluation Documentation	Investigation Results Registration		Audit Trial
28					Change Request Cancellation							

#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Disposition											
29	Change Build & Test Authorisation		Change Disposition	Requested Change Disposition	Change Request Approval			Change Disposition	Disposition	Decision Making		
30	Change Authority Level Identification							Dispositioning Authority Identification		Competent Authority Identification		CCB Identification
31			Change Package Submission to CCB	Integrated RFC Submission to the Approval Authority	Findings Submission to A Proper Assessment Entity		Request Submission for Review & Approval		Evaluation Submission to Disposition Authority	Request Submission to Change Mgmt. Authority	ECP Submission to a CC Authority	Attribution
32	Change Authority Authorisation	Change Assessment & Review	Change Authority Disposition	Approval Authority Evaluation & Disposition	Change Authority Assessment and Approval	ECP Approval	CCB Approval	Change Evaluation Revie	Disposition Authority Decision	Go/No Go Decision	ECP or RFV Disposition	Change Disposition
	Change Priority Allocation	Accepted Change Prioritisation					Approved Change Prioritisation	Proper Categorisation Check		Change Classification		
								Proper CR Documentation Check				
								Planned Implementation Activities Check				
33	Appeal											
34	Rejected Change Review & Closure	Rejected Change Closure			Denied CR Closure							Rejected Change Review
					Rejected CR Associated Documentation Disposal							
35			Feedback to Change Originator		Rejected CR Initiator Notification						CR Originator Notification	Notification
36			Minutes of Meetings Preparation				Change & Rational Recordation	Disposition Decision Record				Change Disposition Documentation
37			Approved Changes Submission to the CMO									
			Minutes of Meetings Distribution	Disposition Results dissemination to affected parties				Disposition Circulation to Relevant Parties				Change Deposition Dissemination
38			CR Record Update									

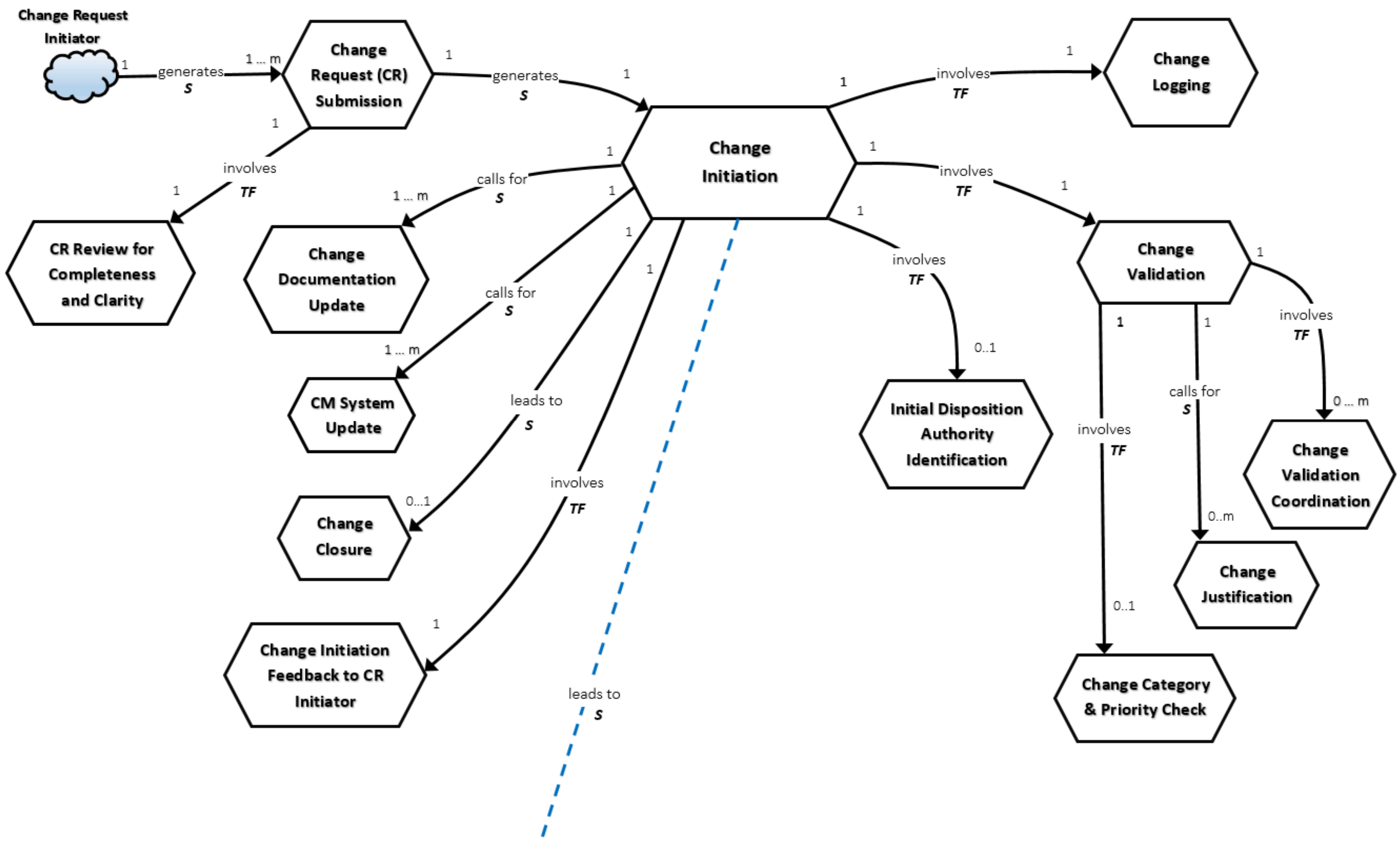
#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Detailed Planning & Scheduling											
39	Change Planning & Scheduling			Implementation & Verification Planning					Implementation & Verification Planning	Change Detailed Design		
40			Approved Change Submission to the Development Team	Implementation Actions Direction	Approved CR Submission to the Planning Phase							
41	Change Planning		Design Development	Detailed Implementation Planning	Implementation Planning		Approved Change Tracking & Management to the Baseline, RFC & RFV		Change Implementation Plan and Incorporation	Change Detailed Definition, Detailed Design, and Definition of Implementation Conditions		
42	Change Scheduling		Resources Schedule		Implementation Scheduling		Approved Change Schedule		Effectivity Date			
43				Detailed Verification Planning					Verification Plan			
44	Change Projected Service Outage											
45	Remediation Planning											
46	Release and Deployment Planning											
47	Change Plans, Schedule, and PSO Agreement with Stakeholders				Plans/Budget/ Schedule Authorisation Implementation Plans and Schedule Review					Definition Qualification and Change Validation Examination of Technical, Financial and Scheduling Repercussions Definition file elaboration		
	Change Build & Test											
48	Authorised Change Submission to Relevant Technical Groups Coordination	Accepted Change Submission to the Development Team	Approved Change Submission to the Development Team	Implementation Coordination								

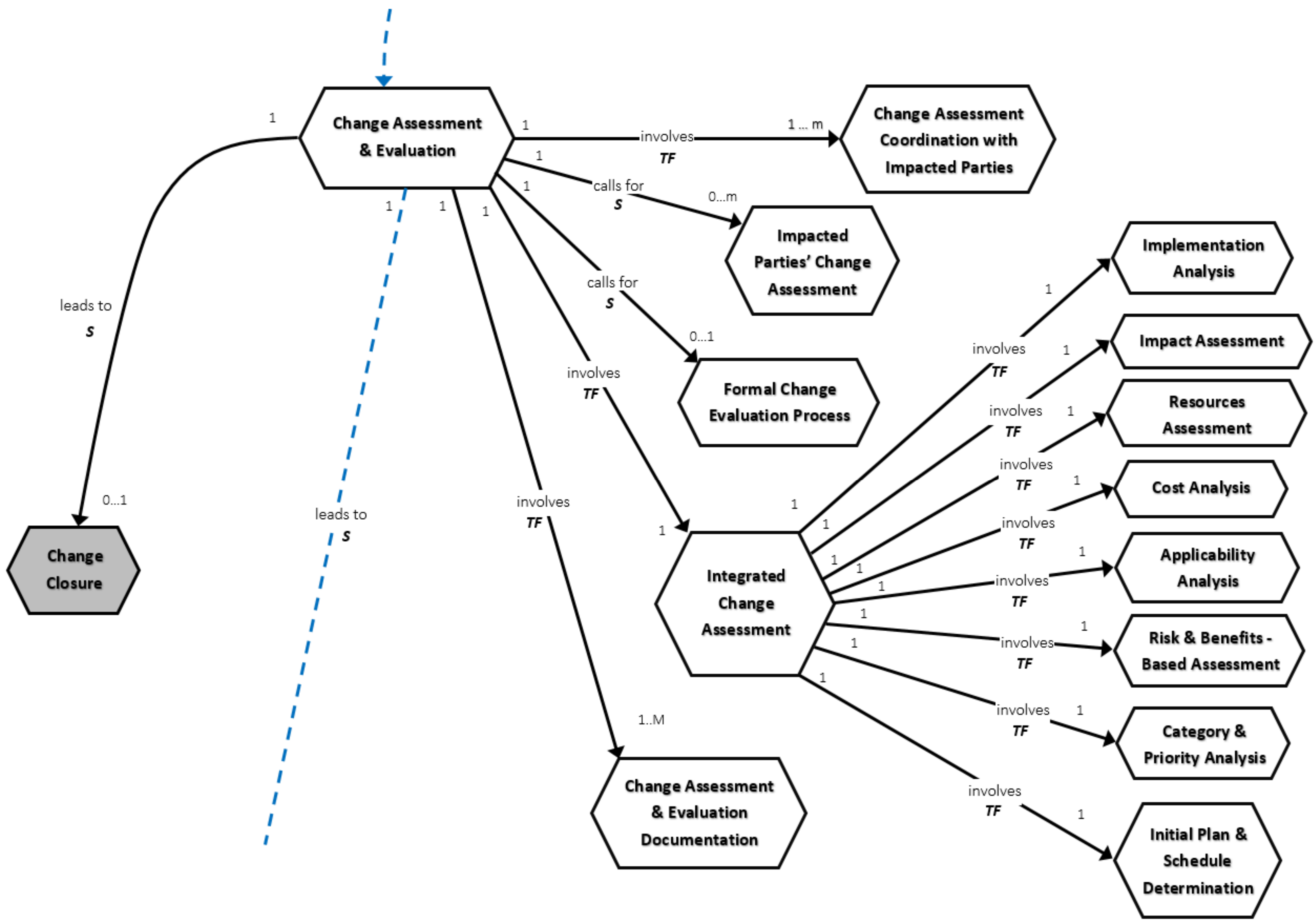
<table>
<tr><th>#</th><th>ITIL
2011</th><th>Sommerville
2016</th><th>SCM Handbook
2015</th><th>EIA649-B
2011</th><th>CCRM Guide
2012</th><th>INCOSE
2015</th><th>IEEE std.
15288:2015</th><th>BS ISO
10007:2017</th><th>JSP 886:
2015</th><th>BS EN 9223-
104:2018</th><th>MIL-STD-
3046:2013</th><th>IEEE
828:2012</th></tr>
<tr><td rowspan="6">49</td><td rowspan="6">Change Build</td><td rowspan="6">Software Modification</td><td>Change Implementation</td><td>Approved Change Implementation</td><td rowspan="4">Change Implementation</td><td rowspan="6">RFC Processing</td><td rowspan="6">Technical Processes Initiation</td><td rowspan="2">Approved Change Implementation</td><td>Authorised Change Implementation</td><td rowspan="2">Change Implementation on Product and Product Process</td><td>Approved Change Incorporation in the configuration documentation</td><td rowspan="6">Approved Change Implementation</td></tr>
<tr><td>Items Check out from Config. Library</td><td>Product Definition Information Update & Release</td><td>Product Configuration Information Update</td><td>Approved Change Incorporation into the product configuration</td></tr>
<tr><td rowspan="2">Change Coding</td><td rowspan="2">Operation and Maintenance, and Sales Information Update and Release</td><td rowspan="2">Product Configuration Information Change</td><td>Baseline Update</td><td rowspan="2">Modification of the Documentation</td><td rowspan="2">Approved Change Incorporation via retrofit into existing products</td></tr>
<tr><td>Affected Support Elements Update</td></tr>
<tr><td>Associated Documentation Revision</td><td>Build & Test Information Update and Release</td><td rowspan="2">Change Implementation Pre-staging</td><td rowspan="2">Relevant Interested Parties Action</td><td>Retrofit Arrangement to existing Products</td><td>Modification and/or Update Support Systems</td><td>Approved Change Incorporation into sub-contractor configuration when required</td></tr>
<tr><td>New Items Check into Config. Library</td><td>Correlated Documents Revision</td><td>Change Implementation Actions Taken by Relevant Stakeholders</td><td>Establishment of Measures Associated to the Change</td><td>Approved Change Incorporation into product operational information</td></tr>
<tr><td rowspan="2">50</td><td>Thorough Test Coordination</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Change Test</td><td>New Software Test</td><td>Change Testing</td><td></td><td>Change Testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Approved Change Testing</td></tr>
<tr><td rowspan="2">51</td><td></td><td></td><td></td><td>Documents Changes Dissemination</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Change Implementation Information Recordation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Approved Change Implementation & Testing Documentation</td></tr>
<tr><td>52</td><td>Design, Build, and Test Evaluation Coordination</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

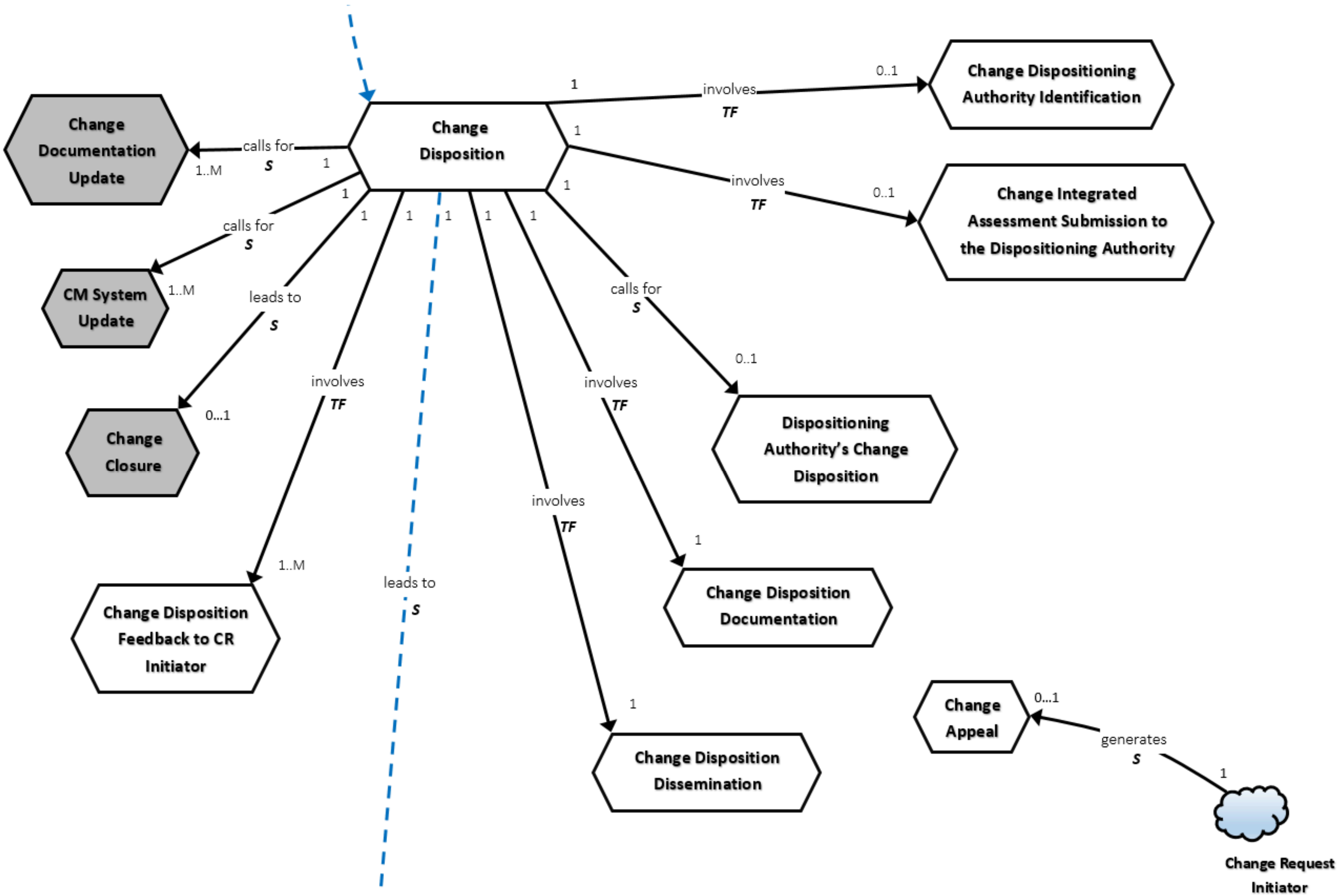
#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
53	Design, Build, and Test Evaluation											Approved Change Implementation & Testing Verification
												Approved Change Traceability Verification
54	Evaluation Results Submission to Change Authority											
55	Change Deployment Authorisation Design, Build, and Test Evaluation Check Interim Evaluation Report Review											
	Remediation											
56	Change Remediation											Reversibility
	Deployment and Release											
57	Change Deployment Coordination											
58	Change Deployment											Change Commit
59			Baseline Release			Change Release			Product Configuration Information Release			
	Status Accounting											
60					Status Accounting Procedures Initiation	Change Processing and Implementation Status Record, Track, and Report			Establishment of Records Compliance with Authorised Change	Configuration Status Report and Update	ECP Archival	
	Change Final Evaluation											
61	Change Review		Change Verification	Change Verification	Configuration Database Audit	Configuration Evaluation and Audit	Validation and Verification Process	Change Verification	Change Verification			

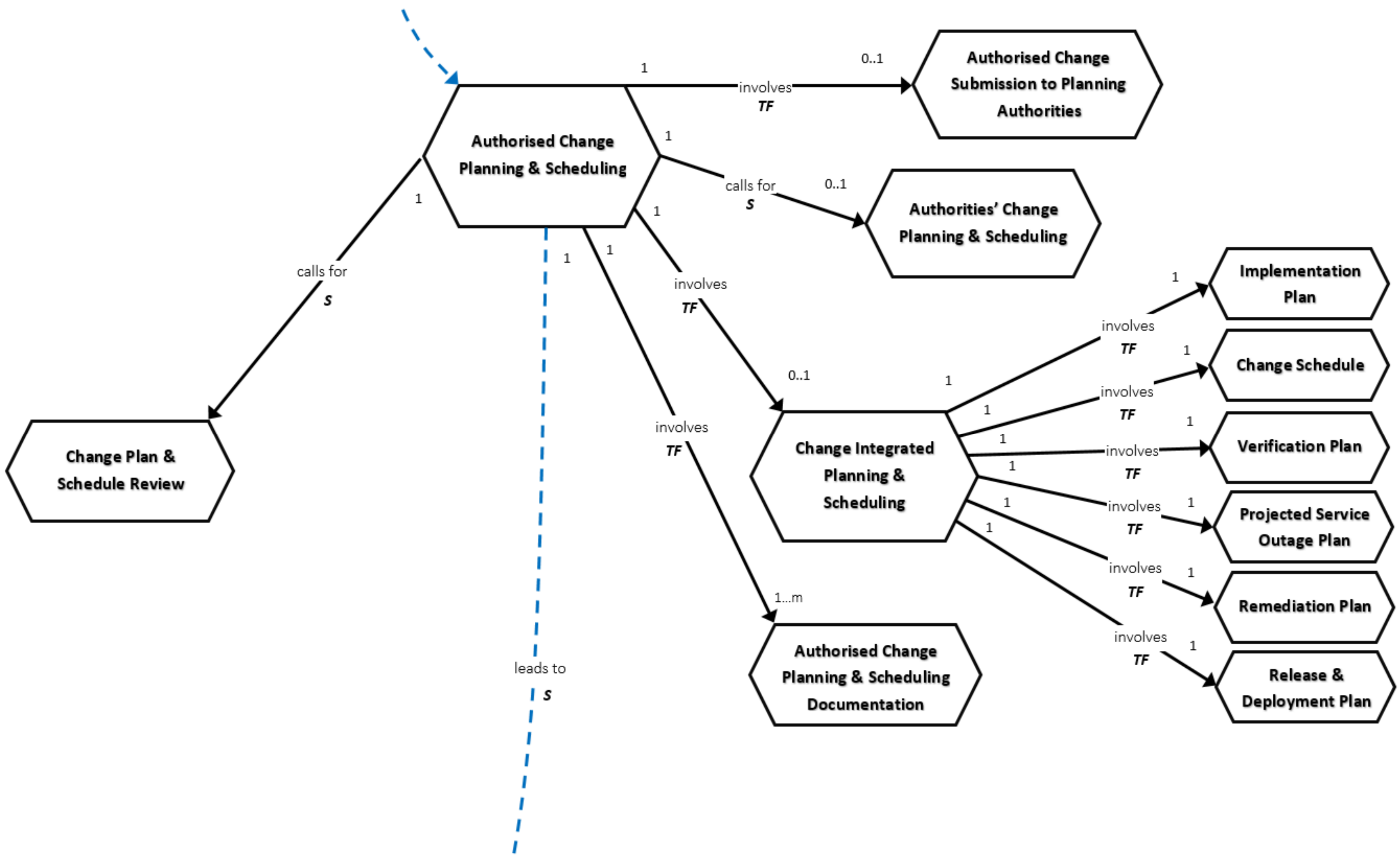
#	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288:2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
62	Formal Change Evaluation Process Initiation											
63	Change Check											
64								Verification Recordation	Verification Recordation			
65	Review Results Communicatio n with Change Stakeholder s		Verification Evidence Disposition									
66	Follow Up Action											
67			Occurrence Recordation into the Tracking Database									
	Change Closure											
68	Change Record Closure	CR Closure			Change Request Closure		Change Closure					
69	Change Logging System Update		Change History Update									

APPENDIX - C: DEVELOPED RIVA-DRIVEN CHM-UOWS DIAGRAM

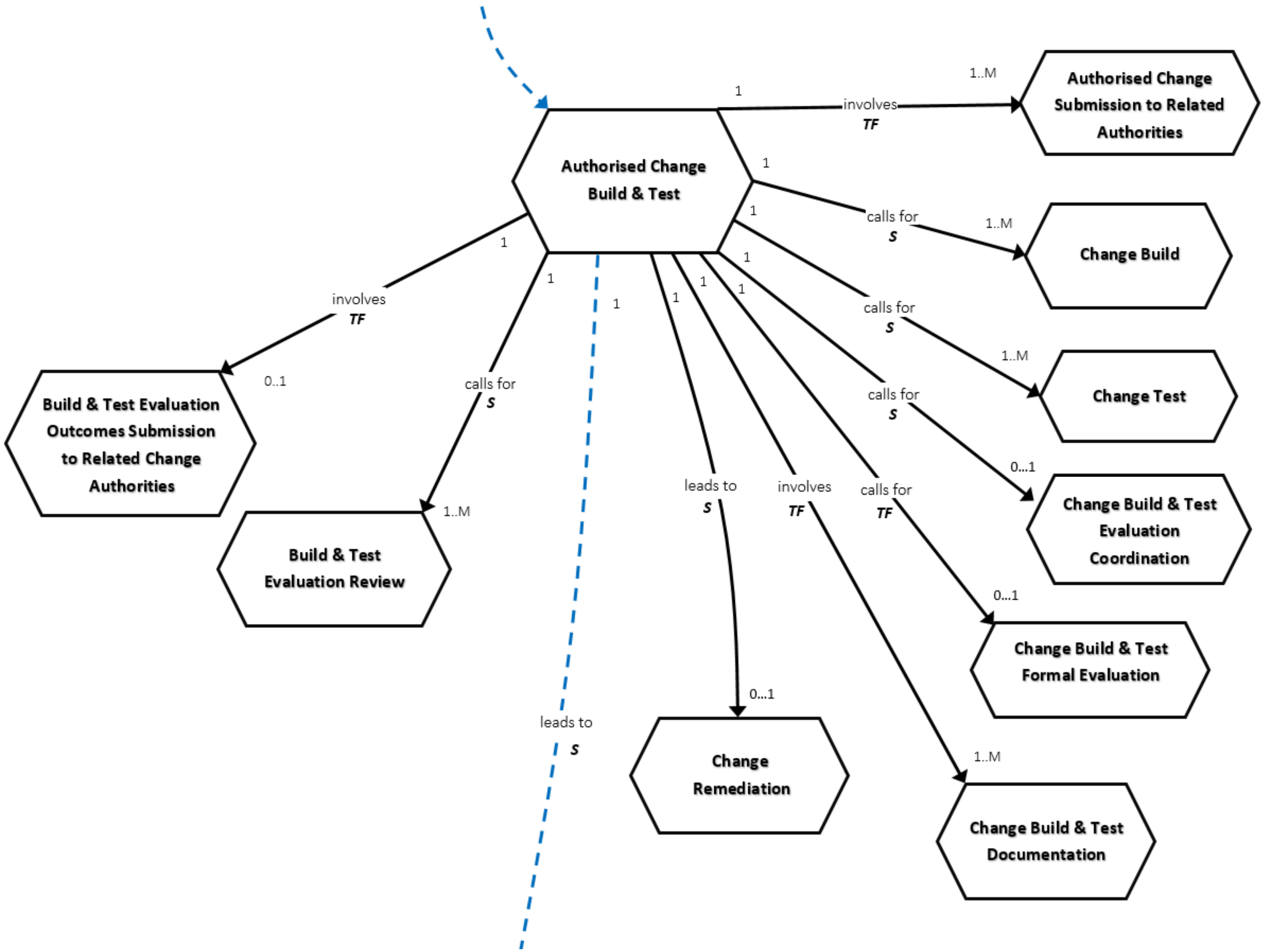


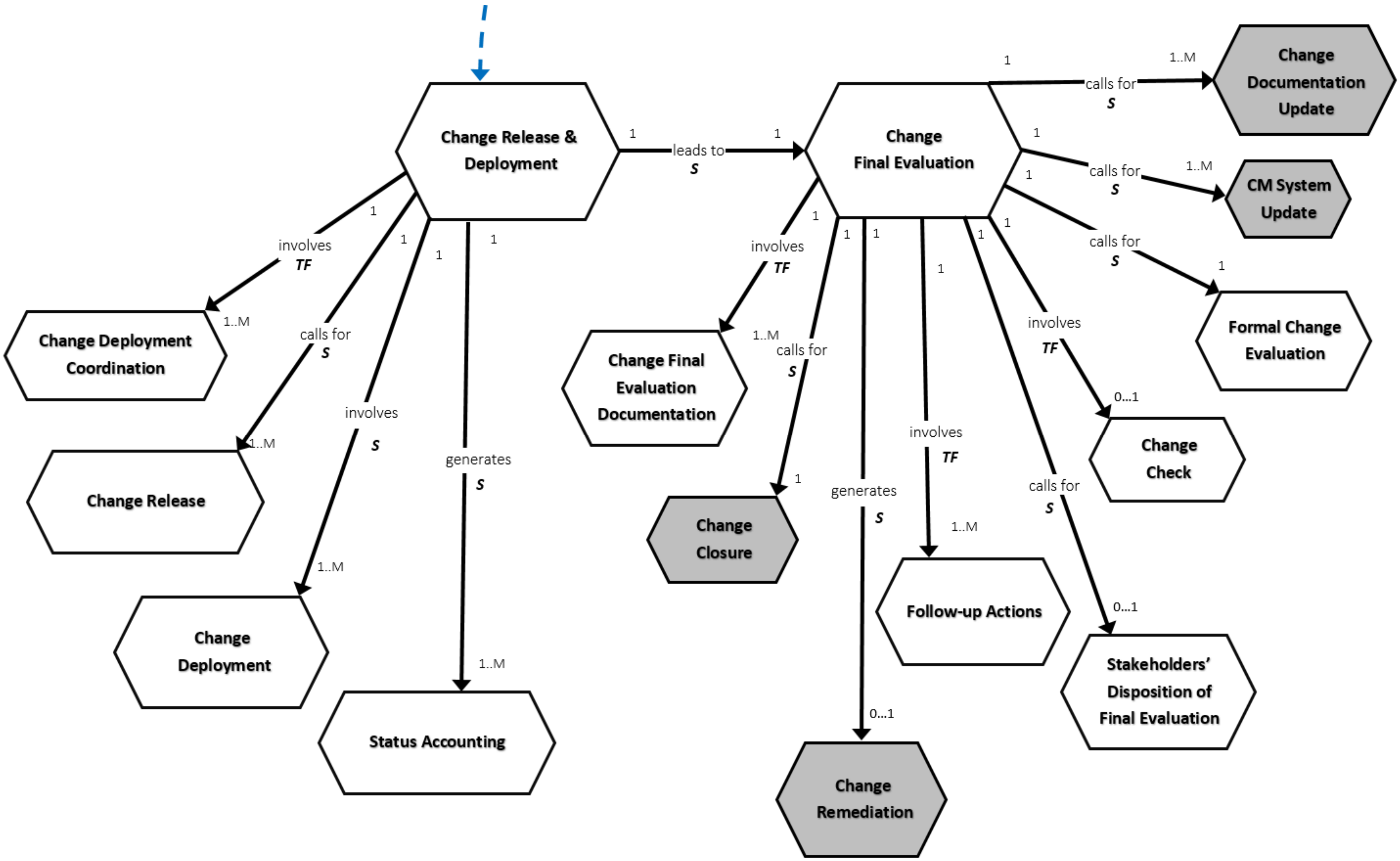

Change Assessment & Evaluation
involves
TF
1 ... m
Change Assessment Coordination with Impacted Parties
calls for
S
0...m
Impacted Parties' Change Assessment
calls for
S
0...1
Formal Change Evaluation Process
involves
TF
Integrated Change Assessment
Implementation Analysis
Impact Assessment
Resources Assessment
Cost Analysis
Applicability Analysis
Risk & Benefits - Based Assessment
Category & Priority Analysis
Initial Plan & Schedule Determination
involves
TF
1..M
Change Assessment & Evaluation Documentation
leads to
S
0...1
Change Closure


Change Disposition
Change Documentation Update
calls for S
1..M
1
CM System Update
calls for S
1..M
Change Closure
leads to S
0...1
Change Disposition Feedback to CR Initiator
involves TF
1..M
leads to S
involves TF
1
Change Disposition Dissemination
involves TF
1
Change Disposition Documentation
calls for S
0..1
Dispositioning Authority's Change Disposition
involves TF
0..1
Change Integrated Assessment Submission to the Dispositioning Authority
involves TF
0..1
Change Dispositioning Authority Identification
Change Appeal
0...1
generates S
1
Change Request Initiator



Authorised Change Planning & Scheduling
involves
TF
1
0..1
Authorised Change Submission to Planning Authorities
calls for
S
1
0..1
Authorities' Change Planning & Scheduling
calls for
S
1
Change Plan & Schedule Review
involves
TF
1
0..1
Change Integrated Planning & Scheduling
involves
TF
1
1...m
Authorised Change Planning & Scheduling Documentation
leads to
S
1
Implementation Plan
Change Schedule
Verification Plan
Projected Service Outage Plan
Remediation Plan
Release & Deployment Plan


Authorised Change Build & Test
1
involves
TF
1..M
Authorised Change Submission to Related Authorities
1
calls for
S
1..M
Change Build
1
calls for
S
1..M
Change Test
1
calls for
S
0...1
Change Build & Test Evaluation Coordination
1
calls for
TF
0...1
Change Build & Test Formal Evaluation
1
involves
TF
1..M
Change Build & Test Documentation
1
leads to
S
0...1
Change Remediation
1
leads to
S
1
calls for
S
1..M
Build & Test Evaluation Review
1
involves
TF
0..1
Build & Test Evaluation Outcomes Submission to Related Change Authorities


Change Release & Deployment
leads to
S
Change Final Evaluation
calls for
S
Change Documentation Update
CM System Update
Formal Change Evaluation
Change Check
Stakeholders' Disposition of Final Evaluation
Follow-up Actions
Change Remediation
Change Closure
Change Final Evaluation Documentation
involves
TF
generates
Change Deployment Coordination
Change Release
Change Deployment
Status Accounting
1
1..M
0...1

APPENDIX - D: SEGMENTS OF THE WALKTHROUGH-BASED QUESTIONNAIRE USED FOR THE EVALUATION OF THE DEVELOPED RIVA-DRIVEN CHM-BPA MODELS

Questionnaire

Faculty of Environment and Technology,
Software Engineering Research Group (SERG).

Dear Participants,

This Questionnaire is part of a PhD research work namely **a Semantically-enriched and Business Process Architecture-driven Change Management Framework for Change Management in System of Systems Context.** It aims to verify and validate a generalised "Change Management Business Process Architecture" model developed for the purpose of this research. Participants are asked to answer different questions related to various elements of this model. The provided feedback is highly valuable for the research and will allow to further develop and mature the framework for the next stages of the research.

Please note that to protect the participant's confidentiality, no personal information will be collected that would identify any of the participants, and the results will be used only for scholarly purposes and may only be shared amongst members of the research team.

This questionnaire consists of the following eleven sections:

- The **First Section** includes questions regarding the respondent's background;
- The **Second Section** includes questions regarding the organisational boundaries and business scope for change management;
- The **Third Section** investigates the standards, practices and guidelines used to drive the development of the change management framework;
- The **Fourth Section** investigates the elicited Essential Business Entities (EBEs).
- The **Fifth Section** investigates the validity of the filtered Units Of Work (UOWs).
- The **Sixth Section** includes question to validate the UOWs Diagram's elements.
- The **Seventh Section** includes questions that help to validate the proposed Case Strategy Process translation;
- The **Eighth Section** investigates the proposed application of Ould's heuristics for the selected Case Strategy Process concepts and its translation;
- The **Ninth Section** includes questions to validate the proposed second cut process architecture diagram for change management.

It would be very much appreciated if you could complete the attached questionnaire and return it back to the researcher. Thank you ever so much for your valuable participation in this research. Please do not hesitate to contact the researcher if you have any questions regarding this questionnaire or the research.

* **Following, are segments that represent examples of each conducted section.**

Section 1: Participant's Background

Q1.

Age:	
☐ 20 - 24	☐ 46 - 50
☐ 25 - 30	☐ 51 - 55
☐ 31 - 35	☐ 56 - 60
☐ 36 - 40	☐ 61 - 65
☐ 41 - 45	☐ 66 - 70

Q2.

Job Title:	

Q3.

Years of Experience:	
☐ 0 - 4	☐ 15 - 19
☐ 5 - 9	☐ 20 – 24
☐ 10 - 14	☐ More than 24

Section 2: Organisation and Business Identification

In this research, it is hypothesised that the organisation and business that need to be under consideration are:

"The part of an Information Systems-based Organisation that is responsible for managing and dealing with a change of a system's configuration item(s) from its proposal until closure."

Q1. To what extent do you agree with the change management functional area **organisational boundary** highlighted and underlined in the following statement?

*"**The part of an Information Systems-based Organisation** that is responsible for managing and dealing with a change of a system's configuration item(s) from its proposal until closure."*

Strongly Agree	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
Comment:				

Q2. To what extent do you agree with the change management functional area **Business Nature** highlighted and underlined in the following statement?

*"The part of an Information Systems-based Organisation that **<u>is responsible for managing and dealing with a change of a system's configuration item(s)</u>** from its proposal until closure."*

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
<u>Comment</u>:				

<u>Section 3: Sources, Standards, Practices, and Guidelines</u>

Q1. Which of the stated standards and guidelines do you **use directly** to manage systems and software related changes within your organisation?

* *Please mark the appropriate box(es) with the symbol ✓ Or* ***X****.*

☐ ITIL, 2011	☐ IEEE Std. 15288, 2015
☐ Sommerville, 2016	☐ BS ISO 10007, 2017
☐ SCM Leon, 2015	☐ JSP 886, 2015
☐ EIA-649B, 2011	☐ prEN 9223-104, 2018
☐ CCRM, 2012	☐ MIL-STD-3046, 2013
☐ INCOSE, 2015	☐ IEEE Std. 828, 2012

Q4. To what extent do you agree that the stated standards and guidelines listed **are sufficient** to drive the development of a generalised change management process architecture?

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
<u>Comment</u>:				

Section 4: Consolidated Essential Business Entities

Q1. To what extent do you agree with the following as Consolidated and Generic Change Management Essential Business Entities (EBEs); (i.e. represent the essential change management entities that are there because of the nature of the change management business and adhere to Ould's EBE's filters)?

ID	EBE Name	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	Comment
1	Change Request Initiator	☐	☐	☐	☐	☐	
2	Change Request Form	☐	☐	☐	☐	☐	
3	Change Request (CR) Submission	☐	☐	☐	☐	☐	
4	Change Request Receiver	☐	☐	☐	☐	☐	
5	CR Review for Completeness and Clarity	☐	☐	☐	☐	☐	
6	Change Officer	☐	☐	☐	☐	☐	
7	Change Initiation	☐	☐	☐	☐	☐	
8	Change ID	☐	☐	☐	☐	☐	
9	Change Logging	☐	☐	☐	☐	☐	
10	Change Validation	☐	☐	☐	☐	☐	
11	Change Validator	☐	☐	☐	☐	☐	
12	Initial Impacted Partied Identification	☐	☐	☐	☐	☐	
13	Change Validation Coordination	☐	☐	☐	☐	☐	
14	Change Justification	☐	☐	☐	☐	☐	
15	Change Justification/ Validation Report	☐	☐	☐	☐	☐	
16	Change Category and Priority Check	☐	☐	☐	☐	☐	
17	Change Category	☐	☐	☐	☐	☐	
18	Change Priority	☐	☐	☐	☐	☐	
19	Initial Disposition Authority Identification	☐	☐	☐	☐	☐	

Section 5: Consolidated Units of Work

Q1. To what extent do you agree with the following as Consolidated and Generic Change Management Units Of Work (UOWs); (i.e. represent the main entities that the change management process needs to manage its lifetimes and adhere to Ould's UOW Filters?

ID	UOW Name	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	Comment
1	Change Request (CR) Submission	☐	☐	☐	☐	☐	
2	CR Review for Completeness and Clarity	☐	☐	☐	☐	☐	
3	Change Initiation	☐	☐	☐	☐	☐	
4	Change Logging	☐	☐	☐	☐	☐	
5	Change Validation	☐	☐	☐	☐	☐	
6	Initial Impacted Partied Identification	☐	☐	☐	☐	☐	
7	Change Validation Coordination	☐	☐	☐	☐	☐	
8	Change Justification	☐	☐	☐	☐	☐	
9	Change Category and Priority Check	☐	☐	☐	☐	☐	
10	Initial Disposition Authority Identification	☐	☐	☐	☐	☐	
11	Change Initiation Documentation	☐	☐	☐	☐	☐	
12	Change Documentation Update	☐	☐	☐	☐	☐	
13	Configuration Management System Update	☐	☐	☐	☐	☐	
14	Change Closure	☐	☐	☐	☐	☐	
15	Change initiation Feedback to CR Initiator	☐	☐	☐	☐	☐	
16	Change Assessment and Evaluation	☐	☐	☐	☐	☐	
17	Impacted Parties Identification	☐	☐	☐	☐	☐	

Section 6: Units Of Work Diagram

In this section, six parts of the "**Units Of Work diagram for ChM**" will be presented for you. Please, inspect the figures and answer the following questions. Please add a comment if you do not agree to some extent with the proposed ideas.

Q1. To what extent do you agree with the following elements: Name, Type (Service, Task Force) and Cardinality that are related to each 'Generate' relation presented in the above UOW's diagram part?

Relation's ID	Element	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	Comment
G1	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G2	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G3	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G4	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G5	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	
G5-1	Name	☐	☐	☐	☐	☐	
	Type (S/TF)	☐	☐	☐	☐	☐	
	Cardinality	☐	☐	☐	☐	☐	

Q2. To what extent do you agree that the presented "Units of Work" in the previous figure are **adequate** to cover a generalised presentation of the "change request submission" and "change initiation" related UOWs?

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Q3. To what extent do you agree that the presented "Units of Work" in the previous figure are at the **right level of abstraction** to present the "change request submission" and "change initiation" related UOWs with maintaining the right coverage of the main ones? (i.e. do we need fewer units of work? do we need more units of work?)

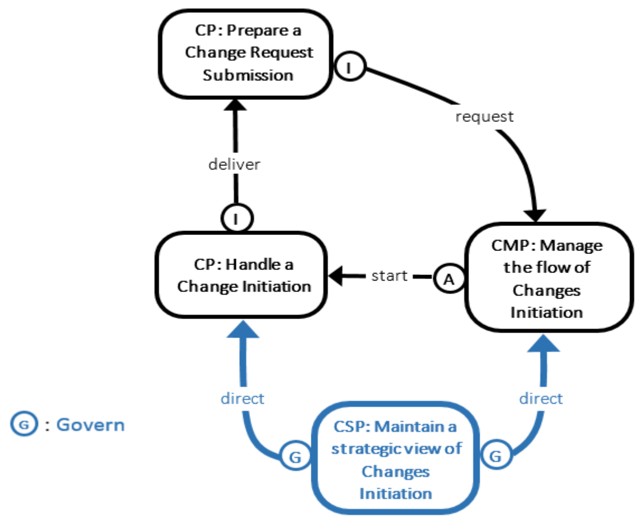
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Q4. Please comment if you would like to **"Add"**, **"Remove"**, or **"Modify"** any of the model's components related to the previous figure (i.e. Adding a new UoW, Removing an existing UoW, Modifying a Relationship title, Modify a cardinality, Modifying a Relationship Type, etc.)?

Comments:

Section 7: Case Strategy Process Translation

For the purpose of this research, it had been concluded from the Riva-BPA Literature that every "Case Strategy Process" (CSP) has an associated "Case Process" (CP) and "Case Management Process" (CMP) and maintains a strategic view for each of them. Hence it is proposed that each CSP investigates the internal and external environments of a given "Unit of Work" and '**G**overn' the associated CP and CMP by '**D**irecting' each of them in a way that fulfils the adherence to the strategic view. Hence, to depict this conclusion, additions to the first-cut architecture notations have been proposed. The following Figure shows an example of the proposed additions to the model which appear in **blue colour**, the proposed additions are the same for the 'Service' or the 'Task Force' relationships translation.



The Proposed Additions to the Relationships Translation into the first cut architecture diagram

Q1. To what extent do you agree with the **proposed translation** of the "**Case Strategy Process**" relationship with the associated "**Cases Management Process**"? *Please Comment if possible.*

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Q2. To what extent do you agree with the **proposed translation** of the "**Case Strategy Process**" relationship with the associated "**Cases Process**"? *Please Comment if possible.*

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree

Section 8: The Application of Ould's Heuristics on the CSP concept and its Translation

Q1. To what extent do you agree with the following proposition? *Please comment if possible.*

"When any of the CMPs is decided to be folded into the requesting CP as a result of applying the 'Folding a task force CMP into the requesting CP' heuristic, the associated CSP is decided to be folded as well. It is assumed that when the management process role can be folded and included into the requesting CP because of the reason stated on the mentioned heuristic, the strategic process role can also be folded, but here it will be included into the requesting CP associated CSP. Hence, the requesting CP will be in charge of managing, ordering, prioritising…etc. the flow of cases of the requested CP, and the associated CSP of the requesting CP will be in charge of maintaining a strategic view of the flow of cases of the requested CP and maintain a strategic view of the requested CP itself as well".

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Q2. To what extent do you agree with the following proposition? *Please comment if possible.*

"When any of the CMPs is decided to be folded into the requesting CP as a result of applying the 'Dealing with collections' heuristic, the associated CSP is decided to be folded as well. It is assumed that when the management process role can be folded and included into the requesting CP because of the reason stated on the mentioned heuristic, the strategic process role can also be folded, but here it will be included into the requesting CP associated CSP. Hence, the requesting CP will be in charge of managing, ordering, prioritising…etc. the flow of cases of the requested CP, and the associated CSP of the requesting CP will be in charge of maintaining a strategic view of the flow of cases of the requested CP and maintain a strategic view of the requested CP itself as well".

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comment:				

Section 9: Second Cut Process Architecture Diagram

Please note the following related to the application of the Ould's heuristics on this stage findings:

(A) Folding a task force CMP into the requesting CP

This heuristic was the most applied heuristic on the investigated first-cut process architecture diagram. All the encapsulated CMPs in the diagram were folded in the requesting CPs. When a CMP is folded into the requesting CP, it is not assumed that the CMP does not exist anymore or there is no case management to be applied. It is assumed that it resides in the requesting CP and it is better to be modelled there, as the requesting CP has the control of managing the flow of the requested CPs. In addition, the related CPSs are folded as well into the requesting CP associated CSP.

(B) Dealing with collections

It is likely to fold the CMP of the part into the CP of the whole. However, this heuristic is not applied in this work, as none of the proposed UOWs is part of another UOWs collections.

(C) Dealing with 1:1 'generates' relationships

For this research, even most of the relationships have (1:1) cardinality, but the relationships of the type 'Service' were not folded into the requesting CPs. This is done to address the above recommendations and to maintain a 'generalised' form of the aimed at process architecture.

(D) Dealing with delivery interactions and delivery chains

In this research, this heuristic was not applied to the investigated first-cut architecture to maintain a form of 'generalisation' in the proposed model. Later, it can be customised, and the 'deliver' interactions can be omitted per-situation. However, when the resulted process architecture is validated during the future research stages, the feedback of the validation may affect the application of this heuristic on the resulted process architecture diagrams.

(E) Dealing with empty CMPS

In this research, all the CMPs remained after applying the previous heuristics are assumed to be not empty. Hence, they had not been removed from the produced process architecture.

Seven parts of the second cut process architecture diagram for the generalised change management business process architecture developed in this research will be presented to you. Please read the figures and provide your answers to the related questions; add a comment if you do not agree to some extent with the proposed ideas.

Q1: To what extent do you agree with the second process architecture diagram translation of the above presented "**Change Request Submission**" and "**Change Initiation**" processes? *Please Comment if possible.*

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Comments:				

APPENDIX - E: SETS OF THE ELICITED AND LINKED CHM DOCUMENTS AND ROLES

Table G.1: Elicited and linked ChM processes related artefacts (documents).

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104: 2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	Change Proposal / Problem Report	Problem/Bug Report				Problem Statement			Problem Report			
2	Change Record, Change Document, or Change Log	Change Request Form (accumulated document)	Change Record (accumulated document)	Request For Change Document (accumulated document)		Change Report (accumulated document)		Change Documentation (accumulated document) * all related findings should be documented	Documented Change Request (accumulated document) * all related findings should be documented	Change File (accumulated document)	Engineering Change Proposal/ Request For Variance Document	Change Request Form (accumulated document)
3	RFC Form	Change Request	Change Request Form, Problem Report Form, Software Change Notice	Request For Change or Variance	Change Request Form	Request For Change/ Engineering Change Proposal/ Request for variance or Deviation	Request For Change/Variance/Deviation/ Waiver/Concession	Change Proposal Form	Change/ modification Proposal	Statement of Need/ Request Application	Engineering Change Proposal / Request For Variance	Change Request
4					Initiation Feedback							
	Change Evaluation and Assessment											
5	Evaluation Plan		SCM Plan as a reference for classification criteria	Classification Criteria	Assessment Criteria				Classification Criteria			
6	Formal Evaluation Request/ Work Order for Assessing											Notification

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104: 2018	MIL-STD-3046:2013	IEEE 828:2012
7	Impact Assessment Form / Change Evaluation Output	Change Impact Form	Change Analysis Documentation Evaluation Reports/ Impact Analysis Reports	Change Justification and Assessment Reports /(Primary Assessment, Risk and Benefits…)	Assessment Findings and Recommendations	Impact Assessment	Impact Assessment	Assessment related Change Documentation	Assessment related Change Documentation	Change File That Includes Assessment Data		Change Request Form That Includes Assessment Data
8			Change Package including CRF, Change Impact Report, etc.	Integrated RFC	Combined Findings and Recommendations						Supporting Data, An output of the review and evaluation process	
	Change Disposition											
9	Authorisation Hierarchy		Approval Authority Hierarchy	Documented Criteria for the identification of Approval Authority	Approval Authority Identification Criteria					Management Authority Tree Structure		Pre-Established Disposition Criteria
10	Formal Change Authorisation		Change Authorisation Form or Change Directives	RFC Document including the Deposition Decision	Change Disposition Decision			Disposition related Change Documentation	Decision Report	Change File That Includes Disposition Decisions	Configuration Control Board Directives	Change Request Form That Includes Disposition Decisions

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104: 2018	MIL-STD-3046:2013	IEEE 828:2012
11			Change Rejection Feedback to Originator									
12			Disposition minutes of meeting	Change Notice (To distribute RFC updates)							Notification	Notification
	Authorised Change Plan & Schedule											
13	Work Order for planning											
14	Change Plan Change Schedule Projected Service Outage Release and Deployment Plan Remediation Plan/ Mitigation Plan	Within the Approved CRF	Within the Change Package/ Change Record	Implementation Plans and Delivery Schedules to be included within the RFC document	Schedule Pre-staging Release Plan			Plan and Schedule related Change Documentation	Plan and Schedule related Change Documentation	Change File To include related plans		Change Request Form / Reversibility Information
	Authorised Change Build & Test											
15	Work Order for Building and Testing		Work Instructions for implantation	Change Notice								
16		Derivation History Record of a Component / Component Change Report	Implementation Information / Change/Patch History	Product Definition Information / Product Configuration Information				Build and Test related Change Documentation	Build and Test related Change Documentation	Change File		

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886: 2015	BS EN 9223-104: 2018	MIL-STD-3046:2013	IEEE 828:2012
17	Interim Evaluation Report to evaluate Build and Test											
18	Formal Change Deployment Authorisation											
	Change Release & Deployment											
19	Work Order/ Formal Request			Change Notice								
20								Release Related Documentation	Release Related Documentation	Change File		
	Change Final Evaluation & Closure											
21	Work Order/ Formal Evaluation Request			Change Notice	Notification							
22	Formal Change Evaluation Report / ChM Check output / Revised RFC to follow up action							Review related Change Documentation	Review related Change Documentation and Concessions			

Table G.2: Elicited and linked ChM processes related roles.

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Request Submission & Initiation											
1	Change Request Initiator	Change Requester/ System Stakeholder	Change Originator		Change Request Initiator	Customer / Supplier		Organisation Customer / provider		Request Originating Authority (Customer, user, supplier, sub-contractor)	Change Originator	Change Originator
2		Initial Validity Checker (Customer Support, Application Support, Member of the development team)	Receiving Authority (ChM Officer or Software CM team member)		Help Desk/ As a Process Owner						Configuration Management Officer	
3	Change Management Authority (for RFC Approval or Rejection in the Initiation stage)		ChM Authority (ChM, ChM Officer)		Configuration Control Manager (Initiation Resolution) / As a Process Owner					Management Authority		
	Change Evaluation and Assessment											
4					Configuration Control Manager As a Process Owner / (coordinates assessment and combines findings)						Configuration Management Officer	

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
5	Change Evaluator (Formal Authority)/ Impact Assessor/ Change Authority (To evaluate regular Change)	Change Assessment and Costing Analyser (Development or Maintenance team, Architect)	Software Engineering Staff / Analysis Group	Impacted areas of responsibility / Affected personnel and interfacing organisations/ Justification and Assessment Authority	Review Cycle (includes Assessment Entity/ Subject Matter Experts/ Stakeholders)				Stakeholder/ Design Organisation/ Authority's Representative	Management Authority		
	Change Disposition											
6			Change Manager or ChM officer for pre-evaluation screening and coordination									

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
7	Change Authority for Disposition and authorise build and Test/ Change Advisory Board (CAB) for Disposition Emergency CAB (ECAB) (As a Change Authority Disposition)	Change Control Board (CCB) Product Development Group	CCB/ CMO/ Project Leader as Approving/ Dis-Approving Authority	Change Approval Authority / Change Boards CCB/Program Review Board/ Change Review Board	Configuration Control Board / Subject Matter Experts/ Peer Review/ Independent Verification Authority as a Process Owner	Change Control Board/ Review Board	Configuration Control Board	Dispositioning Authority	Configuration Change Authority/ Subsidiary Committee/ Authority Representative	Authority Board / Configuration Item Management Authority	Configuration Change Authority/ Configuration Control Board	Change Disposition Authority/ Disposition Authority Representative/ Stakeholder/ Functional Area/ Change Control Board
8											Configuration Management Officer for notification	
	Authorised Change Plan & Schedule											
9	Change Management as Planning Authority			Planning Authorities	Planning Authorities					Designing Authority		
10	Stakeholders (Customer, Service Level Management, Service Desk, Service Provider/Management) to agree the Plans and schedule											

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Authorised Change Build & Test											
11	Change Management or Change Release and Deployment to coordinate the Build and Test				Project Manager as Process Owner							
12	Technical Authorities for Build and Test	Development Team Change Implementer	Development Team for building and Testing	Implementation Authorities	Assigned Implementation Authority (IT member) IT member / System owner for Testing		Technical Processes Related Authorities			Change Responsible Authority		
13	Change Authority (To evaluate build and test then authorise change deployment)				Implementation Project Manager							
	Change Release & Deployment											
14	Change Management to Coordinate the Release and Deployment											
15	Change Release and Deployment Management	Development Team	Release Authority		IT Member or Assigned Authority					Change Responsible Authority		

Row ID	ITIL 2011	Sommerville 2016	SCM Handbook 2015	EIA649-B 2011	CCRM Guide 2012	INCOSE 2015	IEEE std. 15288-2015	BS ISO 10007:2017	JSP 886-2015	BS EN 9223-104:2018	MIL-STD-3046:2013	IEEE 828:2012
	Change Final Evaluation & Closure											
16	CAB, Change Authority, impact assessors, product authorities, and release authorities to review final evaluation results, Change Evaluation Process Management, Customer, Stakeholder	Product Development Group / CCB to Review	Reviewing Team/ Authority	Verification and Auditing Authority		Configuration Management and Product Assurance	Verification and Validation Processes related Authorities		In-service configuration control Authority/ Subsidiary Committee (Reviewing Authority)			
17	Change Management Staff (to close a change)				Help Desk (To Close the Change) / Configuration Control Manager							

APPENDIX - F: DESIGN AND DEVELOPMENT ASPECTS RELATED TO THE ONTOLOGY-BASED SOS CONTEXT VIEW COMPONENT

As highlighted in Section 6.2.3, each of the intended ontologies for the development of the SoS context view artefact considers the representation of a specific concern. The 'Abstract SoS Context View Ontology' concerns the semantic representation of the main elements of the SoS context view conceptual model, illustrated previously in Figure 6.3. The 'Adapted-srBPA Ontology' concerns the representation of the Riva-based BPA elements (e.g. EBEs, UOWs, BPs, Relations). The 'BPM Ontology' concerns the representation of the main elements related to BP modelling, based on adopting the Semantic Business Process Model and Notation (sBPMN) ontology of the SUPER-project (Hepp and Roman, 2007). The 'BPAOntoSOA-driven Ontology' concerns the representation of elements derived by enacting the BPAOntoSOA framework to derive candidate software services and its related BPs and tasks. These ontologies are linked using specific object properties to establish the proposed holistic view and traceability network between them. For instance, using an object property to link a BP in the abstract SoS context view ontology with the related BP in the Adapted-srBPA ontology, or using an object property to link between a BP in the abstract SoS context view ontology with the related BPM. The resulting ontology will be an 'Integrated SoS Context View Ontology' that includes all the aforementioned ontological elements.

(I) The Abstract SoS Context View Ontology Elements

As discussed in Chapter 2, ontology development involves: (i) defining the main ontology concepts (classes); (ii) arranging the identified concepts in a taxonomic (superclass-subclass) hierarchy; (iii) defining slots (properties) and facets (restrictions on slots); and (iv) instantiating the defined classes and filling the related slots (Noy and McGuinness et al., 2001).

To develop the abstract SoS context view ontology, an OWL 2.0 ontology-based meta-model has been developed using the Protégé 5.5 development environment to semantically represent the elements of the developed abstract SoS context view conceptual model presented previously. Accordingly, the conceptual model for the BPA-driven SoS context view has been translated into a formal ontology representation. Two main sub-concepts have been identified for most of the concepts considered within the conceptual meta-model. One sub-concept concerns the global-level of the arrangement, while the other concerns the local-level of the arrangement. For example, the Business Service concept has two main sub-concepts; a Global-Level (GL) Business Service linked to the GL-Business Area of an SoS arrangement, and a Local-Level (LL) Business Service linked to each Constituent Business Area participating in the LL-Business Area of an SoS arrangement. Figure XV.1 shows a class hierarchy of the developed ontology related concepts.

In addition to identifying the data properties (i.e. hasID_Name_Version), two types of object properties were also identified: the first being transitive (e.g. isPartOf_Transitive, hasPart_Transitive); and the second is more specific to the relations between the sub-concepts (e.g. BPAModel_isPartOf_BPA, BPM_hasPart_BPool). The use of transitive object properties allows the reasoner to automatically infer semantic transitive relations. For example, if an instance of a Constituent Business Area is defined as 'isPartOf_Transitive' an instance of a Local Level Business Area, and the instance of a Local Level Business Area is defined as 'isPartOf_Transitive' an instance of an SoS arrangement, the reasoner will automatically infer that the instance of Constituent Business Area 'isPartOf_Transitive'the identified instance of an SoS arrangement. Figure XV.2 presents an example of this property type utilisation.

Figure J.1: A class hierarchy of the developed abstract SoS context view ontology concepts.

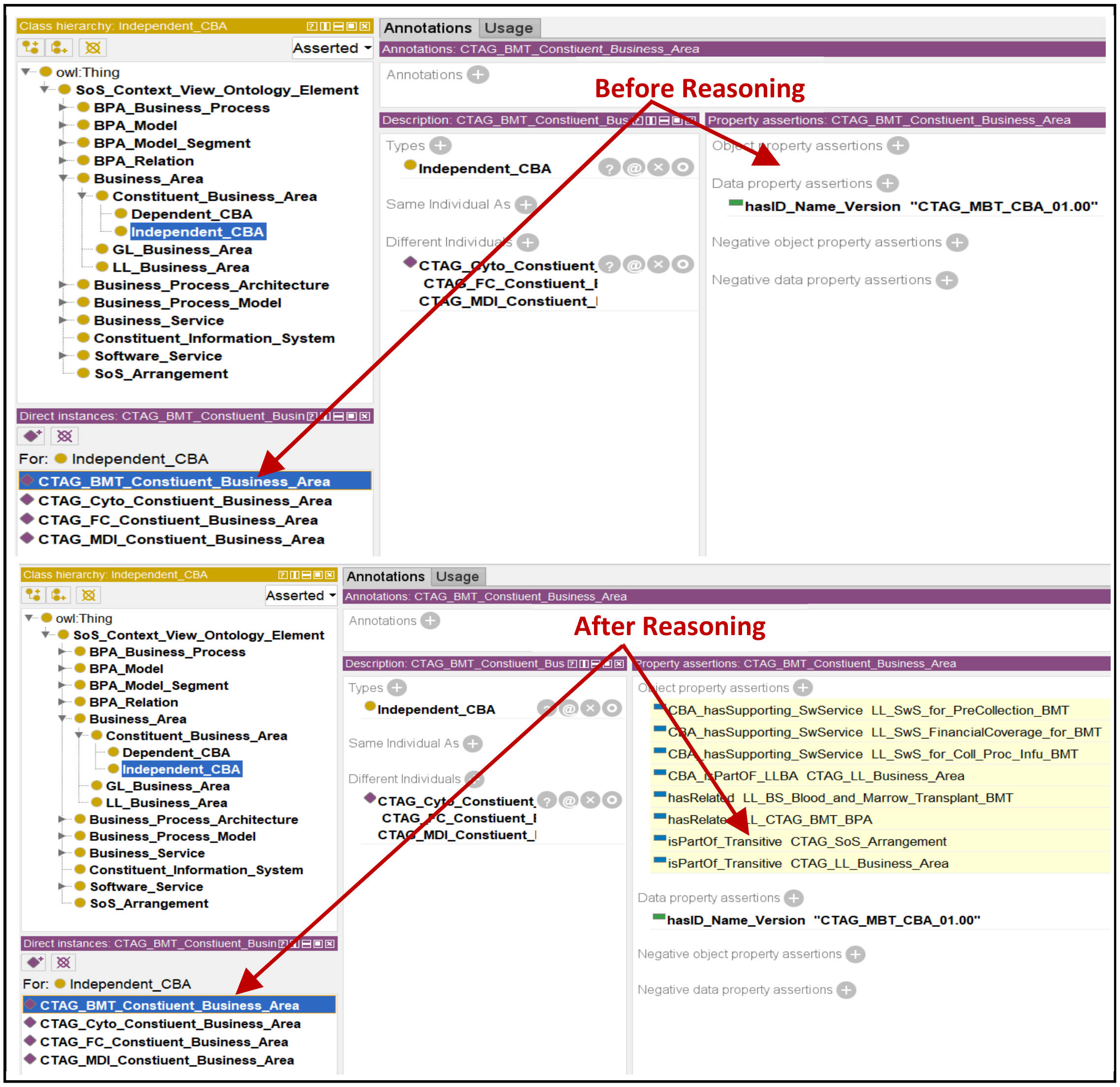


Figure J.2: Example of using a transitive property within the SoS context view ontology to reason semantic relations.

However, restrictions such as identifying the property as 'Functional' (only one instance can be identified for the property range) or applying 'Universal Restriction' to the range of a property cannot be used with transitive properties. Therefore, another set of object properties has been created to identify specific restrictions on object properties. These properties can be used to help semantically enrich the developed concepts and the relationships between them, reflecting the identified cardinalities, and confining them with restrictions requires to maintain the correctness of the relations between the identified concepts. Figures XV.3 and XV.4 show an example of this property type utilisation.

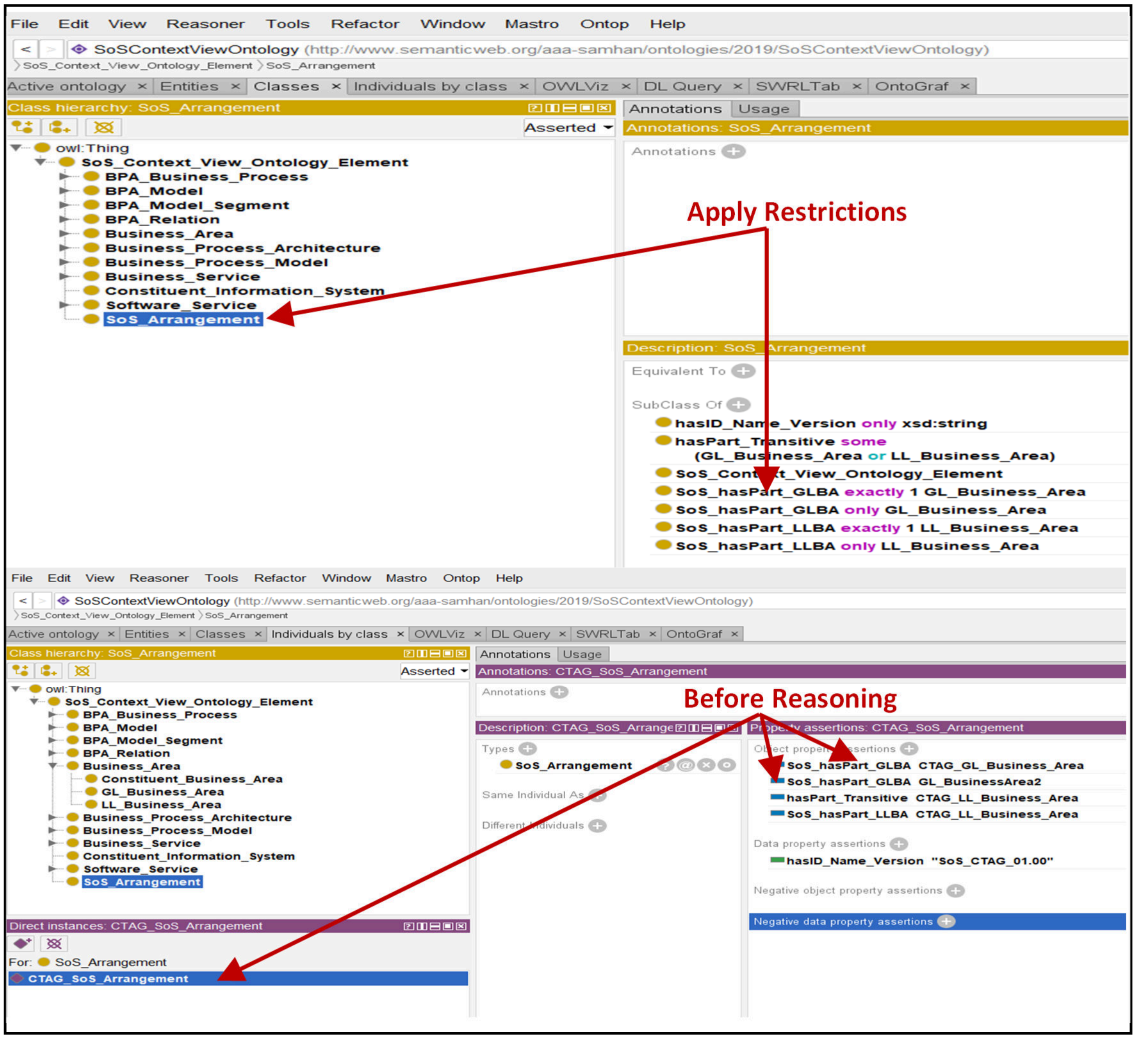


Figure J.3: Example – using restrictions with properties to maintain the correctness of the abstract SoS context view ontology – before reasoning.

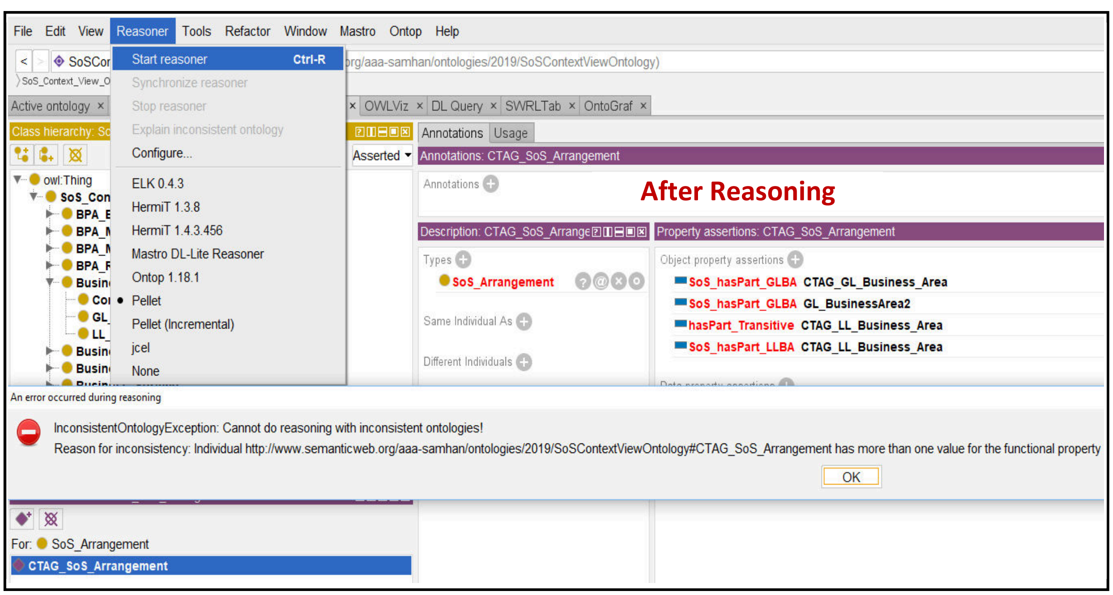


Figure J.4: Example, cont. – using restrictions with properties to maintain the correctness of the abstract SoS context view ontology – after reasoning.

(II) The Adapted-srBPA Ontology

As discussed in **Chapter 5**, the Adapted-srBPA ontology adapts the original srBPA Ontology (Yousef, 2010) that semantically enriches, captures, and represents the Riva-based BPA modelling elements. The adaptation was proposed to represent the CSP concept, its related relationships, and the applied 2nd-Cut PAD generation heuristics. See **Chapter 5, Section 5.3** for a detailed description of this ontology. Figure XV.5 shows the class hierarchy of the Adapted-srBPA ontology.

At this stage of the research, the Adapted-srBPA was used to capture and formally model the BPA of the GL-Business Area and the BPA of each LL-Constituent Business Area that participates in forming the GL-Business Area.

(III) The sBPMN Ontology

Driven by the adoption of the BPAOntoSOA framework (Yousef, 2010) to identify the candidate software services related to a constituent business area participating in an SoS arrangement, the sBPMN ontology of the SUPER project (2008) has been adopted to capture and represent the BPM elements considered in the present research. The sBPMN ontology defines classes related to the core concepts of the BPMN 1.0 specification, such as BusinesProcessDiagram; GraphicalObject including Artefact, ConnectionObject, FlowObject; and Input and Output Sets to formally conceptualise BPMN related elements. Details of the sBPMN ontology can be obtained from deliverable 4.5 of the SUPER project (Hepp and Roman, 2007). Figure XV.6 shows the main concepts included in the class hierarchy for the adopted sBPMN ontology. Furthermore, Figure XV.7 represents the class hierarchy of the GraphicalObject concept, including the core elements used in the BPM diagrams based on the BPMN specification. Abramowicz et al. (2011) described the main core concepts entailed in the sBPMN ontology.

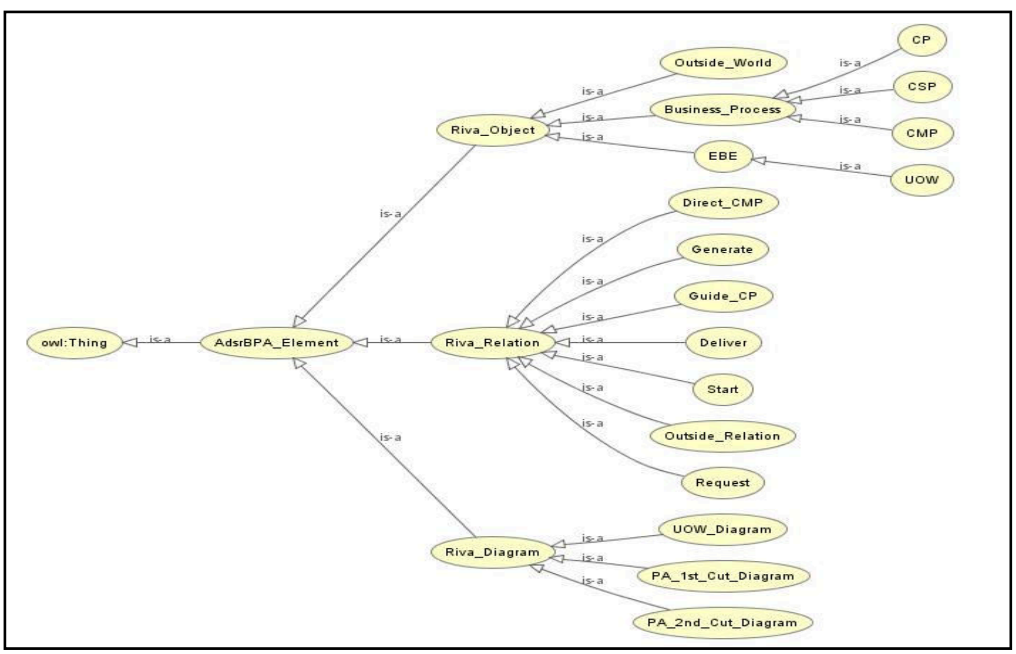


Figure J.5: Class hierarchy of the Adapted-srBPA ontology.

The current BPMN 2.0 specification contains almost twice the number of elements entailed in the BPMN 1.0 specification. Yet, this research considers the representation of the core BPMN elements related to BP modelling (BPMN 1.0 or 2.0), including core elements related to Swim Lanes, Flow Objects, Data, Artefacts, and Connecting Objects, which are covered by the sBPMN provided by SUPER project (2008). Additionally, the BPAOntoSOA framework (adopted for this framework development) is established

based on using the SUPER-sBPMN ontology. Therefore, use of the sBPMN ontology -based on BPMN 1.0 specification - was selected for this research. For future directions, sBPMN 2.0 specification-based ontologies can be adopted to represent BPM related aspects considered in this research.

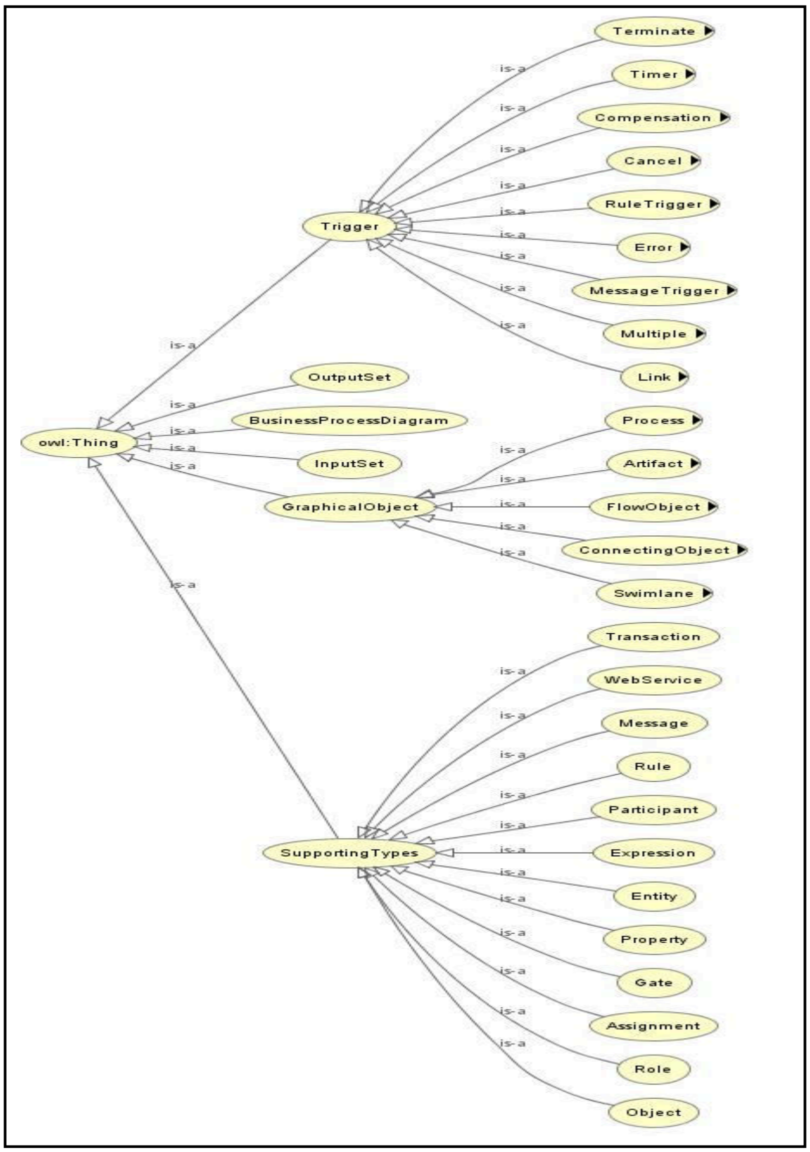


Figure J.6: Class hierarchy of the adopted sBPMN ontology.

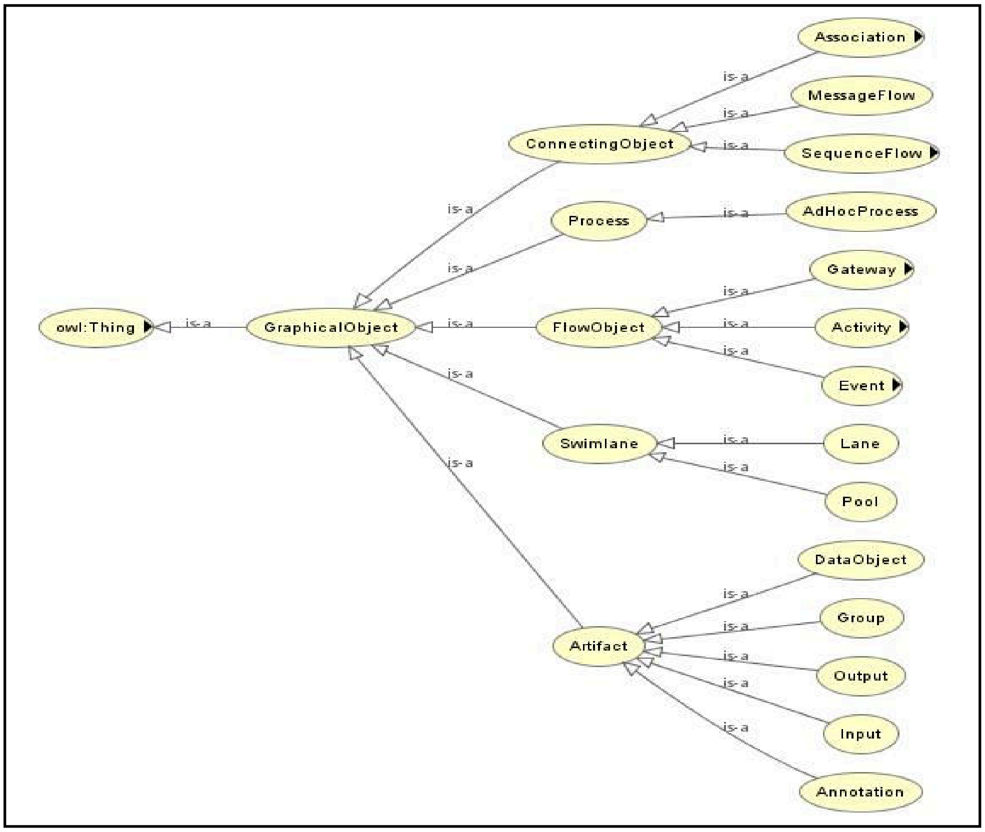


Figure J.7: Class hierarchy of the GraphicalObject concept entailed in the adopted sBPMN ontology.

The sBPMN ontology is used in this research to semantically enrich, capture, and formally model the core elements of the BPMs supporting the BPs included in the BPA of each LL-Constituent Business Area.

(IV) The BPAOntoSOA Framework-driven Ontology

As discussed in Chapter 2, the BPAOntoSOA framework (Yousef, 2010) was proposed to identify candidate software services from a semantically enriched Riva-based BPA. It also enriches the identified software services by linking them to the capabilities related to the encapsulated BPs. This could be performed by linking semantically enriched BPMs to the related semantically enriched BPA. For these purposes, the BPAOntoSOA framework relates between the srBPA ontology and sBPMN ontology using the 'hasCorrespondingBPM' object property. It then applies algorithms to derive Riva Process Architecture (RPA)-Cluster instances that represent the candidate Sw-Services. Furthermore, it utilises SWRL rules to identify the capabilities related to each identified candidate Sw service. Figure XV.8 shows an example snapshot of using the BPAOntoSOA framework related ontology for a case study from Yousef (2010).

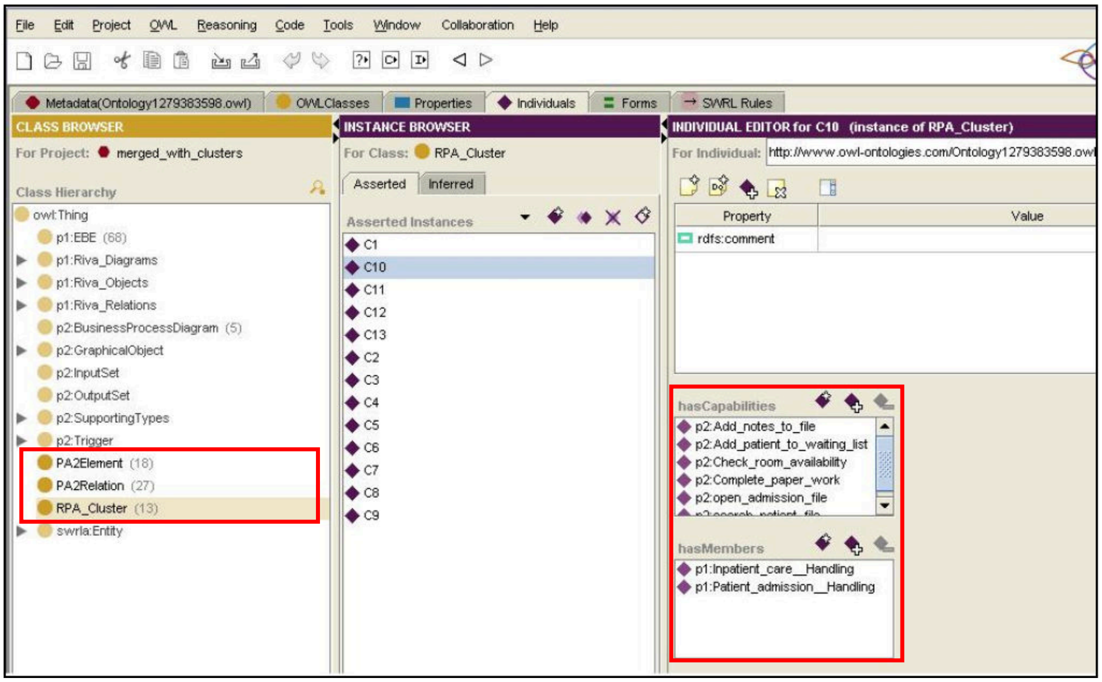


Figure J.8: Example snapshot of using the BPAOntoSOA framework ontology for SW services identification for a case study at KHCC/Jordan (Yousef, 2010, p. 130), ©UWE & Yousef, 2010.

In this research, the use of the BPAOntoSOA framework for the semantic identification of the business supporting software services was conducted for each local-level constituent business area participating in an SoS arrangement. This had to be done after adapting the used properties and algorithms within the BPAOntoSOA framework to include the CSP concept and its related relations (i.e. object properties) proposed in the Adapted-srBPA ontology. The instantiated BPA and BPMs related to a specific local-level constituent business area were linked, and then the related software services identification algorithms were applied to identify the related Sw services (i.e. RPA Clusters) and encapsulating capabilities. Achieving this allows for the business aspects of each participating local-level constituent business area to be linked with the related IT aspects represented by the identified software services.

(V) The Semantic Enrichment of the Linkages Between the Adopted and Adapted Ontologies

To develop a more holistic view entailing the abstract SoS context view ontology elements and its related BPA, BPM, and software services identification elements, the ontologies' elements related to Riva-based BPA, BPMN-based BPM, and BPAOntoSOA-driven were added and linked to the developed abstract SoS context view ontology, resulting in an 'Integrated SoS Context View Ontology'. This also enables the provision of a traceability network between them. A set of object properties was used to link these ontologies. Part of the used object properties was already covered by the BPAOntoSOA framework (coloured blue in Figure XV.9, while others are proposed by this research (coloured green in Figure XV.9). Figure XV.9 shows the proposed linkages based on using object properties between specific elements of the related ontologies.

The adapted srBPA ontology is linked to the abstract SoS context view ontology via three main object properties. The 'Has_Related_Process' property links a BP instance from the first ontology (the Adapted srBPA ontology) to a BP instance from the second ontology (SoS context view ontology). The 'Has_Related_PADiagram' links a PA Diagram instance from the first ontology to a BPA model instance from the second ontology. The 'Has_Related_Relation' property links a relation instance from the first ontology to a relation instance from the second ontology.

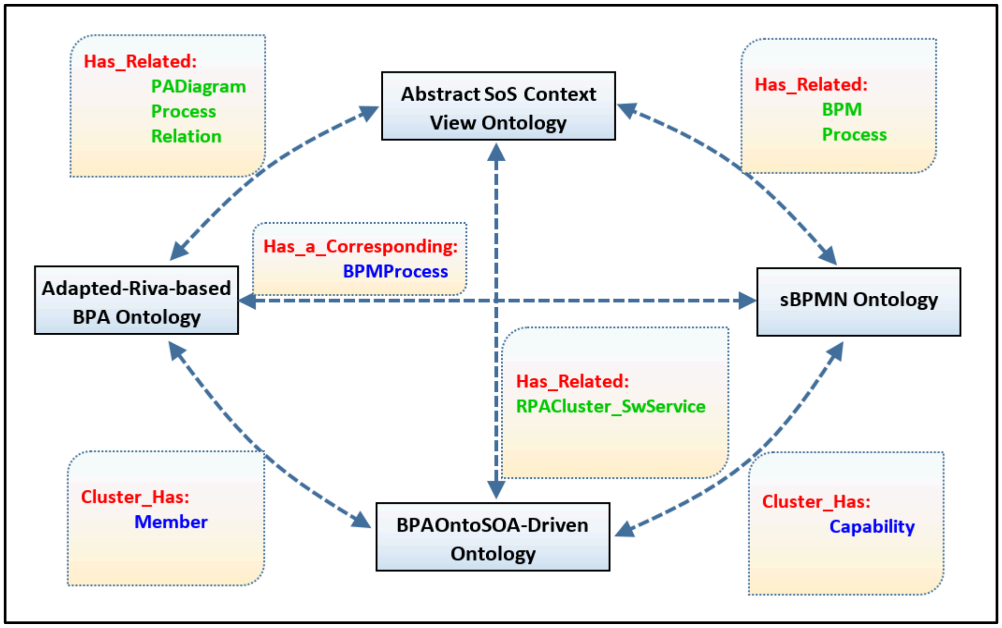


Figure J.9: The proposed linkages between the incorporated ontologies.

As proposed by Yousef (2010), the 'hasCorrespondingBPM' object property was used to relate between the srBPA ontology BPs (CP and CMP) and the sBPMN ontology Process, which covers the 'Has_a_Corresponding_BPMPorcess' object property proposed in this research between the Adapted srBPA ontology and the sBPMN ontology. In this research to fully link the Adapted srBPA ontology to the sBPMN ontology, the domain of this property was adapted to further include the CSP concept. Additionally, the object properties 'Has_Related_BPM' and 'Has_Related_Process' are proposed to link instances of the Abstract SoS context view ontology (i.e. BPM and Process) and the related instances of the sBPMN ontology (i.e. BPMN diagram and Process), respectively.

Implementation of the BPAOntoSOA framework results in proposing ontology elements (i.e. RPA_Cluster and PA2_Element) that can be linked to the related srBPA and sBPMN ontologies. Therefore, the 'Cluster_Has_Member' is an object property proposed to link the RPA_Cluster instances from the BPAOntoSOA-driven ontology with the related BP in the Adapted srBPA ontology (CP, CMP, or CSP), as covered by the original 'hasMembers' object property of the BPAOntoSOA-driven ontology. Furthermore, the 'Has_Related_RPACluster_SwService' property is proposed to link the RPA_Cluster element of the BPAOntoSOA-driven ontology and the Sw service element of the Abstract SoS context view ontology. Moreover, the 'Cluster_Has_Capability' object property (proposed by the BPAOntoSOA framework using the 'hasCapability' object property) links the RPA cluster element of the BPAOntoSOA-driven ontology and the related Task elements in the sBPMN ontology.

APPENDIX - G: TRACEABILITY ROUTES IDENTIFIED TO GUIDE THE DEVELOPMENT OF THE ALGORITHMIC AND SQWRL-BASED KNOWLEDGE RETRIEVAL CAPABILITIES

#	Change Traceability Starting Point	Candidate Implications and related ChM-driven Stakeholders Traceability Route For Related Cis and ChM-driven Stakeholders Identification
1	GL-Business Service	Related ChM-driven Roles
		Related GL-BPA Segment
		Related GL-BPs
		Related GL-Relations
		Related GL-BPA and its related entailed elements
		Related GL-BPA's ChM-driven Roles
		Related GL-Business Area
		Related LL-Business Area
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-BPs
		Related LL-BPA Segment
		Related LL-Relations
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related LL-BPA and its related entailed elements
		Related LL-BPA's ChM-driven Roles
		Related LL-BPMs
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles
2	GL-BPA Element	Related GL-BPA
		Related GL-BPA's ChM-driven Roles
		Related elements entailed in the GL-BPA
		Related GL-BPA Segments
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
		Related GL-Business Area
		Related LL-Business Area
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-BPs
		Related LL-BPA Segments
		Related LL-Relations
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related LL-BPA and its related entailed elements
		Related LL-BPA's ChM-driven Roles
		Related LL-BPMs
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles

#	Change Traceability Starting Point	Candidate Implications and related ChM-driven Stakeholders Traceability Route For Related Cis and ChM-driven Stakeholders Identification
3	LL- Business Service	Related ChM-driven Roles
		Related LL-BPA Segment
		Related LL-BPs
		Related LL-Relations
		Related LL-BPA and its related entailed elements
		Related LL-BPA's ChM-driven Roles
		Related LL-BPMs
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-Business Area
		Related GL-Business Area
		Related GL-BPs
		Related GL-BPA Segment
		Related GL-Relations
		Related GL-BPA and its related entailed elements
		Related GL-BPA's ChM-driven Roles
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
4	LL-BPA Element	Related LL-BPA
		Related LL-BPA's ChM-driven Role
		Related elements entailed in the LL-BPA
		Related LL-BPA Segments
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related LL-BPMs
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-Business Area
		Related GL-Business Area
		Related GL-BPs
		Related GL-BPA Segment
		Related GL-Relations
		Related GL-BPA and its related entailed elements
		Related GL-BPA's ChM-driven Roles
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
5	LL-BPM Element (Tasks or Pool)	Other related LL-BPM elements
		Related LL-BPM
		Related LL-BPMs' ChM-driven Roles
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs

#	Change Traceability Starting Point	Candidate Implications and related ChM-driven Stakeholders Traceability Route For Related Cis and ChM-driven Stakeholders Identification
		Related LL-Constituent ISs' ChM-driven Roles
		Related LL-BPs
		Related LL-BPA-Segment
		Related LL-Relations
		Related LL-BPA
		Related LL-BPA's ChM-driven Roles
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-Business Area
		Related GL-Business Area
		Related GL-BPs
		Related GL-BPA-Segments
		Related GL-Relations
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
		Related GL-BPA
		Related GL-BPA's ChM-driven Roles
6	LL-SW-Service	Related LL-SW-Services' ChM-driven Roles
		Related LL-Constituent ISs
		Related LL-Constituent ISs' ChM-driven Roles
		Related LL-BPM
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-BPs
		Related LL-Relations
		Related LL-BPA Segments
		Related LL-BPA
		Related LL-BPA's ChM-driven Roles
		Related LL-Business Services
		Related LL-Business Services' ChM-driven Roles
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-Business Area
		Related GL-Business Area
		Related GL-BPs
		Related GL-BPA-Segments
		Related GL-Relations
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
		Related GL-BPA
		Related GL-BPA's ChM-driven Roles
7	LL-Constituent Information System	Related LL-CIS's ChM-driven Roles
		Related LL-SW-Services
		Related LL-SW-Services' ChM-driven Roles
		Related LL-BPM
		Related LL-BPMs' ChM-driven Roles
		Related LL-BPMs' Tasks
		Related LL-BPMs' Users
		Related LL-BPs
		Related LL-Relations
		Related LL-BPA Segments
		Related LL-BPA
		Related LL-BPA's ChM-driven Roles
		Related LL-Business Services

#	Change Traceability Starting Point	Candidate Implications and related ChM-driven Stakeholders Traceability Route For Related Cis and ChM-driven Stakeholders Identification
		Related LL-Business Services' ChM-driven Roles
		Related Constituent Business Areas
		Related Constituent Business Areas' ChM-driven Roles
		Related LL-Business Area
		Related GL-Business Area
		Related GL-BPs
		Related GL-BPA-Segments
		Related GL-Relations
		Related GL-Business Services
		Related GL-Business Services' ChM-driven Roles
		Related GL-BPA
		Related GL-BPA's ChM-driven Roles

APPENDIX - H: DESCRIPTION FOR THE IDENTIFIED GENERALISED CHM STAGES AND THEIR RELATED DECISION GATES

Element	Type	Brief Description
Change Submission	**Change Stage**	During this ChM Stage, a change request is filled and submitted by a change initiator and then checked for completeness and clarity by the change request receiving authority.
Change Is Complete and Clear	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the completeness and clarity of the submitted change request conducted in the change submission stage.
Change Initiation	**Change Stage**	During this ChM Stage, the submitted change request is logged in, initially validated and recorded. In addition, other aspects as the initial identification of related authorities, categorisation, selecting a related change model are considered.
Change Is Initially Valid	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the initial validity of the submitted change request conducted in the change initiation stage.
Change Assessment and Evaluation	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related change authorities thoroughly assess and evaluate the submitted change. In addition, an integrated change assessment is prepared and analysed by the ChM authorities.
Change Is Valid	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the validity of the submitted change request after the assessment is done in the change assessment stage.
Change Disposition	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related change disposition authorities decide whether to approve/disapprove the submitted change request.
Change Is Approved	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the deposition decision of the change disposition stage.
Authorised Change Plan and Schedule	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities plan and schedule the authorised change.
Change Build and Test Authorisation	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities approve/disapprove the identified change plans and schedule.
Change Is Authorised For Building and Testing	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the change build and test authorisation decision.
Authorised Change Build and Test	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities implement the authorised change.
Change Release and Deployment Authorisation	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities approve/disapprove the implemented changes.
Change Is Authorised For Release and Deployment	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the change release and deployment authorisation decision.

Element	Type	Brief Description
Authorised Change Release and Deployment	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities release and deploy the authorised change.
Change Final Evaluation	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities evaluate the change for the final acceptance.
Change Is Accepted After Evaluation	**Decision Gate**	This decision gate is about deciding to progress to the next ChM stage based on the acceptance decision of the evaluated change.
Change Remediation	**Change Stage**	During this ChM Stage, ChM authorities coordinate and make sure that the related authorities implement the identified change remediation plans.
Change Closure	**Change Stage**	During this ChM Stage, ChM authorities closes the change based on authorities' decisions of related to the approving or rejecting the change.
Change Appeal	**Change Stage**	During this ChM Stage, the change initiator appeals to reconsider a closed or rejected change.
Change Record	**Change Stage**	During this ChM Stage, ChM authorities update the change record related to a submitted change based on the conducted ChM stage and its outputs.

APPENDIX - I: SEGMENTS OF THE DEVELOPED CHM-ASPECTS RELATED KNOWLEDGE RETRIEVAL ALGORITHMS AND SUPPORTING SQWRL-BASED CAPABILITIES

ALGORITHM I: CHM ASPECTS KNOWLEDGE RETRIEVAL

INPUT:

- The Integrated BPA-driven Ontology for ChM.

OUTPUT:

- Knowledge related to the identified category.

```
BEGIN

        Print 'Which Knowledge Retrieval Category you would like to execute?
                        Choice 1: General Knowledge about all the ChM Stages.
                        Choice 2: Knowledge about a specific ChM Stage.
                        Choice 3: Knowledge about a specific ChM Abstract Process.'

   IF (Choice 1 Is Selected)

        Results [ ] =Call General ChM Stages Flow Knowledge Retrieval Algorithm ( )

   Else IF (Choice 2 Is Selected)
        ChM Stage = Retrieve the value of the ChM Stage from the user.
        Results [ ] =Call Specific ChM Stage Knowledge Retrieval Algorithm (ChM Stage)

   Else IF (Choice 3 Is Selected)
        ChM Process = Retrieve the value of the ChM Process from the user.
        Results [ ] =Call Specific ChM Process Knowledge Retrieval Algorithm (ChM
                        Process)
   Else
      Return "Choice is not valid, please revise your choice"

   Return Results [ ] to the User.

End
```

ALGORITHM III: SPECIFIC CHM PROCESS KNOWLEDGE RETRIEVAL ALGORITHM

INPUT:

- The Integrated BPA-driven Ontology for ChM

OUTPUT:

- Knowledge Retrieved Related to a Specific ChM Process.

BEGIN

ChM-Process = **Retrieve** the 'ChM-Process' that is sent to the Algorithm.

Main-ChM-Stage = **Retrieve** the 'ChM-Stage' that encapsulates the **ChM-Process.**

Direct-ChM-Stages [ ] = **Retrieve** the 'ChM Stages' that are directly connected to the identified **Main-ChM-Stage** without decision gates.

Main-Decision-Gate = **Retrieve** the 'Decision Gate' that is related to the identified **Main-ChM-Stage.**

Next-ChM-Stage-IF-Positive = **Retrieve** the 'ChM Stage' that follows the identified **Main-Decision-Gate** if its status is **Positive.**

Next-ChM-Stage-IF-Negative = **Retrieve** the 'ChM Stage' that follows the identified **Main-Decision-Gate** if its status is **Negative.**

Outgoing-Dynamic-Relationships [ ] = **Retrieve** the 'Outgoing Dynamic Relationships' for the identified **ChM-Process.**

ChM-Process-Terminologies [ ] = **Retrieve** the 'Terminology' related to the identified **ChM-Process.**

ChM-Process-Documents [ ] = **Retrieve** the 'ChM Documents' related to the identified **ChM-Process.**

ChM-Process-Documents-Terminologies [ ] = **Retrieve** the 'Terminology' related to each ChM Document in the identified **ChM-Process-Documents [ ].**

ChM-Process-Roles [ ] = **Retrieve** the 'ChM Roles' related to the identified **ChM-Process.**

ChM-Process-Roles-Terminologies [ ] = **Retrieve** the 'Terminology' related to each ChM Roles in the identified **ChM-Process-Roles [ ].**

Riva-based-CP = **Retrieve** the 'Riva-based Case Process' related to the identified **ChM Process.**

Riva-based-CP-IsActive = **Retrieve** the 'Is Active Value' related to the identified **Rive-based-CP.**

Riva-based-CP-DepednecyOnSoS = **Retrieve** the 'Dependency Relation Value' related the identified **Rive-based-CP.**

Riva-based-CMP = **Retrieve** the '**Riva-based Case Management Process**' related to the identified **ChM Process.**

Riva-based-CMP-IsActive = **Retrieve** the '**Is Active Value**' related to the identified **Rive-based-CMP.**

Riva-based-CMP-DepednecyOnSoS = **Retrieve** the '**Dependency Relation Value**' related to the identified **Rive-based-CMP.**

Riva-based-CSP = **Retrieve** the '**Riva-based Case Strategy Process**' related to the identified **ChM Process.**

Riva-based-CSP-IsActive = **Retrieve** the '**Is Active Value**' related to the identified **Rive-based-CSP.**

Riva-based-CSP-DepednecyOnSoS = **Retrieve** the '**Dependency Relation Value**' related to the identified **Rive-based-CSP.**

Riva-based-UOW = **Retrieve** the '**Riva-based Unit Of Work**' related to the identified **ChM Process.**

Riva-based-1st-Cut-PAD = **Retrieve** the '**Riva-based 1st Cut PAD**' related to the identified **ChM Process.**

Riva-based-2nd-Cut-PAD = **Retrieve** the '**Riva-based 1st Cut PAD**' related to the identified **ChM Process.**

Riva-based-CP-Request-Relations [ ] = **Retrieve** the '**Riva-based Request Relations**' related to the identified **Riva-based-CP.**

Riva-based-Requests-IsActive [ ] = **Retrieve** the '**Is Active Value**' related to each Request Relation in the identified **Riva-based-CP-Request-Relations [ ].**

Riva-based-Requests-Sources [ ] = **Retrieve** the '**Source**' related to each Request Relation in the identified **Riva-based-CP-Request-Relations [ ].**

Riva-based-Requests-Destinations [ ] = **Retrieve** the '**Destination**' related to each Request Relation in the identified **Riva-based-CP-Request-Relations [ ].**

Riva-based-CP-Start-Relations [ ] = **Retrieve** the '**Riva-based Start Relations**' related to the identified **Riva-based-CP.**

Riva-based-CP-Starts-IsActive [ ] = **Retrieve** the '**Is Active Value**' related to each Start Relation in the identified **Riva-based-CP-Start-Relations [ ].**

Riva-based-CP-Starts-Sources [ ] = **Retrieve** the '**Source**' related to each Start Relation in the identified **Riva-based-CP-Start-Relations [ ].**

Riva-based-CP-Starts-Destinations [ ] = **Retrieve** the '**Destination**' related to each Start Relation in the identified **Riva-based-CP-Start-Relations [ ].**

Riva-based-CP-Deliver-Relations [ ] = **Retrieve** the 'Riva-based Deliver Relations' related to the identified **Riva-based-CP.**

Riva-based-CP-Delivers-IsActive [ ] = **Retrieve** the 'Is Active Value' related to each Deliver Relation in the identified **Riva-based-CP-Deliver-Relations [ ].**

Riva-based-CP-Delivers-Sources [ ] = **Retrieve** the 'Source' related to each Delivers Relation in the identified **Riva-based-CP-Deliver-Relations [ ].**

Riva-based-CP-Delivers-Destinations [ ] = **Retrieve** the 'Destination' related to each Deliver Relation in the identified **Riva-based-CP-Start-Relations [ ].**

Riva-based-CMP-Start-Relation = **Retrieve** the 'Riva-based Start Relation' related to the identified **Riva-based-CMP.**

Riva-based-CMP-Start-IsActive = **Retrieve** the 'Is Active Value' related to the identified **Riva-based-CMP-Start-Relation.**

Riva-based-CMP-Start-Source = **Retrieve** the 'Source' related to the identified **Riva-based-CMP-Start-Relation.**

Riva-based-CMP-Start-Destination = **Retrieve** the 'Destination' related to the identified **Riva-based-CMP-Start-Relation.**

Riva-based-CSP-Guide_CP-Relation = **Retrieve** the 'Riva-based Guide_CP Relation' related to the identified **Riva-based-CSP.**

Riva-based-CSP-Guide_CP-IsActive = **Retrieve** the 'Is Active Value' related to the identified **Riva-based-CSP-Guide_CP-Relation.**

Riva-based-CSP-Guide_CP-Source = **Retrieve** the 'Source' related to the identified **Riva-based-CSP-Guide_CP-Relation.**

Riva-based-CSP-Guide_CP-Destination = **Retrieve** the 'Destination' related to the identified **Riva-based-CSP-Guide_CP-Relation.**

Riva-based-CSP-Direct_CMP-Relation = **Retrieve** the 'Riva-based Direct_CMP Relation' related to the identified **Riva-based-CSP.**

Riva-based-CSP-Direct_CMP-IsActive = **Retrieve** the 'Is Active Value' related to the identified **Riva-based-CSP-Direct_CMP-Relation.**

Riva-based-CSP-Direct_CMP-Source = **Retrieve** the 'Source' related to the identified **Riva-based-CSP-Direct_CMP -Relation.**

Riva-based-CSP-Direct_CMP-Destination = **Retrieve** the 'Destination' related to the identified **Riva-based-CSP-Direct_CMP -Relation.**

Return All Of The Retrieved Elements.

END

Supporting SQWRL-Based Statements To Enable Knowledge Aspects Retrieval Related to a Specific ChM Process
ChM-SQWRL-01: For a specific ChM Abstract Process, retrieve the encapsulating ChM Stage.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AbstractChMProcess_Has_Encapsulating_ChMStage (?related_uow, ?related_chm_stage) ^ -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_chm_stage)
ChM-SQWRL-02: For a specific ChM Abstract Process, retrieve the encapsulating ChM Stage. In addition, retrieve the Direct Stages, Decision Gates, and next ChM Stages following the Decision Gates related to the identified encapsulating ChM Stage.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AbstractChMProcess_Has_Encapsulating_ChMStage (?related_uow, ?related_chm_stage) ^ ChMStage_Has_Related_DirectStage(?related_chm_stage, ?direct_related_stage) ^ ChMStage_Has_Related_StageDecisionGate (?related_chm_stage, ?related_decision_gate) ^ NextSage_IF_Positive (?related_decision_gate, ?next_stage_if_positive) ^ NextStage_IF_Negative(?related_decision_gate, ?next_stage_if_negative) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_chm_stage, ?direct_related_stage, ?related_decision_gate, ?next_stage_if_positive, ?next_stage_if_negative)
ChM-SQWRL-03: For a specific Abstract ChM Process, retrieve its outgoing Dynamic Relationships.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:Has_a_Generate_Relation (?related_uow, ?process_has_a_dynamic_relation) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?process_has_a_dynamic_relation)
ChM-SQWRL-04: For a specific Abstract ChM Process, retrieve its related detected Terminologies.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:Has_Synonym(?related_uow, ?has_terminology) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?has_terminology)
ChM-SQWRL-05: For a specific Abstract ChM Process, retrieve its related ChM Documents.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChMExtension:ChM_Process_Has_Related_Document(ChMExtension:P01_Change_Request_Submission, ?process_related_document) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?process_related_document) ^ sqwrl:orderBy(?process_related_document)

ChM-SQWRL-06: For a specific Abstract ChM Process, retrieve its related ChM Documents alongside the Documents related detected Terminologies.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChMExtension:ChM_Process_Has_Related_document (ChMExtension:P01_Change_Request_Submission, ?process_related_document) ^ ChMExtension:Has_Synonym(?process_related_document, ? document_related_terminology) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?process_related_document, ?document_related_terminology) ^ sqwrl:orderBy(?process_related_document) ^ sqwrl:orderBy(?artefact_related_terminology)

ChM-SQWRL-07: For a specific Abstract ChM Process, retrieve its related ChM Roles.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChMExtension:ChM_Process_Has_Related_Role(ChMExtension:P01_Change_Request_Submission, ?process_related_role) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?process_related_role) ^ sqwrl:orderBy(?process_related_role)

ChM-SQWRL-08: For a specific Abstract ChM Process, retrieve its related ChM Roles alongside the Roles related detected Terminologies.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChMExtension:ChM_Process_Has_Related_Role(ChMExtension:P01_Change_Request_Submission, ?process_related_role) ^ ChMExtension:Has_Synonym(?process_related_role, ?role_related_terminology) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?process_related_role, ?role_related_terminology) ^ sqwrl:orderBy(?process_related_role) ^ sqwrl:orderBy(?role_related_terminology)

ChM-SQWRL-09: For a specific Abstract ChM Process, retrieve its related Case Process, Case Management Process, and Case Strategy Process. In addition, retrieve the Is_Active and Dependency on SoS Context Values related to the identified Riva-Processes.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CP(?related_uow, ?related_case_process) ^ AdsrBPA:UOW_Has_a_Corresponding_CMP(?related_uow, ?related_case_management_process) ^ AdsrBPA:UOW_Has_a_Corresponding_CSP(?related_uow, ?related_case_strategy_process) ^ AdsrBPA:Is_Active(?related_case_process, ?cp_is_active_value) ^ AdsrBPA:Is_Active(?related_case_management_process, ?cmp_is_active_value) ^ AdsrBPA:Is_Active(?related_case_strategy_process, ?csp_is_active_value) ^ AdsrBPA:CP_IsDependentOn_SoS(?related_case_process, ?cp_is_SoS_dependent_value) ^ AdsrBPA:CMP_IsDependentOn_SoS(?related_case_management_process, ?cmp_is_SoS_dependent_value) ^ AdsrBPA:CSP_IsPartiallyDependentOn_SoS(?related_case_strategy_process, ?csp_is_SoS_partially_dependent_value) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_process, ?cp_is_active_value, ?cp_is_SoS_dependent_value, ?related_case_management_process, ?cmp_is_active_value, ?cmp_is_SoS_dependent_value, ?related_case_strategy_process, ?csp_is_active_value, ?csp_is_SoS_partially_dependent_value) ^

sqwrl:orderBy(?related_case_process) ^ sqwrl:orderBy(?related_case_management_process) ^ sqwrl:orderBy(?related_case_strategy_process)
ChM-SQWRL-10: For a specific Abstract ChM Process, retrieve its related Case Process that has Request Relations and the related Request Relations. In addition, retrieve the Is_Active Values, Sources and Destinations of the identified Request Relations.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CP(?related_uow, ?related_case_process) ^ AdsrBPA:Has_a_Request_Relation(?related_case_process, ?cp_has_a_request_relation) ^ AdsrBPA:Is_Active (?cp_has_a_request_relation, ?request_relation_is_active_value) ^ AdsrBPA:Has_a_CP_Source(?cp_has_a_request_relation, ?requst_has_cp_source) ^ AdsrBPA:Has_a_CMP_Destination(?cp_has_a_request_relation, ?requst_has_cmp_destination) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_process, ?cp_has_a_request_relation, ?request_relation_is_active_value, ?requst_has_cp_source, ?requst_has_cmp_destination) ^ sqwrl:orderBy(?related_case_process)
ChM-SQWRL-11: For a specific Abstract ChM Process, retrieve its related Case Process that has Start Relations and the related Start Relations. In addition, retrieve the Is_Active Values, Sources and Destinations of the identified Start Relations.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CP(?related_uow, ?related_case_process) ^ AdsrBPA:Has_a_Start_Relation(?related_case_process, ?cp_has_a_start_relation) ^ AdsrBPA:Is_Active (?cp_has_a_start_relation, ?start_relation_is_active_value) ^ AdsrBPA:Has_a_CP_Source(?cp_has_a_start_relation, ?start_has_a_source) ^ AdsrBPA:Has_a_CP_Destination(?cp_has_a_start_relation, ?start_has_a_destination) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_process, ?cp_has_a_start_relation, ?start_relation_is_active_value, ?start_has_a_source, ?start_has_a_destination) ^ sqwrl:orderBy(?related_case_process)
ChM-SQWRL-12: For a specific Abstract ChM Process, retrieve its related Case Process that has Deliver Relations and the related Deliver Relations. In addition, retrieve the Is_Active Values, Sources and Destinations of the identified Deliver Relations.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CP(?related_uow, ?related_case_process) ^ AdsrBPA:Has_a_Deliver_Relation(?related_case_process, ?cp_has_a_deliver_relation) ^ AdsrBPA:Is_Active (?cp_has_a_start_relation, ?deliver_relation_is_active_value) ^ AdsrBPA:Has_a_CP_Source(?cp_has_a_deliver_relation, ?deliver_has_a_source) ^ AdsrBPA:Has_a_CP_Destination(?cp_has_a_deliver_relation, ?deliver_has_a_destination) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_process, ?cp_has_a_deliver_relation, ?deliver_relation_is_active_value, ?deliver_has_a_source, ?deliver_has_a_destination) ^ sqwrl:orderBy(?related_case_process)

ChM-SQWRL-13: For a specific Abstract ChM Process, retrieve its related Case Management Process (CMP) alongside the CMP corresponding Is_Active Value and Start Relation. In addition, retrieve the Is_Active Value, Source, and Destination of the identified Start Relation.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CMP(?related_uow, ?related_case_management_process) ^ AdsrBPA:Is_Active(?related_case_management_process, ?cmp_is_active_value) ^ AdsrBPA:Has_a_Start_Relation(?related_case_management_process, ?cmp_has_start_relation) ^ AdsrBPA:Is_Active(?cmp_has_start_relation, ?start_relation_is_active_value) ^ AdsrBPA:Has_a_CMP_Source(?cmp_has_start_relation, ?start_has_cmp_source) ^ AdsrBPA:Has_a_CP_Destination(?cmp_has_start_relation, ?start_has_cp_destination) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_management_process, ?cmp_is_active_value, ?cmp_has_start_relation, ?start_relation_is_active_value, ?start_has_cmp_source, ?start_has_cp_destination) ^ sqwrl:orderBy(?related_case_management_process)

ChM-SQWRL-14: For a specific Abstract ChM Process, retrieve its related Case Strategy Process (CSP) alongside the CSP corresponding Is_Active Value, Guide_CP Relation and Direct CMP Relation. In addition, retrieve the Is_Active Values, Sources and Destinations of the CSP related identified Relations.
ChMExtension:ChM_Process(ChMExtension:P01_Change_Request_Submission) ^ ChM_Process_Has_Related_CP(ChMExtension:P01_Change_Request_Submission, ?related_cp) ^ AdsrBPA:Has_a_Corresponding_UOW(?related_cp, ?related_uow) ^ AdsrBPA:UOW_Has_a_Corresponding_CSP(?related_uow, ?related_case_strategy_process) ^ AdsrBPA:Is_Active(?related_case_strategy_process, ?csp_is_active_value) ^ ^ AdsrBPA:Has_a_Guide_CP_Relation(?related_case_strategy_process, ?csp_has_guide_cp_relation) ^ AdsrBPA:Is_Active(?csp_has_guide_cp_relation, ?guide_cp_is_active_value) ^ AdsrBPA:Has_a_CSP_Source(?csp_has_guide_cp_relation, ?guide_cp_source) ^ AdsrBPA:Has_a_CP_Destination(?csp_has_guide_cp_relation, ?guide_cp_destination) ^ AdsrBPA:Has_a_Direct_CMP_Relation(?related_case_strategy_process, ?csp_has_direct_cmp_relation) ^ AdsrBPA:Is_Active(?csp_has_direct_cmp_relation, ?direct_cmp_is_active_value) ^ AdsrBPA:Has_a_CSP_Source(?csp_has_direct_cmp_relation, ?direct_cmp_source) ^ AdsrBPA:Has_a_CMP_Destination(?csp_has_direct_cmp_relation, ?direct_cmp_destination) -> sqwrl:select(ChMExtension:P01_Change_Request_Submission, ?related_case_strategy_process, ?csp_is_active_value,?csp_has_guide_cp_relation, ?guide_cp_is_active_value, ?guide_cp_source, ?guide_cp_destination, ?csp_has_direct_cmp_relation, ?direct_cmp_is_active_value, ?direct_cmp_source, ?direct_cmp_destination) ^ sqwrl:orderBy(?related_case_strategy_process)

APPENDIX - J: SEGMENTS OF THE DEVELOPED SOS-ASPECTS RELATED KNOWLEDGE RETRIEVAL ALGORITHMS AND SUPPORTING SQWRL-BASED CAPABILITIES

ALGORITHM SOS-I: CANDIDATE CHANGE IMPLICATIONS TRACEABILITY

INPUT: A fully filled and validated **Change Type Form** (CTF); where it consists of a set of fields filled a ChM authority.

OUTPUT:

- A list of candidate impacted CIs, Pools and Authorities that are related to a submitted Change Request.

BEGIN

Ch_Type = **Retrieve** the value of the **change main type** from CTF

IF (Ch_Type **Is** 'GL-Business Service Related Change')
 Starting Point = **Retrieve** the value of the **Main Element Name** from the CTF
 Results [ ] =**Call** GL-Business Service Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'GL-Business Process Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** GL-Business Process Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'GL-BPA-Unit Of Work Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** GL-BPA-UOW Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'GL-BPA-Generate Relation Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** GL-BPA-Generate Relation Related Knowledge Retrieval (Starting Point)

Else IF (Ch _Type **Is** 'Constituent Business Area')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** CBA Related Knowledge Retrieval (Starting Point)

Else IF (Ch _Type **Is** 'LL-Business Service Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** LL-Business Service Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'LL-Business Process Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** LL-Business Process Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'LL-BPA-Unit Of Work Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** LL-BPA-UOW Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type **Is** 'LL-BPA-Generate Relation Related Change')
 Starting Point = **Retrieve** the value of the **Element Name** from the CTF
 Results [ ] =**Call** LL-BPA-Generate Relation Related Knowledge Retrieval (Starting Point)

```
Else IF (Ch_Type Is 'LL-BPM-Task Related Change')
    Starting Point = Retrieve the value of the Element Name from the CTF
    Results [ ] =Call LL-BPM-Task Related Knowledge Retrieval (Starting Point)

Else IF (Ch_Type Is 'LL-BPM-Pool Related Change')
    Starting Point = Retrieve the value of the Element Name from the CTF
    Results [ ] =Call LL-BPM-Pool Related Knowledge Retrieval (Starting Point)

Else IF (Ch _Type Is 'LL-SW Service Related Change')
    Starting Point = Retrieve the value of the Element Name from the CTF
    Results [ ] =Call LL-SW Service Related Knowledge Retrieval (Starting Point)

Else IF (Ch _Type Is 'LL-Constituent Information System Related Change')
    Starting Point = Retrieve the value of the Element Name from the CTF
    Results [ ] =Call LL-CIS Related Knowledge Retrieval (Starting Point)

END
```

ALGORITHM SOS-II: GL-BUSINESS SERVICE RELATED KNOWLEDGE RETRIEVAL

INPUT: a CI as Starting Point.
OUTPUT: A set of identified impacted elements and needed authorities related to the identified CI.

BEGIN

GL_BS = Starting Point

GL-BS-Name-ID-Version = **Retrieve** the 'Name_ID_Version' of the identified **GL-BS**
GL-Business-Area = **Retrieve** the 'GL-BA' Related to the identified **GL-BS**
LL-Business-Area = **Retrieve** the 'LL-BA' Related to the identified **GL-Business-Area**

GL-BS-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **GL-BS**
GL-BS-Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **GL-BS**
GL-BS-Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **GL-BS**
GL-BS-Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **GL-BS**
GL-BS-Releasers [ ] = **Retrieve** the 'Releaser (s)' of the identified **GL-BS**
GL-BS-Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **GL-BS**

GL-Supporting-BPA-Model-Segment = **Retrieve** the 'GL-BPA-Segment' that supports the identified **GL-BS**
GL-SoS-BPA-Model = **Retrieve** the 'GL-BPA-Model' that encapsulates the identified **GL-Supporting-BPA-Model-Segment**
GL-SoS-BPA = **Retrieve** the 'GL-BPA' that encapsulates the identified **GL-SoS-BPA-Model**

GL-SoS-BPA-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **GL-SoS-BPA**
GL-SoS-BPA Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Releasers [ ] = **Retrieve** the 'Releaser (s)' of the identified **GL-SoS-BPA**
GL-SoS-BPA-Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **GL-SoS-BPA**

Encapsulated-GL-Business-Processes: E-GL-BPs [ ] = **Retrieve** the 'GL-Business Processes' that are part of the identified **GL-Supporting-BPA-Model-Segment**

Encapsulated-GL-Relations: E-GL-Rels [ ] = **Retrieve** the 'Relations' that are part of the identified **GL-Supporting-BPA-Model-Segment**

For each identified GL-Business_Process: GL-BPi **From** the E-GL-BPs [ ] **Do**

GL-Model-Segments [ ] = **Retrieve** the 'GL-BPA-Model-Segments' that encapsulate the identified **GL-Bpi**

GL-BPA-UOW = Retrieve the 'GL-Adapted Riva UOW' that is related to the identified GL-Bpi

GL-BPA-1st-Cut-PAD = Retrieve the 'GL-Adapted Riva 1st-Cut-PAD' that is related to the identified GL-BPi

GL-BPA-2nd-Cut-PAD = Retrieve the 'GL-Adapted Riva 2nd-Cut-PAD' that is related to the identified GL-Bpi

GL-BPA-BP-CP = Retrieve the 'GL-Adapted Riva CP' that is related to the identified GL-Bpi

GL-BPA-BP-CP-Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CP

GL-BPA-BP-CP-Request-Relations [ ] = Retrieve the 'Request Relations' that are related to the identified GL-BPA-BP-CP

GL-BPA-BP-CP-Request-Relations_Is_Active-Values [ ] = Retrieve the 'Is_Active Values' that are related to the identified GL-BPA-BP-CP-Request-Relations

GL-BPA-BP-CP-Start-Relations [ ] = Retrieve the 'Start Relations' that are related to the identified GL-BPA-BP-CP

GL-BPA-BP-CP-Start-Relations_Is_Active-Values [ ] = Retrieve the 'Is_Active Values' that are related to the identified GL-BPA-BP-CP-Start-Relations

GL-BPA-BP-CP-Deliver-Relations [ ] = Retrieve the 'Deliver Relations' that are related to the identified GL-BPA-BP-CP

GL-BPA-BP-CP-Deliver-Relations_Is_Active-Values [ ] = Retrieve the 'Is_Active Values' that are related to the identified GL-BPA-BP-CP-Deliver-Relations

GL-BPA-BP-CMP = Retrieve the 'GL-Adapted Riva CMP' that is related to the identified GL-Bpi

GL-BPA-BP-CMP-Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CMP

GL-BPA-BP-CMP-Start-Relation = Retrieve the 'Start Relation' that is related to the identified GL-BPA-BP-CMP

GL-BPA-BP-CMP-Start-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CMP-Start-Relation

GL-BPA-BP-CSP = Retrieve the 'GL-Adapted Riva CSP' that is related to the identified GL-Bpi

GL-BPA-BP-CSP-Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CSP

GL-BPA-BP-CSP-Guide_CP-Relation = Retrieve the 'Guide_CP Relation' that is related to the identified GL-BPA-BP-CSP

GL-BPA-BP-CSP-Guide_CP-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CSP-Guide_CP-Relation

GL-BPA-BP-CSP-Direct_CMP-Relation = Retrieve the 'Direct_CMP Relation' that is related to the identified GL-BPA-BP-CSP

GL-BPA-BP-CSP-Direct_CMP-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified GL-BPA-BP-CSP-Direct_CMP-Relation

Related SoS-LL-BP = **Retrieve** the 'SoS-LL-BP' that is related to the identified GL-BPi
LL-BPA-Model-Segments [ ] = **Retrieve** the 'SoS-LL-BPA-Model-Segments' that encapsulate the identified **Related SoS-LL-BP**
LL-BSs [ ] = **Retrieve** the 'LL-Business Services' that are supported by each BPA-Model Segment identified in the **LL-BPA-Model-Segments [ ]**
LL-BSs-Owners [ ] = **Retrieve** the 'Owner (s)' for each LL-BS of the identified **LL-BSs [ ]**
LL-BSs-Managers [ ] = **Retrieve** the 'Manager (s)' for each LL-BS of the identified **LL-BSs [ ]**
LL-BSs-Engineers [ ] = **Retrieve** the 'Engineer (s)' for each LL-BS of the identified **LL-BSs [ ]**
LL-BSs-Evaluators [ ] = **Retrieve** the 'Evaluator (s)' for each LL-BS of the identified **LL-BSs [ ]**
LL-BSs-Releasers [ ] = **Retrieve** the 'Releaser (s)' for each LL-BS of the identified **LL-BSs [ ]**
LL-BSs-Deployers [ ] = **Retrieve** the 'Deployer (s)' for each LL-BS of the identified **LL-BSs [ ]**

LL-SoS-BPA-Model = **Retrieve** the 'LL-SoS-BPA-Model' that is related to the identified **Related SoS-LL-BP**
LL-SoS-BPA = **Retrieve** the 'LL-SoS-BPA' that is related to the identified **Related SoS-LL-BP**

LL-BPA-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **LL-SoS-BPA**
LL-BPA-Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **LL-SoS-BPA**
LL-BPA-Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **LL-SoS-BPA**
LL-BPA Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **LL-SoS-BPA**
LL-BPA-Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **LL-SoS-BPA**
LL-BPA-Releasers [ ] = **Retrieve** the 'Releaser (s)' of the identified **LL-SoS-BPA**

LL-CBA = **Retrieve** the 'Constituent Business Area' that is related to the identified **LL-BPA**
LL-CBA-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **LL-CBA**
LL-CBA-Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **LL-CBA**
LL-CBA-Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **LL-CBA**

LL-SoS-BPM = **Retrieve** the 'LL-SoS-BP-Model' that is related to the identified **Related SoS-LL-BP**
LL-SoS-BPM-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **LL-SoS-BPM**
LL-SoS-BPM -Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **LL-SoS-BPM**
LL-SoS-BPM -Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **LL-SoS-BPM**
LL-SoS-BPM -Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **LL-SoS-BPM**
LL-SoS-BPM -Releasers [ ] = **Retrieve** the 'releaser (s)' of the identified **LL-SoS-BPM**
LL-SoS-BPM -Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **LL-SoS-BPM**

LL-SoS-SwS = **Retrieve** the 'LL-SoS-SwS' that is related to the identified **Related SoS-LL-BP**
LL-SoS- SwS -Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **LL-SoS-SwS**
LL-SoS- SwS -Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **LL-SoS-SwS**
LL-SoS- SwS -Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **LL-SoS-SwS**
LL-SoS- SwS -Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **LL-SoS-SwS**
LL-SoS- SwS -Releasers [ ] = **Retrieve** the 'Releaser (s)' of the identified **LL-SoS-SwS**
LL-SoS- SwS -Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **LL-SoS-SwS**

LL-Supporting-Constituent-ISs [ ] = **Retrieve** the 'Constituent Information Systems' that support the identified **LL-SoS-SwS**
LL-CISs-Owners [ ] = **Retrieve** the 'Owner (s)' of the identified **LL-CISs**
LL- CISs-Managers [ ] = **Retrieve** the 'Manager (s)' of the identified **LL-CISs**
LL- CISs-Engineers [ ] = **Retrieve** the 'Engineer (s)' of the identified **LL-CISs**
LL- CISs-Evaluators [ ] = **Retrieve** the 'Evaluator (s)' of the identified **LL-CISs**
LL- CISs-Releasers [ ] = **Retrieve** the 'Releaser (s)' of the identified **LL-CISs**
LL- CISs-Deployers [ ] = **Retrieve** the 'Deployer (s)' of the identified **LL-CISs**

LL-BPM-Process = **Retrieve** the 'LL-BPM-Process' **that** is related to the identified **Related SoS-LL-BP**
LL-Encapsulated-Tasks [ ] = **Retrieve** the 'LL-BPM-Tasks' **that** are related to the identified **LL-BPM-Process**
LL-Encapsulated-Pools [ ] = **Retrieve** the 'LL-BPM-Pools' **that** are related to the identified **LL-BPM-Process**

LL-RPA-Cluster = **Retrieve** the 'LL-RPA-Cluster' that is related to the identified **LL-SoS-SwS**
LL-RPA-Cluster-Members [ ] = **Retrieve** the 'LL-RPA-Cluster-Members' of the identified **LL-RPA-Cluster**
LL-RPA-Cluster-Capabilities [ ] = **Retrieve** the 'LL-RPA-Cluster-Capabilities' of the identified **LL-RPA-Cluster**
LL-BPA-UOW = **Retrieve** the 'LL-Adapted Riva UOW' **that** is related to the identified **Related LL-SoS-BP**
LL-BPA-1st-Cut-PAD = **Retrieve** the '1st-Cut-PAD' **that** is related to the identified **Related LL-SoS-BP**
LL-BPA-2nd-Cut-PAD = **Retrieve** the '2nd-Cut-PAD' **that** is related to the identified **Related LL-SoS-BP**
LL-BPA-BP-CP = **Retrieve** the 'LL-Adapted Riva CP' **that** is related to the identified **Related LL-SoS-BP**
LL-BPA-BP-CP-Is_Active-Value = **Retrieve** the 'Is_Active Value' **that** is related to the identified **LL-BPA-BP-CP**
LL-BPA-BP-CP-Request-Relations [ ] = **Retrieve** the 'Request Relations' **that** are related to the identified **LL-BPA-BP-CP**
LL-BPA-BP-CP-Request-Relations_Is_Active-Values [ ] = **Retrieve** the 'Is_Active Values' **that** are related to the identified **LL-BPA-BP-CP-Request-Relations**
LL-BPA-BP-CP-Start-Relations [ ] = **Retrieve** the 'Start Relations' **that** are related to the identified **LL-BPA-BP-CP**
LL-BPA-BP-CP-Start-Relations_Is_Active-Values [ ] = **Retrieve** the 'Is_Active Values' **that** are related to the identified **LL-BPA-BP-CP-Start-Relations**

LL-BPA-BP-CP-Deliver-Relations [ ] = Retrieve the 'Deliver Relations' that are related to the identified LL-BPA-BP-CP

LL-BPA-BP-CP-Deliver-Relations_Is_Active-Values [ ] = Retrieve the 'Is_Active Values' that are related to the identified GL-BPA-BP-CP-Deliver-Relations

LL-BPA-BP-CMP = Retrieve the 'LL-Adapted Riva CMP' that is related to the identified Related LL-SoS-BP

LL-BPA-BP-CMP-Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified LL-BPA-BP-CMP

LL-BPA-BP-CMP-Start-Relation = Retrieve the 'Start Relation' that is related to the identified LL-BPA-BP-CMP

LL-BPA-BP-CMP-Start-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified LL-BPA-BP-CMP-Start-Relation

LL-BPA-BP-CSP = Retrieve the 'LL-Adapted Riva CSP' that is related to the identified Related LL-SoS-BP

LL-BPA-BP-CSP-Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified LL-BPA-BP-CSP

LL-BPA-BP-CSP-Guide_CP-Relation = Retrieve the 'Guide_CP Relation' that is related to the identified LL-BPA-BP-CSP

LL-BPA-BP-CSP-Guide_CP-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified LL-BPA-BP-CSP-Guide_CP-Relation

LL-BPA-BP-CSP-Direct_CMP-Relation = Retrieve the 'Direct_CMP Relation' that is related to the identified LL-BPA-BP-CSP

LL-BPA-BP-CSP-Direct_CMP-Relation_Is_Active-Value = Retrieve the 'Is_Active Value' that is related to the identified LL-BPA-BP-CSP-Direct_CMP-Relation

End For

Return (All the retrieved elements)

END

SQWRL-based Capabilities To Retrieve Knowledge Related to a Specific GL-Business Service
GL-BS-01: For a specific GL-Business Service, retrieve its related ID_Name_Version, GL-Business Area and LL-Business Areas.
GL_Business_Service (GL_BS_Cytogenetics_Cyto) ^ Has_ID_Name_Version (GL_BS_Cytogenetics_Cyto, ?related_id_name_version) ^ Has_Related_GL_BA(GL_BS_Cytogenetics_Cyto, ?related_gl_business_area) ^ Has_Related_LL_BA(?related_gl_business_area, ?related_ll_business_area) -> sqwrl:select(GL_BS_Cytogenetics_Cyto, ?related_id_name_version, ?related_gl_business_area, ?related_ll_business_area)
GL-BS-02: For a specific GL-Business Service, retrieve its related ChM-Driven Roles.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ Has_Owner(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_owner) ^ Has_Manager(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_manager) ^ Has_Engineer(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_engineer) ^ Has_Evaluator(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_evaluator) ^ Has_Builder(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_builder) ^ Has_Tester(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_tester) ^ Has_Releaser(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_releaser) ^ Has_Deployer(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_deployer) -> sqwrl:select(GL_BS_Cytogenetics_Cyto, ?gl_bs_related_owner, ?gl_bs_related_manager, ?gl_bs_related_engineer, ?gl_bs_related_evaluator, ?gl_bs_related_builder, ?gl_bs_related_tester, ?gl_bs_related_releaser, ?gl_bs_related_deployer)
GL-BS-03: For a specific GL-BS, retrieve its related supporting GL BPA-Model-Segment, BPA-Model, and BPA.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_bpa_mSegment) ^ GL_BPA_Model(?related_bpa_model) ^ GL_BPA(?related_bpa) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment) ^ BPAMSegment_IsPartOf_BPAModel(?related_mSegment, ?related_bpa_model) ^ BPAModel_IsPartOf_BPA(?related_bpa_model, ?related_bpa) -> sqwrl:selectDistinct (GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment, ?related_bpa_model, ?related_bpa)
GL-BS-04: For a specific GL-Business Service, retrieve the related GL-BPA. In addition, retrieve the ChM-driven Roles that are related to the identified GL-BPA.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_bpa_mSegment) ^ GL_BPA_Model(?related_bpa_model) ^ GL_BPA(?related_bpa) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment) ^ BPAMSegment_IsPartOf_BPAModel(?related_mSegment, ?related_bpa_model) ^ BPAModel_IsPartOf_BPA(?related_bpa_model, ?related_bpa) ^ Has_Owner(?related_bpa, ?gl_bpa_owner) ^ Has_Manager(?related_bpa, ?gl_bpa_manager) ^

Has_Engineer(?related_bpa, ?gl_bpa_engineer) ^ Has_Evaluator (?related_bpa, ?gl_bpa_evaluator) ^ Has_Builder (?related_bpa, ?gl_bpa_builder) ^ Has_Tester (?related_bpa, ?gl_bpa_tester) ^ Has_Releaser (?related_bpa, ?gl_bpa_releaser) ^ Has_Deployer(?related_bpa, ?gl_bpa_deployer) -> sqwrl:selectDistinct (GL_BS_Cytogenetics_Cyto, ?related_bpa, ?gl_bpa_owner, ?gl_bpa_manager, ?gl_bpa_engineer,?gl_bpa_evaluator, ?gl_bpa_builder,?gl_bpa_tester, ?gl_bpa_releaser, ?gl_bpa_deployer)
GL-BS-05: For a specific GL-Business Service, retrieve the related supporting BPA-Model-Segment and the GL-Business Processes that are encapsulated in the identified BPA-Model-Segment.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?related_bpa_mSegment, ?encapsulated_gl_business_process) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment, ? encapsulated_gl_business_process)
GL-BS-06: For a specific GL-Business Service, retrieve the related supporting BPA-Model-Segment and the GL-Relations that are encapsulated in the identified BPA-Model-Segment.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment) ^ BPAMSegment_HasPart_BPARelation(?related_bpa_mSegment, ?related_gl_relation_between_bps) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_bpa_mSegment, ?related_gl_relation_between_bps)
GL-BS-07: For a specific GL-Business Service, retrieve the related supporting GL BPA-Model-Segment and the encapsulated GL-BPs. In addition, retrieve the list of the GL-BPA-Model-Segments that the encapsulated BPs participate in.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?bs_related_gl_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?bs_related_gl_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?bs_related_gl_bpa_mSegment, ?related_gl_business_process) ^ BPABP_IsPartOf_BPAMSegmnet(?related_gl_business_process, ?bp_gl_related_bpaMsegment) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?bs_related_gl_bpa_mSegment, ?related_gl_business_process, ?bp_gl_related_bpaMsegment)

GL-BS-08: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Processes (CPs), Case Management Processes (CMPs), Case Strategy Processes (CSPs), Units Of Work (UOWs) and 1st-and-2nd-Cut Process Architecture Diagrams. In addition, retrieve the Is_Active Values related to the identified CPs, CMPs and CSPs.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:CP_has_a_Managing_CMP(?related_gl_srbpa_cp, ?related_gl_srbpa_cmp) ^ gl_ctag_bpa:CP_has_a_Strategically_Managing_CSP(?related_gl_srbpa_cp, ?related_gl_srbpa_csp) ^ gl_ctag_bpa:Belongs_To_a_1st_Cut_Diagram(?related_gl_srbpa_cp, ?related_gl_1st_cut_pad) ^ gl_ctag_bpa:Belongs_To_a_2nd_Cut_Diagram(?related_gl_srbpa_cp, ?related_gl_2nd_cut_pad) ^ gl_ctag_bpa:Is_Active (?related_gl_srbpa_cp, ?cp_is_active_value) ^ gl_ctag_bpa:Is_Active (?related_gl_srbpa_cmp, ?cmp_is_active_value) ^ gl_ctag_bpa:Is_Active (?related_gl_srbpa_csp, ?csp_is_active_value) -> sqwrl:selectDistinct(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process, ?related_gl_srbpa_cp, ?cp_is_active_value, ?related_gl_srbpa_cmp, ?cmp_is_active_value, ?related_gl_srbpa_csp,?csp_is_active_value, ?related_gl_srbpa_uow, ?related_gl_1st_cut_pad, ?related_gl_2nd_cut_pad)
GL-BS-09: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Processes (CPs) that have Request Relations. In addition, retrieve the CPs related Request Relations and their Is_Active values, Sources and Destinations.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:Has_a_Request_Relation(?related_gl_srbpa_cp, ?cp_has_request_relation) ^ gl_ctag_bpa:Has_a_CP_Source(?cp_has_request_relation, ?request_has_cp_source) ^ gl_ctag_bpa:Has_a_CMP_Destination(?cp_has_request_relation, ?request_has_a_cmp_destination) gl_ctag_bpa:Is_Active (?cp_has_request_relation, ?request_is_active_value) ->

sqwrl:selectDistinct(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process, ?related_gl_srbpa_cp, ?cp_has_request_relation, ?request_is_active_value, ?request_has_cp_source, ?request_has_a_cmp_destination) ^ sqwrl:orderBy(?related_gl_srbpa_cp)
GL-BS-10: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Processes (CPs) that have Start Relations. In addition, retrieve the CPs related Start Relations and their Is_Active values, Sources and Destinations.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:Has_a_Start_Relation(?related_gl_srbpa_cp, ?cp_has_start_relation) ^ gl_ctag_bpa:Has_a_CP_Source(?cp_has_start_relation, ?start_has_cp_source) ^ gl_ctag_bpa:Has_a_CP_Destination(?cp_has_start_relation, ?start_has_a_cp_destination) gl_ctag_bpa:Is_Active (?cp_has_start_relation, ?start_is_active_value) -> sqwrl:selectDistinct (sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process, ?related_gl_srbpa_cp, ?cp_has_start_relation, ?start_is_active_value, ?start_has_cp_source, ?start_has_a_cp_destination) ^ sqwrl:orderBy(?related_gl_srbpa_cp)
GL-BS-11: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Processes (CPs) that have Deliver Relations. In addition, retrieve the CPs related Deliver relations and their Is_Active values, Sources, and Destinations.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:Has_a_Deliver_Relation(?related_gl_srbpa_cp, ?cp_has_deliver_relation) ^ gl_ctag_bpa:Has_a_CP_Source(?cp_has_deliver_relation, ?deliver_has_cp_source) ^ gl_ctag_bpa:Has_a_CP_Destination(?cp_has_deliver_relation, ?deliver_has_a_cp_destination) gl_ctag_bpa:Is_Active (?cp_has_deliver_relation, ?deliver_is_active_value) -> sqwrl:selectDistinct

(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process, ?related_gl_srbpa_cp, ?cp_has_deliver_relation, ?deliver_is_active_value, ?deliver_has_cp_source, ?deliver_has_a_cp_destination) ^ sqwrl:orderBy(?related_gl_srbpa_cp)
GL-BS-12: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Management Processes (CMPs). In addition, retrieve the CMPs related Is_Active Values and Start Relations alongside the Start Relations Is_Active values, Sources and Destinations.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:CP_has_a_Managing_CMP(?related_gl_srbpa_cp, ?related_gl_srbpa_cmp) ^ gl_ctag_bpa:Is_Active (?related_gl_srbpa_cmp, ?cmp_is_active_value) ^ gl_ctag_bpa:Has_a_Start_Relation(?related_gl_srbpa_cmp, ?cmp_has_start_relation) ^ gl_ctag_bpa:Is_Active(?cmp_has_start_relation, ?start_relation_is_active_value) ^ gl_ctag_bpa:Has_a_CMP_Source(?cmp_has_start_relation, ?start_has_cmp_source) ^ gl_ctag_bpa:Has_a_CP_Destination(?cmp_has_start_relation, ?start_has_cp_destination) -> sqwrl:selectDistinct (sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process,?related_gl_srbpa_cmp, ?cmp_is_active_value,?cmp_has_start_relation, ?start_has_cmp_source, ?start_has_cp_destination) ^ sqwrl:orderBy(?related_gl_srbpa_cmp)
GL-BS-13: For a specific GL-Business Service, retrieve the related supporting GL-BPs and their related Riva-based GL- Case Strategy Processes (CSPs). In addition, retrieve the CSPs related Is_Active Values, Guide_CP Relations and Direct_CMP Relations alongside the relations Is_Active values, Sources and Destinations.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ integrated_ctag_sos_ontology:Has_Related_Process(?related_gl_business_process, ?related_gl_srbpa_process) ^ gl_ctag_bpa:Has_a_Corresponding_UOW (?related_gl_srbpa_process, ?related_gl_srbpa_uow) ^ gl_ctag_bpa:UOW_Has_a_Corresponding_CP(?related_gl_srbpa_uow, ?related_gl_srbpa_cp) ^ gl_ctag_bpa:CP_has_a_Strategically_Managing_CSP(?related_gl_srbpa_cp, ?related_gl_srbpa_csp) ^ gl_ctag_bpa:Is_Active (?related_gl_srbpa_csp, ?csp_is_active_value) ^ gl_ctag_bpa:Has_a_Guide_CP_Relation(?related_gl_srbpa_csp, ?csp_has_guide_cp_relation) ^ gl_ctag_bpa:Is_Active(?csp_has_guide_cp_relation, ?guide_cp_is_active_value) ^

gl_ctag_bpa:Has_a_CSP_Source(?csp_has_guide_cp_relation, ?guide_cp_source) ^ gl_ctag_bpa:Has_a_CP_Destination(?csp_has_guide_cp_relation, ?guide_cp_destination) ^ gl_ctag_bpa:Has_a_Direct_CMP_Relation(?related_gl_srbpa_csp, ?csp_has_direct_cmp_relation) ^ gl_ctag_bpa:Is_Active(?csp_has_direct_cmp_relation, ?direct_cmp_is_active_value) ^ gl_ctag_bpa:Has_a_CSP_Source(?csp_has_direct_cmp_relation, ?direct_cmp_source) ^ gl_ctag_bpa:Has_a_CMP_Destination(?csp_has_direct_cmp_relation, ?direct_cmp_destination) -> sqwrl:selectDistinct (sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_business_process,?related_gl_srbpa_csp, ?csp_is_active_value,?csp_has_guide_cp_relation, ?guide_cp_is_active_value, ?guide_cp_source, ?guide_cp_destination, ?csp_has_direct_cmp_relation, ?direct_cmp_is_active_value, ?direct_cmp_source, ?direct_cmp_destination) ^ sqwrl:orderBy(?related_gl_srbpa_csp)
GL-BS-14: For a specific GL-Business Service, retrieve the related supporting GL-BPA-Model-Segment, the encapsulated GL-BPs, the related LL-BPs and the LL-BPA-Model-Segments that the LL-BPs participate in. In addition, retrieve the LL-Business Services that are supported by the identified LL-BPA-Model-Segments.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^ BPABP_IsPartOf_BPAMSegmenet(?related_ll_business_process, ?related_ll_bpa_mSegment) ^ Has_Related_LL_BS(?related_ll_bpa_mSegment, ?related_ll_business_service) -> sqwrl:selectDistinct (GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment, ?related_gl_business_process, ?related_ll_business_process, ?related_ll_bpa_mSegment, ?related_ll_business_service) ^ sqwrl:orderBy (?related_gl_bpa_mSegment) ^ sqwrl:orderBy (?related_gl_business_process)
GL-BS-15: For a specific GL-Business Service, retrieve the related supporting LL–Business Services and the ChM-driven roles related to the identified LL-Business Services.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^ BPABP_IsPartOf_BPAMSegmenet(?related_ll_business_process, ?related_ll_bpa_mSegment) ^ Has_Related_LL_BS(?related_ll_bpa_mSegment, ?related_ll_business_service) ^ Has_Owner(?related_ll_business_service, ?related_ll_bs_owner) ^ Has_Manager(?related_ll_business_service, ?related_ll_bs_manager) ^ Has_Engineer(?related_ll_business_service, ?related_ll_bs_engineer) ^ Has_Evaluator(?related_ll_business_service, ?related_ll_bs_evaluator) ^ Has_Builder(?related_ll_business_service, ?related_ll_bs_builder) ^

Has_Tester(?related_ll_business_service, ?related_ll_bs_tester) ^ Has_Releaser(?related_ll_business_service, ?related_ll_bs_releaser) ^ Has_Deployer(?related_ll_business_service, ?related_ll_bs_deployer) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_business_service, ?related_ll_bs_owner, ?related_ll_bs_manager, ?related_ll_bs_engineer, ?related_ll_bs_evaluator, ?related_ll_bs_builder, ?related_ll_bs_tester, ?related_ll_bs_deployer) ^ sqwrl:orderBy(?related_ll_business_service)
GL-BS-16: For a specific GL-Business Service, retrieve the related supporting LL BPA-Model-Segments, BPA-Models, BPAs and Constituent Business Areas.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^ BPABP_IsPartOf_BPAMSegmenet(?related_ll_business_process, ?related_ll_bpa_mSegment) ^ BPAMSegment_IsPartOf_BPAModel(?related_ll_bpa_mSegment, ?related_ll_bpa_model) ^ BPAModel_IsPartOf_BPA(?related_ll_bpa_model, ?related_ll_bpa) ^ Has_Related_CBA(?related_ll_bpa, ?related_constituent_business_area) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_bpa_mSegment, ?related_ll_bpa_model, ?related_ll_bpa, ?related_constituent_business_area) ^ sqwrl:orderBy(?related_gl_bpa_mSegment)
GL-BS-17: For a specific GL-Business Service, retrieve the related supporting LL-BPAs and their related ChM-driven Roles.
GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^ GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^ BPABP_IsPartOf_BPAMSegmenet(?related_ll_business_process, ?related_ll_bpa_mSegment) ^ BPAMSegment_IsPartOf_BPAModel(?related_ll_bpa_mSegment, ?related_ll_bpa_model) ^ BPAModel_IsPartOf_BPA(?related_ll_bpa_model, ?related_ll_bpa) ^ Has_Owner(?related_ll_bpa, ?related_ll_bpa_owner) ^ Has_Manager(?related_ll_bpa, ?related_ll_bpa_manager) ^ Has_Engineer(?related_ll_bpa, ?related_ll_bpa_engineer) ^ Has_Evaluator(?related_ll_bpa, ?related_ll_bpa_evaluator) ^ Has_Builder(?related_ll_bpa, ?related_ll_bpa_builder) ^ Has_Tester(?related_ll_bpa, ?related_ll_bpa_tester) ^ Has_Releaser(?related_ll_bpa, ?related_ll_bpa_releaser) ^ Has_Deployer(?related_ll_bpa, ?related_ll_bpa_deployer) -> sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_bpa, ?related_ll_bpa_owner, ?related_ll_bpa_manager, ?related_ll_bpa_engineer, ?related_ll_bpa_evaluator,

?related_ll_bpa_builder, ?related_ll_bpa_tester, ?related_ll_bpa_releaser,
?related_ll_bpa_deployer) ^
sqwrl:orderBy(?related_ll_bpa)

GL-BS-18: For a specific GL-Business Service, retrieve the related supporting LL-Constituent Business Areas and their related ChM-driven Roles.

GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^
GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^
Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^
BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process)
^
Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^
BPABP_IsPartOf_BPAMSegmenet(?related_ll_business_process, ?related_ll_bpa_mSegment)
^
BPAMSegment_IsPartOf_BPAModel(?related_ll_bpa_mSegment, ?related_ll_bpa_model) ^
BPAModel_IsPartOf_BPA(?related_ll_bpa_model, ?related_ll_bpa) ^
Has_Related_CBA(?related_ll_bpa, ?related_constituent_business_area)

Has_Owner(?related_constituent_business_area, ?related_ll_cba_owner) ^
Has_Manager(?related_constituent_business_area, ?related_ll_cba_manager) ^
Has_Engineer(?related_constituent_business_area, ?related_ll_cba_engineer) ^
->
sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_constituent_business_area,
?related_ll_cba_owner,
?related_ll_cba_manager, ?related_ll_cba_engineer) ^
sqwrl:orderBy(?related_constituent_business_area)

GL-BS-19: For a specific GL-Business Service, retrieve the related supporting LL-BPs and their related supporting LL-Software Services. In addition, retrieve the ChM-driven Roles that are related to the identified LL-Software Services.

GL_Business_Service(GL_BS_Cytogenetics_Cyto) ^
GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^
Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^
BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process)
^
Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^
Has_Related_SwService (?related_ll_business_process, ?related_supporting_sw_service)
Has_Owner(?related_supporting_sw_service, ?sw_service_owner) ^
Has_Manager(?related_supporting_sw_service, ?sw_service_manager) ^
Has_Engineer(?related_supporting_sw_service, ?sw_service_engineer) ^
Has_Evaluator(?related_supporting_sw_service, ?sw_service_evaluator) ^
Has_Builder(?related_supporting_sw_service, ?sw_service_builder) ^
Has_Tester(?related_supporting_sw_service, ?sw_service_tester) ^
Has_Releaser(?related_supporting_sw_service, ?sw_service_releaser) ^
Has_Deployer(?related_supporting_sw_service, ?sw_service_deployer)
->
sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_business_process,
?related_supporting_sw_service,
?sw_service_owner, ?sw_service_manager, ?sw_service_engineer, ?sw_service_evaluator,
?sw_service_builder, ?sw_service_tester, ?sw_service_releaser, ?sw_service_deployer) ^
sqwrl:orderBy(?related_ll_business_process)

GL-BS-20: For a specific GL-Business Service, retrieve the related supporting LL-BPs and their related supporting LL-Software Services and Constituent Information Systems. In addition, retrieve the ChM-driven Roles that are related to the identified Constituent Information Systems.

```
GL_Business_Service(GL_BS_Cytogenetics_Cyto)  ^
GL_BPA_Model_Segment(?related_gl_bpa_mSegment)  ^
Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment)
BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process)
^
Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process)  ^
Has_Related_SwService (?related_ll_business_process, ?related_supporting_sw_service) ^
SwService_IsSupportedBy_CIS (?related_supporting_sw_service, ?related_supporting_cis)
Has_Owner(?related_supporting_cis, ?cis_owner)  ^
Has_Manager(?related_supporting_cis, ?cis_manager)  ^
Has_Engineer(?related_supporting_cis, ?cis_engineer)  ^
Has_Evaluator(?related_supporting_cis, ?cis_evaluator)  ^
Has_Builder(?related_supporting_cis, ?cis_builder)  ^
Has_Tester(?related_supporting_cis, ?cis_tester)  ^
Has_Releaser(?related_supporting_cis, ?cis_releaser)  ^
Has_Deployer(?related_supporting_cis, ?cis_deployer)
->
sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_business_process,
?related_supporting_sw_service,?related_supporting_cis,
?cis_owner, ?cis_manager, ?cis_engineer, ?cis_evaluator,
 ?cis_builder, ?cis_tester, ?cis_releaser, ?cis_deployer )  ^
sqwrl:orderBy(?related_ll_business_process)
```

GL-BS-21: For a specific GL-Business Service, retrieve the related supporting LL-BPs and their related supporting LL-BPMs. In addition, retrieve the ChM-driven Roles that are related to the identified LL-BPMs.

```
GL_Business_Service(GL_BS_Cytogenetics_Cyto)  ^
GL_BPA_Model_Segment(?related_gl_bpa_mSegment)  ^
Has_Related_GL_BPAMSegment(GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment)  ^
BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process)
^
Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process)  ^
LLBP_HasAssociated_LLBPM(?related_ll_business_process, ?associated_ll_bpm)
Has_Owner(?associated_ll_bpm, ?related_ll_bpm_owner)  ^
Has_Manager(?associated_ll_bpm, ?related_ll_bpm_manager)  ^
Has_Engineer(?associated_ll_bpm, ?related_ll_bpm_engineer)  ^
Has_Evaluator(?associated_ll_bpm, ?related_ll_bpm_evaluator)  ^
Has_Builder(?associated_ll_bpm, ?related_ll_bpm_builder)  ^
Has_Tester(?associated_ll_bpm, ?related_ll_bpm_tester)  ^
Has_Releaser(?associated_ll_bpm, ?related_ll_bpm_releaser)  ^
Has_Deployer(?associated_ll_bpm, ?related_ll_bpm_deployer)
 ->
sqwrl:selectDistinct(GL_BS_Cytogenetics_Cyto, ?related_ll_business_process,
?associated_ll_bpm,
?related_ll_bpm_owner, ?related_ll_bpm_manager, ?related_ll_bpm_engineer,
?related_ll_bpm_evaluator,
 ?related_ll_bpm_builder, ?related_ll_bpm_tester, ?related_ll_bpm_releaser,
?related_ll_bpm_deployer )  ^
sqwrl:orderBy(?related_ll_business_process)
```

GL-BS-22: For a Specific LL-BP related to a specific GL-Business Service, retrieve the Tasks that are related to its corresponding LL-BPM.
sos_cvo:LL_Business_Process(sos_cvo:LL_Approval_for_Cyto1_CP) ^ sos_cvo:LLBP_HasAssociated_LLBPM(sos_cvo:LL_Approval_for_Cyto1_CP, ?associated_ll_bpm) ^ integrated_ctag_sos_ontology:Has_Related_Process(?associated_ll_bpm, ?ll_bpm_related_sbpmn_process) ^ sbpmn_cyto1:hasGraphicalElementsProcess(?ll_bpm_related_sbpmn_process, ?related_sbpmn_task_event_or_gateway) -> sqwrl:selectDistinct(sos_cvo:LL_Approval_for_Cyto1_CP, ?related_sbpmn_task_event_or_gateway)

GL-BS-23: For a Specific LL-BP related to a specific GL-Business Service, retrieve the Pools that are related to its corresponding LL-BPM.
sos_cvo:LL_Business_Process(sos_cvo:LL_Approval_for_Cyto1_CP) ^ sos_cvo:LLBP_HasAssociated_LLBPM(sos_cvo:LL_Approval_for_Cyto1_CP, ?associated_ll_bpm) ^ integrated_ctag_sos_ontology:Has_Related_Process(?associated_ll_bpm, ?ll_bpm_related_sbpmn_process) ^ sbpmn_cyto1:hasPool (?ll_bpm_related_sbpmn_process, ?related_sbpmn_pool) -> sqwrl:selectDistinct(sos_cvo:LL_Approval_for_Cyto1_CP, ?related_sbpmn_pool)

GL-BS-24: For a specific GL-Business Service, retrieve the related supporting LL-Software Services and the services related RPA_Clusters.
sos_cvo:GL_Business_Service (sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment (?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ sos_cvo:Has_Related_LL_BP (?related_gl_business_process, ?related_ll_business_process) ^ sos_cvo:Has_Related_SwService (?related_ll_business_process, ?related_supporting_sw_service) ^ integrated_ctag_sos_ontology:Has_Related_RPACluster_SwService(?related_supporting_sw_ service, ?related_rpa_cluster) -> sqwrl:selectDistinct(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_supporting_sw_service, ?related_rpa_cluster)

GL-BS-25: Retrieve the RPA-Clusters related to the GL-BS supporting LL-Software Services. In addition, retrieve the RPA_Clusters encapsulated Capabilities.
sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^ sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^ sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^ sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ sos_cvo:Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^ sos_cvo:Has_Related_SwService(?related_ll_business_process, ?related_supporting_sw_service) ^

integrated_ctag_sos_ontology:Has_Related_RPACluster_SwService(?related_supporting_sw_service, ?related_rpa_cluster) ^
integrated_ctag_sos_ontology:Cluster_Has_Capability(?related_rpa_cluster, ?related_cluster_capability)
->
sqwrl:selectDistinct(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_supporting_sw_service, ?related_rpa_cluster, ?related_cluster_capability)

GL-BS-26: Retrieve the RPA-Clusters related to the GL-BS supporting LL-Software Services. In addition, retrieve the RPA_Clusters encapsulated Members.

sos_cvo:GL_Business_Service(sos_cvo:GL_BS_Cytogenetics_Cyto) ^
sos_cvo:GL_BPA_Model_Segment(?related_gl_bpa_mSegment) ^
sos_cvo:Has_Related_GL_BPAMSegment(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_gl_bpa_mSegment) ^
sos_cvo:BPAMSegment_HasPart_BPABP(?related_gl_bpa_mSegment, ?related_gl_business_process) ^ sos_cvo:Has_Related_LL_BP(?related_gl_business_process, ?related_ll_business_process) ^
sos_cvo:Has_Related_SwService(?related_ll_business_process, ?related_supporting_sw_service) ^
integrated_ctag_sos_ontology:Has_Related_RPACluster_SwService(?related_supporting_sw_service, ?related_rpa_cluster) ^
integrated_ctag_sos_ontology:Cluster_Has_Member(?related_rpa_cluster, ?related_cluster_memebr)
->
sqwrl:selectDistinct(sos_cvo:GL_BS_Cytogenetics_Cyto, ?related_supporting_sw_service, ?related_rpa_cluster, ?related_cluster_memebr)

GL-BS-27: For a specific LL-BP identified for a specific GL-Business Service, retrieve the related LL Riva-driven CP, CMP, CSP, Is_Active Values of the Riva Processes, UOW, 1st_Cut_PAD and 2nd_Cut_PAD.

sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^
integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^
ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^
ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^
ll_ctag_cyto_bpa:CP_has_a_Managing_CMP(?related_ll_srbpa_cp, ?related_ll_srbpa_cmp) ^
ll_ctag_cyto_bpa:CP_has_a_Strategically_Managing_CSP(?related_ll_srbpa_cp, ?related_ll_srbpa_csp) ^
ll_ctag_cyto_bpa:Belongs_To_a_1st_Cut_Diagram(?related_ll_srbpa_cp, ?related_ll_1st_cut_pad) ^
ll_ctag_cyto_bpa:Belongs_To_a_2nd_Cut_Diagram(?related_ll_srbpa_cp, ?related_ll_2nd_cut_pad)
ll_ctag_cyto_bpa:Is_Active (?related_ll_srbpa_cmp, ?cmp_is_active_value) ^
ll_ctag_cyto_bpa:Is_Active (?related_ll_srbpa_csp, ?csp_is_active_value)
->
sqwrl:selectDistinct(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_cp, ?related_ll_srbpa_cmp, ?cmp_is_active_value, ?related_ll_srbpa_csp,?csp_is_active_value, ?related_ll_srbpa_uow, ?related_ll_1st_cut_pad, ?related_ll_2nd_cut_pad)

GL-BS-28: For a specific LL-BP identified to support a specific GL-Business Service, retrieve the related Riva-driven LL-Case Process (CP) that has Request Relations. In addition, retrieve the CP related Request Relations and their Is_Active values, Sources and Destinations.
sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^ integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^ ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^ ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^ ll_ctag_cyto_bpa:Has_a_Request_Relation(?related_ll_srbpa_cp, ?cp_has_request_relation) ^ ll_ctag_cyto_bpa:Has_a_CP_Source(?cp_has_request_relation, ?request_has_cp_source) ^ ll_ctag_cyto_bpa:Has_a_CMP_Destination(?cp_has_request_relation, ?request_has_a_cmp_destination) ll_ctag_cyto_bpa:Is_Active (?cp_has_request_relation, ?request_is_active_value) -> sqwrl:selectDistinct(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_cp, ?cp_has_request_relation, ?request_is_active_value, ?request_has_cp_source, ?request_has_a_cmp_destination) ^ sqwrl:orderBy(?related_ll_srbpa_cp)
GL-BS-29: For a specific LL-BP identified to support a specific GL-Business Service, retrieve the related Riva-driven LL-Case Process (CP) that has Start Relations. In addition, retrieve the CP related Start Relations and their Is_Active values, Sources and Destinations.
sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^ integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^ ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^ ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^ ll_ctag_cyto_bpa:Has_a_Start_Relation(?related_ll_srbpa_cp, ?cp_has_start_relation) ^ ll_ctag_cyto_bpa:Has_a_CP_Source(?cp_has_start_relation, ?start_has_cp_source) ^ ll_ctag_cyto_bpa:Has_a_CP_Destination(?cp_has_start_relation, ?start_has_a_cp_destination) ll_ctag_cyto_bpa:Is_Active (?cp_has_start_relation, ?start_is_active_value) -> sqwrl:selectDistinct(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_cp, ?cp_has_start_relation, ?start_is_active_value, ?start_has_cp_source, ?start_has_a_cp_destination) ^ sqwrl:orderBy(?related_ll_srbpa_cp)
GL-BS-30: For a specific LL-BP identified to support a specific GL-Business Service, retrieve the related Riva-driven LL-Case Process (CP) that has Deliver Relations. In addition, retrieve the CP related Deliver Relations and their Is_Active values, Sources and Destinations.
sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^ integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^ ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^ ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^ ll_ctag_cyto_bpa:Has_a_Deliver_Relation(?related_ll_srbpa_cp, ?cp_has_deliver_relation) ^ ll_ctag_cyto_bpa:Has_a_CP_Source(?cp_has_deliver_relation, ?deliver_has_cp_source) ^

ll_ctag_cyto_bpa:Has_a_CP_Destination(?cp_has_deliver_relation, ?deliver_has_a_cp_destination)
ll_ctag_cyto_bpa:Is_Active (?cp_has_deliver_relation, ?deliver_is_active_value)
->
sqwrl:selectDistinct(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_cp, ?cp_has_deliver_relation, ?deliver_is_active_value, ?deliver_has_cp_source, ?deliver_has_a_cp_destination) ^ sqwrl:orderBy(?related_ll_srbpa_cp)

GL-BS-31: For a specific LL-BP identified to support a specific GL-Business Service, retrieve the related LL- Case Management Process (CMP). In addition, retrieve the CMP related Is_Active Value and Start Relations alongside the Start relations Is_Active values, Sources and Destinations.

sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^
integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^
ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^
ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^
ll_ctag_cyto_bpa:CP_has_a_Managing_CMP(?related_ll_srbpa_cp, ?related_ll_srbpa_cmp) ^
ll_ctag_cyto_bpa:Is_Active (?related_ll_srbpa_cmp, ?cmp_is_active_value) ^
ll_ctag_cyto_bpa:Has_a_Start_Relation(?related_ll_srbpa_cmp, ?cmp_has_start_relation) ^
ll_ctag_cyto_bpa:Is_Active(?cmp_has_start_relation, ?start_relation_is_active_value) ^
ll_ctag_cyto_bpa:Has_a_CMP_Source(?cmp_has_start_relation, ?start_has_cmp_source) ^
ll_ctag_cyto_bpa:Has_a_CP_Destination(?cmp_has_start_relation, ?start_has_cp_destination)
->
sqwrl:selectDistinct (sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_cmp, ?cmp_is_active_value,?cmp_has_start_relation, ?start_has_cmp_source, ?start_has_cp_destination) ^ sqwrl:orderBy(?related_ll_srbpa_cmp)

GL-BS-32: For a specific LL-BP identified to support a specific GL-Business Service, retrieve the related LL- Case Strategy Process (CSP). In addition, retrieve the CSP related Is_Active Value, Guide_CP Relation and Direct_CMP Relation alongside the relations Is_Active values, Sources and Destinations.

sos_cvo:LL_Business_Process(sos_cvo:LL_Analysis_for_Cyto2_CP) ^
integrated_ctag_sos_ontology:Has_Related_Process(sos_cvo:LL_Analysis_for_Cyto2_CP, ?related_ll_srbpa_process) ^
ll_ctag_cyto_bpa:Has_a_Corresponding_UOW (?related_ll_srbpa_process, ?related_ll_srbpa_uow) ^
ll_ctag_cyto_bpa:UOW_Has_a_Corresponding_CP(?related_ll_srbpa_uow, ?related_ll_srbpa_cp) ^
ll_ctag_cyto_bpa:CP_has_a_Managing_CMP(?related_ll_srbpa_cp, ?related_ll_srbpa_cmp) ^
ll_ctag_cyto_bpa:CP_has_a_Strategically_Managing_CSP(?related_ll_srbpa_cp, ?related_ll_srbpa_csp) ^
ll_ctag_cyto_bpa:Is_Active (?related_ll_srbpa_csp, ?csp_is_active_value) ^
ll_ctag_cyto_bpa:Has_a_Guide_CP_Relation(?related_ll_srbpa_csp, ?csp_has_guide_cp_relation) ^
ll_ctag_cyto_bpa:Is_Active(?csp_has_guide_cp_relation, ?guide_cp_is_active_value) ^
ll_ctag_cyto_bpa:Has_a_CSP_Source(?csp_has_guide_cp_relation, ?guide_cp_source) ^
ll_ctag_cyto_bpa:Has_a_CP_Destination(?csp_has_guide_cp_relation, ?guide_cp_destination) ^

```
ll_ctag_cyto_bpa:Has_a_Direct_CMP_Relation(?related_ll_srbpa_csp,
?csp_has_direct_cmp_relation)  ^
ll_ctag_cyto_bpa:Is_Active(?csp_has_direct_cmp_relation, ?direct_cmp_is_active_value)  ^
ll_ctag_cyto_bpa:Has_a_CSP_Source(?csp_has_direct_cmp_relation, ?direct_cmp_source)  ^
ll_ctag_cyto_bpa:Has_a_CMP_Destination(?csp_has_direct_cmp_relation,
?direct_cmp_destination)
->
 sqwrl:selectDistinct (sos_cvo:LL_Approval_for_Cyto1_CP,?related_ll_srbpa_csp,
?csp_is_active_value,?csp_has_guide_cp_relation, ?guide_cp_is_active_value,
?guide_cp_source, ?guide_cp_destination, ?csp_has_direct_cmp_relation,
?direct_cmp_is_active_value, ?direct_cmp_source, ?direct_cmp_destination) ^
sqwrl:orderBy(?related_ll_srbpa_csp)
```

APPENDIX - K: SEGMENTS OF THE COMPETENCY QUESTIONS-BASED TEST CASES FOR THE DEMONSTRATION AND EVALUATION OF THE CHM-ASPECTS RELATED KNOWLEDGE RETRIEVAL CAPABILITIES

ChM Competency Questions-Based Test Cases - Category 1	
CQ1: What are the main ChM stages related to manage a normal change request?	
Expected Output	**Retrieved?**
Main ChM Stage	✓
Stage01_Change_Submission	✓
Stage02_Change_Initiation	✓
Stage03_Change_Assessment_And_Evlauation	✓
Stage04_Change_Dispostion	✓
Stage05_Authorised_Change_Plan_And_Schedule	✓
Stage06_Change_Builde_And_Test_Authoristation	✓
Stage07_Authorised_Change_Build_And_Test	✓
Stage08_Change_Release_And_Deployment_Authorisation	✓
Stage09_Authorised_Change_Release_And_Deployment	✓
Stage10_Change_Final_Evlaution	✓
Stage11_Change_Record_Common	✓
Stage12_Change_Closure_Common	✓
Stage13_Change_Appeal_Common	✓
Stage14_Change_Remediation_Common	✓

ChM Competency Questions-Based Test Cases – Category 1		
CQ2: What are the main ChM stages related to manage a normal change request? In addition, what are the direct main ChM stages related to them?		
Expected Output		**Retrieved?**
Main ChM Stage	**Direct Related Stage**	✓
Stage01_Change_ Submission	No Related Direct Stage	✓
Stage02_Change_Initiation	Stage11_Change_Record_ Common	✓
Stage03_Change_Assessment_ And_Evlauation	Stage11_Change_Record_ Common	✓
Stage04_Change_Dispostion	Stage11_Change_Record_ Common	✓
Stage05_Authorised_Change_ Plan_And_Schedule	Stage11_Change_Record_ Common	✓
Stage05_Authorised_Change_ Plan_And_Schedule	Stage06_Change_Build_ And_Test_Authorisation	✓
Stage06_Change_Builde_And_ Test_Authoristation	Stage11_Change_Record_ Common	✓
Stage07_Authorised_Change_ Build_And_Test	Stage11_Change_Record_ Common	✓
Stage07_Authorised_Change_ Build_And_Test	Stage08_Change_Release_ And_Deployment_ Authorisation	✓
Stage08_Change_Release_And_ Deployment_Authorisation	Stage11_Change_Record_ Common	✓
Stage09_Authorised_Change_ Release_And_Deployment	Stage11_Change_Record_ Common	✓
Stage10_Change_Final_Evlaution	Stage11_Change_Record_ Common	✓
Stage11_Change_Record_Common	No Related Direct Stage	✓
Stage12_Change_Closure_Common	Stage11_Change_Record_ Common	✓
Stage12_Change_Closure_Common	Stage13_Change_Appeal_Common	✓
Stage13_Change_Appeal_Common	Stage11_Change_Record_ Common	✓
Stage13_Change_Appeal_Common	Stage01_Change_Submission	✓
Stage14_Change_Remediation_ Common	Stage11_Change_Record_ Common	✓
Stage14_Change_Remediation_ Common	Stage11_Change_Closure_ Common	✓

ChM Competency Questions-Based Test Cases – Category 1		
CQ3: What are the main ChM stages related to manage a normal change request? In addition, what are the main decision gates related to the ChM stages?		
Expected Output		**Retrieved?**
Main ChM Stage	**Related Decision Gate**	✓
Stage01_Change_ Submission	Gate01_Ch_Is_Complete_And_ Clear	✓

Stage02_Change_Initiation	Gate02_Ch_Is_Initially_Valid	✓
Stage03_Change_Assessment_ And_Evlauation	Gate03_Ch_Is_Valid	✓
Stage04_Change_Dispostion	Gate04_Ch_Is_Approved	✓
Stage05_Authorised_Change_ Plan_And_Schedule	No Related Decision Gate	✓
Stage06_Change_Builde_And_ Test_Authoristation	Gate05_Ch_BuildAndTest_Is_ Authorised	✓
Stage07_Authorised_Change_ Build_And_Test	No Related Decision Gate	✓
Stage08_Change_Release_And_ Deployment_Authorisation	Gate06_Ch_ReleaseAnd Deployment_Is_Authorised	✓
Stage09_Authorised_Change_ Release_And_Deployment	No Related Decision Gate	✓
Stage10_Change_Final_Evlaution	Gate07_Ch_Final_ Evalution_Is_Accepted	✓
Stage11_Change_Record_Common	No Related Decision Gate	✓
Stage12_Change_Closure_Common	No Related Decision Gate	✓
Stage13_Change_Appeal_Common	No Related Decision Gate	✓
Stage14_Change_Remediation_ Common	No Related Decision Gate	✓

ChM Competency Questions-Based Test Cases – Category 1

CQ4: What are the main ChM stages related to manage a normal change request, their related decision gates and the next ChM stages following the decision gates?

Expected Output				Retrieved?
Main ChM Stage	**Related Decision Gate**	**Next Stage If Positive**	**Next Stage IF Negative**	✓
Stage01	Gate01	Stage02	Stage12	✓
Stage02	Gate02	Stage03	Stage12	✓
Stage03	Gate03	Stage04	Stage12	✓
Stage04	Gate04	Stage05	Stage12	✓
Stage05	No Decision Gate	N/A	N/A	✓
Stage06	Gate05	Stage06	Stage05	✓
Stage06	Gate05	Stage06	Stage12	✓
Stage07	No Decision Gate	N/A	N/A	✓
Stage08	Gate06	Stage09	Stage07	✓
Stage08	Gate06	Stage09	Stage12	✓
Stage08	Gate06	Stage09	Stage14	✓
Stage09	No Decision Gate	N/A	N/A	✓
Stage10	Gate07	Stage12	Stage07	✓
Stage10	Gate07	Stage12	Stage14	✓
Stage11	No Decision Gate	N/A	N/A	✓
Stage12	No Decision Gate	N/A	N/A	✓
Stage13	No Decision Gate	N/A	N/A	✓
Stage14	No Decision Gate	N/A	N/A	✓

ChM Competency Questions-Based Test Cases – Category 3

CQ33: For the abstract ChM process 'P01_Change_Request_Submission', what is the encapsulating main ChM stage?

Expected Output		Retrieved?
ChM Process	**Related ChM Stage**	✓
P01:Change_Request_Submission	Stage01_Change_Submission	✓

ChM Competency Questions-Based Test Cases – Category 3

CQ34: For the abstract ChM process 'P01_Change_Request_Submission', what is the encapsulating main ChM stage and the direct ChM stages, decision gates and the next ChM stages following the decision gates that are related to the encapsulating ChM stage?

Expected Output	Retrieved?

ChM Process	Related ChM Stage	Direct Related ChM Stage	Related Decision Gate	Next ChM Stage If Positive	Next ChM Stage If Negative	✓
P01:Change _Request_ Submission	Stage01	NO Direct ChM Stage	Gate01	Stage02	Stage12	✓

ChM Competency Questions-Based Test Cases – Category 3		
CQ35: For the abstract ChM process 'P01_Change_Request_Submission', what are its related outgoing dynamic relationships?		
Expected Output		**Retrieved?**
ChM Process	**Outgoing Dynamic Relationship**	✓
P01_Change_Request_Submission	G02_Ch_Submission_Generates_Ch_ Review_For_Completness	✓
P01_Change_Request_Submission	G03_Ch_Submission_Generates_ Ch_Initiation	✓

ChM Competency Questions-Based Test Cases – Category 3		
CQ36: For the abstract ChM process 'P01_Change_Request_Submission', what are its related detected terminologies?		
Expected Output		**Retrieved?**
ChM Process	**Detect Terminology**	✓
P01_Change_Request_Submission	Change Request (INCOSE 2015; BS EN 9223-104:2018; IEEE 828:2012)	✓
P01_Change_Request_Submission	Change Request Preparation and Submission (CCRM Guide 2012)	✓
P01_Change_Request_Submission	Request For Change (EIA-649B, 2011; IEEE std. 15288:2015)	✓
P01_Change_Request_Submission	Change Proposal (BS ISO 10007:2017; JSP 886:2015)	✓
P01_Change_Request_Submission	Request For Change Submission (ITIL, 2011; SCM Handbook, 2015)	✓
P01_Change_Request_Submission	Engineering Change Proposal Submission (MIL0STD-3046:2013)	✓

ChM Competency Questions-Based Test Cases – Category 3		
CQ36: For the abstract ChM process 'P01_Change_Request_Submission', what are its related ChM documents?		
Expected Output		**Retrieved?**
ChM Process	**Related Document**	✓
P01_Change_Request_Submission	Change Statement	✓
P01_Change_Request_Submission	Change Request Form	✓

ChM Competency Questions-Based Test Cases – Category 3			
CQ37: For the abstract ChM process 'P01_Change_Request_Submission', what are its related ChM documents and the detected terminologies that are related to the identified artefacts?			
Expected Output			**Retrieved?**
ChM Process	**Related Document**	**Artefact Detected Terminology**	✓
P01_Change_ Request_ Submission	Change Request Form	Change Proposal Form (BS ISO 10007:2017)	✓
P01_Change_ Request_ Submission	Change Request Form	Problem Report Form (SCM Handbook, 2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Modification Proposal (JSP 886:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Engineering Change Proposal (INCOSE 2015)	✓

P01_Change_ Request_ Submission	Change Request Form	Request For Change Form (ITIL, 2011)	✓
P01_Change_ Request_ Submission	Change Request Form	Request For Waiver (IEEE std. 15288:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Statement Of Need (BS EN 9223-104:2018)	✓
P01_Change_ Request_ Submission	Change Request Form	Request For Concession (IEEE std. 15288:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Request For Change (EIA-649-B, 2011; INCOSE, 2015; IEEE std. 15288:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Request Application (BS EN 9223-104:2018)	✓
P01_Change_ Request_ Submission	Change Request Form	Request For Deviation (INCOSE, 2015; IEEE std. 15288:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Change Request (Sommerville, 2016; IEEE 828:2012)	✓
P01_Change_ Request_ Submission	Change Request Form	Request For Variance (EIA-649-B, 2011; INCOSE, 2015; IEEE std. 15288:2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Software Change Notice (SCM Handbook, 2015)	✓
P01_Change_ Request_ Submission	Change Request Form	Change Proposal (JSP 886:2015)	✓
P01_Change_ Request_ Submission	Change Statement	Problem Report (ITIL, 2011; JSP 886:2015; Sommerville, 2016)	✓
P01_Change_ Request_ Submission	Change Statement	Bug Report (Sommerville, 2016)	✓
P01_Change_ Request_ Submission	Change Statement	Change Proposal (ITIL, 2011)	✓
P01_Change_ Request_ Submission	Change Statement	Problem Statement (INCOSE, 2015)	✓

ChM Competency Questions-Based Test Cases – Category 3		
CQ38: For the abstract ChM process 'P01_Change_Request_Submission', what are its related ChM roles?		
Expected Output		**Retrieved?**
ChM Process	**Related Role**	✓
P01_Change_Request_Submission	Change_Request_Initiator	✓
P01_Change_Request_Submission	Help_Desk	✓
P01_Change_Request_Submission	Change_Request_Recieving_Authority	✓

ChM Competency Questions-Based Test Cases – Category 3			
CQ39: For the abstract ChM process 'P01_Change_Request_Submission', what are its related ChM roles and the detected terminologies that are related to the identified roles?			
Expected Output			**Retrieved?**
ChM Process	**Related Role**	**Role Detected Terminology**	✓

P01_Change_ Request_ Submission	Change_Request_I nitiator	Change Originator (SCM Handbook, 2015; IEEE 828:2012; MIL-STD-3046:2013)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Request Originating Authority (BS EN 9223-104:2018)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Change Requester (Sommerville, 2016)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Organisation (BS ISO 10007:2017)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Customer (INCOSE, 2015; BS ISO 10007:2017; BS EN 9223-104:2018)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Provider (BS ISO 10007:2017)	✓
P01_Change_ Request_ Submission	Change_Request_I nitiator	Supplier (INCOSE, 2015; BS ISO 10007:2017; BS EN 9223-104:2018)	✓
P01_Change_ Request_ Submission	Change_Request_ Recieving_ Authority	Configuration Management Officer (MIL-STD-3046:2013)	✓
P01_Change_ Request_ Submission	Change_Request_ Recieving_ Authority	Receiving Authority (SCM Handbook, 2015	✓
P01_Change_ Request_ Submission	Change_Request_ Recieving_ Authority	Initial Validity Checker (Sommerville, 2016)	✓
P01_Change_ Request_ Submission	Help_Desk	No Detected Synonym	✓

<table>
<tr><th colspan="7">ChM Competency Questions-Based Test Cases – Category 3</th></tr>
<tr><td colspan="7">CQ47: For the abstract ChM process ‘P01_Change_Request_Submission’, what are its related Riva-based case strategy process and the Is_active value, case process, case management process, unit of work, guide_cp relation and direct_cmp relation? In addition, what are the Is_Active values, Sources and Destination related to the identified guide_cp and direct_cmp relations?</td></tr>
<tr><th colspan="6">Expected Output</th><th>Retrieved?</th></tr>
<tr><th>ChM Process</th><th>Related CSP</th><th>CSP Is_Active</th><th>CSP Related CP</th><th>CSP Related CMP</th><th>CMP Related UOW</th><td>✓</td></tr>
<tr><td>P01_Change_ Request_ Submission</td><td>P01_ CSP</td><td>True</td><td>P01_ Handel</td><td>P01_ CMP</td><td>P01_Change_ Request_ Submission</td><td>✓</td></tr>
<tr><th>CSP Related Guide_CP</th><th>Guide_CP Is_Active</th><th>Guide_CP Source</th><th>Guide_CP Destination</th><th>CSP Related Direct_CMP</th><th>Direct_CMP Is_Active</th><td>✓</td></tr>
<tr><td>P01_ Guide_CP</td><td>True</td><td>P01_ CSP</td><td>P01_ Handle</td><td>P01_ Direct_CMP</td><td>True</td><td>✓</td></tr>
<tr><th>Direct_CMP Source</th><th>Direct_CMP Destination</th><td></td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>P01_ CSP</td><td>P01_ CMP</td><td></td><td></td><td></td><td></td><td>✓</td></tr>
</table>

APPENDIX - L: SEGMENTS OF THE COMPETENCY QUESTIONS-BASED TEST CASES FOR THE DEMONSTRATION AND EVALUATION OF THE SOS-ASPECTS RELATED KNOWLEDGE RETRIEVAL CAPABILITIES

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ1: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related Name_ID_Version, GL-BPA-Model-Segment, GL-BPA-Model, GL-BPA, GL-Business Area and LL-Business Area?

Elements	Instance
GL-BP Related Name_ID_Version	Analysis_For_Cyto2_CP_01.00
GL-BP Related GL-BPA-Model –Segments	GL_MSegment_Cyto
GL-BP Related GL-BPA-Models	GL_CTAG_2nd_Cut_PAD
GL-BP Related GL-BPA	GL_CTAG_BPA
GL-BP Related GL-Business Area	CTAG_GL_Busines_Area
GL-BP Related LL-Business Area	CTAG_LL_Business_Area

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ2: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related GL-BPA? In addition, what are the ChM-driven Roles that are related to the identified GL-BPA?

Elements	Instance
GL-BP Related GL-BPA	GL_CTAG_BPA
GL-BP Related GL-BPA-Owner	GL_CTAG_BPA_Owner
GL-BP Related GL-BPA-Manager	GL_CTAG_BPA_Manager
GL-BP Related GL-BPA-Engineer	GL_CTAG_BPA_Engineer
GL-BP Related GL-BPA-Evaluator	GL_CTAG_BPA_Evaluator
GL-BP Related GL-BPA-Builder	GL_CTAG_BPA_Builder
GL-BP Related GL-BPA-Tester	GL_CTAG_BPA_Tester
GL-BP Related GL-BPA-Releaser	GL_CTAG_BPA_Releaser
GL-BP Related GL-BPA-Deployer	GL_CTAG_BPA_Deployer

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ3: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related GL-BPA-Model-Segments and GL-Business Services? In addition, what are the ChM-driven Roles that are related to the identified GL-Business Services?

Elements	Instance
GL-BP Related GL-BPA-Model –Segments	GL_MSegment_Cyto
GL-BP Related GL-Business Services	GL_BS_Cytogenetics_Cyto
GL-BP Related GL-BSs-Owners	GL_CTAG_BS_Cyto_Owner
GL-BP Related GL-BSs-Managers	GL_CTAG_BS_ Cyto_Manager
GL-BP Related GL-BSs-Engineers	GL_CTAG_BS_ Cyto_Engineer
GL-BP Related GL-BSs-Evaluators	GL_CTAG_BS_ Cyto_Evaluator
GL-BP Related GL-BSs-Builders	GL_CTAG_BS_ Cyto_Builder
GL-BP Related GL-BSs-Testers	GL_CTAG_BS_ Cyto_Tester
GL-BP Related GL-BSs-Releasers	GL_CTAG_BS_ Cyto_Releaser
GL-BP Related GL-BSs-Deployers	GL_CTAG_BS_ Cyto_Deployer

L-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ4: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related GL-BPA-Model-Segments and GL-Business Services? In addition, what are the GL-Business Processes that are encapsulated in the identified GL-BPA-Model-Segments?

Elements	Instance
GL-BP Related GL-BPA-Model–Segments	GL_MSegment_Cyto
GL-BP Related GL-Business Services	GL_BS_Cytogenetics_Cyto
GL-BP Related Encapsulated GL-BPs	GL_Financial_Covergae_CP GL_Specimen_for_Cyto1_CP GL_Approval_for_Cyto1_CP GL_Analysis_For_Cyto2_CP GL_Approval_for_Cyto2_CP GL_Breakage_Analysis_for_Cyto3_CP GL_Approval_for_Cyto3_CP

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ5: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related GL-BPA-Model-Segments and GL-Business Services? In addition, what are the GL-Business Relations that are encapsulated in the identified GL-BPA-Model-Segments?

Elements	Instance
GL-BP Related GL-BPA-Model – Segments	GL-MSegment-Cyto
GL-BP Related GL-Business Services	GL_BS_Cytogenetics_Cyto
GL-BP Related Encapsulated Relations	GL_FinancialCoverage_Starts_Specimen_for_Cyto1 GL_Specimen_Requires_Approval_for_Cyto1 GL_FinancialCoverage_Starts_Analysis_for_Cyto2 GL_Analysis_Requires_Approval_for_Cyto2 GL_FinancialCoverage_Starts_BreakageAnalysis_for_Cyto3 GL_BreakageAnalysis_Requires_Approval_for_Cyto3

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ6: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related Riva-based GL- Case Process (CP), Case Management Process (CMP), Case Strategy Process (CSP), Unit Of Work, and 1st-and-2nd-Cut Diagrams? In addition, what are the Is_Active Values related to the identified CP, CMP and CSP?	
Elements	Instance
GL-BP Related GL-CP	Analysis_for_Cyto2_Handle_GLBPA
GL-CP Is_Active Value	True
GL-BP Related GL-CMP	Analysis_for_Cyto2_ManageTheFlowOf_GLBPA
GL-CMP Is_Active Value	False
GL-BP Related GL-CSP	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
GL-CSP Is_Active Value	False
GL-BP Related GL-UOW	Analysis_for_Cyto2_GLBPA
GL-BP Related GL-1st-Cut-PAD	CTAG_PA_1st_Cut_Diagram_1_GLBPA
GL-BP Related GL-2nd-Cut-PAD	CTAG_PA_2nd_Cut_Diagram_1_GLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ7: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Process (CP) that has Request Relations? In addition, what are the CP related Request Relations and their Is_Active values, Sources and Destinations?	
Elements	Instance
GL-BP Related GL-CP	Analysis_for_Cyto2_Handle_GLBPA
GL-CP Related Request Relations	G14_AnalforCyto2_Generates_ApprovforCyto2_Request_GLBPA
Request Relations Is_Active Values	False
Request Relations Sources	Analysis_for_Cyto2_Handle_GLBPA
Request Relations Destinations	Approval_for_Cyto2_ManageTheFlowOF_GLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ8: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Process (CP) that has Start Relations? In addition, what are the CP related Start Relations and their Is_Active values, Sources, and Destinations?	
Elements	Instance
GL-BP Related GL-CP	Analysis_for_Cyto2_Handle_GLBPA
GL-CP Related Start Relations	Approval_for_Cyto2_Start_Modified_GLBPA
Start Relations Is_Active Values	True
Start Relations Sources	Analysis_for_Cyto2_Handle_GLBPA
Start Relations Destinations	Approval_for_Cyto2_Handle_GLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ9: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Process (CP) that has Deliver Relations? In addition, what are the CP related Deliver Relations and their Is_Active values, Sources, and Destinations?	
Elements	Instance
GL-BP Related GL-CP	Analysis_for_Cyto2_Handle_GLBPA
GL-CP Related Deliver Relations	G05_FinCov_Generates_AnalforCyto2_Deliver_GLBPA
Deliver Relations Is_Active Values	True
Deliver Relations Sources	Analysis_for_Cyto2_Handle_GLBPA
Deliver Relations Destinations	Financial_Coverage_Handle_GLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ10: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Management Process (CMP)? In addition, what are the CMP related Is_Active Value and Start Relation alongside the Start Relation Is_Active values, Sources and Destinations?	
Elements	Instance
GL-BP Related GL-CMP	Analysis_for_Cyto2_ManageTheFlowOF_GLBPA
GL-CMP Related Is_Active Value	False

GL-CMP Related Start Relation	Analysis_for_Cyto2_Start_GLBPA
Start Relation Related Is_Active Value	False
Start Relation Related Source	Analysis_for_Cyto2_ManageTheFlowOF_GLBPA
Start Relation Related Destination	Analysis_for_Cyto2_Handle_GLBPA
GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ11: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what is the related Riva-based GL-Case Strategy Process (CSP)? In addition, what are the CSP related Is_Active Value and Relations alongside the Relations Is_Active values, Sources and Destinations?	
Elements	Instance
GL-BP Related GL-CSP	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
GL-CSP Related Is_Active Value	False
GL-CSP Related Guide_CP Relation	Analysis_for_Cyto2_GuideCP_GLBPA
Guide_CP Relation Related Is_Active Value	False
Guide_CP Relation Related Source	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
Guide_CP Relation Related Destination	Analysis_for_Cyto2_Handle_GLBPA
GL-CSP Related Direct_CMP Relation	Analysis_for_Cyto2_DirectCMP_GLBPA
Direct_CMP Relation Related Is_Active Value	False
Direct_CMP Relation Related Source	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
Direct_CMP Relation Related Destination	Analysis_for_Cyto2_ManageTheFlowOF_GLBPA
GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ12: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process, LL-BPA-Model-Segments that the LL-BP participate in, and the LL-Business Services that are supported by the identified LL-BPA-Model-Segments? In addition, what are the ChM-driven Roles that are related to the identified LL-Business Services?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPA-Model-Segments	LL_MSegement_Cyto2
LL-Business Services	LL_BS_Analysis_Cyto2
LL-BSs-Owners	LL_BS_Analysis_Cyto2_Owner
LL-BSs-Managers	LL_BS_Analysis_Cyto2_Manager
LL-BSs-Engineers	LL_BS_Analysis_Cyto2_Engineer
LL-BSs-Evaluators	LL_BS_Analysis_Cyto2_Evaluator
LL-BSs-Builders	LL_BS_Analysis_Cyto2_Builder
LL-BSs-Testers	LL_BS_Analysis_Cyto2_Tester
LL-BSs-Releasers	LL_BS_Analysis_Cyto2_Releaser
LL-BSs-Deployers	LL_BS_Analysis_Cyto2_Deployer
GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ13: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process, LL-BPA-Model-Segments that the LL-BP participate in, LL-BPA-Model, and Related LL_BPA?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPA-Model-Segments	LL_MSegement_Cyto2
LL-BP Related LL-BPA-Model	LL_CTAG_Cyto_2ndCut_PAD
LL-BP Related LL-BPA	LL_CTAG_Cyto_BPA
GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ14: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process and Related LL_BPA? In addition, what are the ChM-driven Roles that are related to the identified LL-BPA?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPA	LL_CTAG_Cyto_BPA
LL-BPA-Owner	LL_CTAG_Cyto_BPA_Owner
LL-BPA-Manager	LL_CTAG_Cyto_BPA_Manager
LL-BPA-Engineer	LL_CTAG_Cyto_BPA_Engineer
LL-BPA-Evaluator	LL_CTAG_Cyto_BPA_Evaluator
LL-BPA-Builder	LL_CTAG_Cyto_BPA_Builder
LL-BPA-Tester	LL_CTAG_Cyto_BPA_Tester
LL-BPA-Releaser	LL_CTAG_Cyto_BPA_Releaser
LL-BPA-Deployer	LL_CTAG_Cyto_BPA_Deployer

GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ15: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-BP and Constituent Business Area (CBA)? In addition, what are the ChM-driven Roles that are related to the identified CBA?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related CBA	CTAG_Cyto_Constiuent_Business_Area
LL-CBA-Owner	CTAG_Cyto_Constiuent_Business_Area_Owner
LL-CBA-Manager	CTAG_Cyto_Constiuent_Business_Area_Manager
LL-CBA-Engineer	CTAG_Cyto_Constiuent_Business_Area_Engineer

GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ16: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process and its related LL_BPM? In addition, what are the ChM-driven Roles that are related to the identified LL-BPM?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPM	LL_BPM_Analysis_for_Cyto2_CP
LL-BPM-Owner	LL_BPM_Analysis_for_Cyto2_CP_Owner
LL-BPM-Manager	LL_BPM_Analysis_for_Cyto2_CP_Manager
LL-BPM-Engineer	LL_BPM_Analysis_for_Cyto2_CP_Engineer
LL-BPM-Evaluator	LL_BPM_Analysis_for_Cyto2_CP_Evaluator
LL-BPM-Builder	LL_BPM_Analysis_for_Cyto2_CP_Builder
LL-BPM-Tester	LL_BPM_Analysis_for_Cyto2_CP_Tester
LL-BPM-Releaser	LL_BPM_Analysis_for_Cyto2_CP_Releaser
LL-BPM-Deployer	LL_BPM_Analysis_for_Cyto2_CP_Deployer

GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ17: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process and its related LL-Business Process Model? In addition, what are the BPMN-based Task, Gates, and Events that are related to the identified LL-Business Process Model?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPM	LL_BPM_Analysis_for_Cyto2_CP
LL-BPM-Graphical Elements	MT_LogInIntoLogSheet_Cyto2 UT_DoRequestedAnalysis_Cyto2 UT_ReviewTheSlidesByAnotherCytoTechnologist_Cyto2 MT_EnsureSpecimentIDAndIntegrity_Cyto2 ST_SendPaperReportToPatholgistForThirdReview_Cyto2 ST_SendRequestedAnalysisForProcessingToTechnologist_Cyto2 ST_SendApprovedReportToMedicalDirectorForApproval_Cyto2 UT_PrepareTheSlides_Cyto2 RT_ReceiveAnalysisRequestByCytoTechnologist_Cyto2 UT_ScanApprovedReportToVistaCPRS_Cyto2 RT_ReceiveApprovalFromPathologistByCytoTech_Cyto2 ST_InformMainPhysicianDirectlyAboutRejection_Cyto2 MT_GenerateReportByCytoTechnologist_Cyto2

GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ18: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Business Process and its related LL-Business Process Model? In addition, what are the BPMN-based Pools that are related to the identified LL-Business Process Model?	
Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-BPM	LL_BPM_Analysis_for_Cyto2_CP
LL-BPM-Pools	Pool_Cyto_Technologist_Receptionist_Cyto2 Pool_Cyto_Technologist_Cyto2

GL-Business Process Test Case ‘GL_Analysisis_for_Cyto2_CP’	
CQ19: For the GL-BP ‘GL_Analysis_for_Cyto2_CP’, what are the related LL-Software Services? In addition, what are ChM-driven Roles that are related to the identified LL-Software Services?	
Elements	Instance
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2
LL-Software Services-Owners	LL_SwS_for_Analysis_Cyto2_Owner
LL-Software Services-Managers	LL_SwS_for_Analysis_Cyto2_Manger
LL-Software Services-Engineers	LL_SwS_for_Analysis_Cyto2_Engineer

LL-Software Services-Evaluators	LL_SwS_for_Analysis_Cyto2_Evlautor
LL-Software Services-Builders	LL_SwS_for_Analysis_Cyto2_Builder
LL-Software Services-Testers	LL_SwS_for_Analysis_Cyto2_Tester
LL-Software Services-Releasers	LL_SwS_for_Analysis_Cyto2_Releaser
LL-Software Services-Deployers	LL_SwS_for_Analysis_Cyto2_Deployer

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ20: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are Constituent Information Systems that support the identified LL-SW-Services alongside their related ChM-driven Roles?	
Elements	Instance
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2
LL-SW-Services-Related Constituent Information Systems (CISs)	CIS_Samples_Management_Cyto
LL-CIs-Owners	CIS_Samples_Management_Cyto_Owner
LL-CIs-Managers	CIS_Samples_Management_Cyto_Manager
LL-CIs-Engineers	CIS_Samples_Management_Cyto_Engineer
LL-CIs-Evaluators	CIS_Samples_Management_Cyto_Evaluator
LL-CIs-Builders	CIS_Samples_Management_Cyto
LL- CIs-Testers	CIS_Samples_Management_Cyto
LL-CIs-Releasers	CIS_Samples_Management_Cyto
LL-CIs-Deployers	CIS_Samples_Management_Cyto

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ21: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are the RPA-Clusters related to the identified LL-SW-Services?	
Elements	Instance
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2
SW-Service Related RPA-Clusters	C3_Cyto_Analysis

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ22: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are the RPA-Clusters related to the identified LL-SW-Services and the RPA-Clusters encapsulated Capabilities?	
Elements	Instance
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2
SW-Service Related RPA-Clusters	C3_Cyto_Analysis
RPA-Clusters Related Capabilities	MT_LogInIntoLogSheet_Cyto2 UT_DoRequestedAnalysis_Cyto2 UT_ReviewTheSlidesByAnotherCytoTechnologist_Cyto2 MT_EnsureSpecimentIDAndIntegrity_Cyto2 ST_SendPaperReportToPatholgistForThirdReview_Cyto2 ST_SendRequestedAnalysisForProcessingToTechnologist_Cyto2 ST_SendApprovedReportToMedicalDirectorForApproval_Cyto2 UT_PrepareTheSlides_Cyto2 RT_ReceiveAnalysisRequestByCytoTechnologist_Cyto2 UT_ScanApprovedReportToVistaCPRS_Cyto2 RT_ReceiveApprovalFromPathologistByCytoTech_Cyto2 ST_InformMainPhysicianDirectlyAboutRejection_Cyto2 MT_GenerateReportByCytoTechnologist_Cyto2

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ23: For the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL-Software Services? In addition, what are the RPA-Clusters related to the identified LL-SW-Services and the RPA-Clusters encapsulated Members?	
Elements	Instance
Related LL-Software Services	LL_SwS_for_Analysis_Cyto2
SW-Service Related RPA-Clusters	C3_Cyto_Analysis
RPA-Clusters Related Members	Analysis_for_Cyto2_Handle_LLBPA Approval_for_Cyto2_Handle_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'	
CQ24: For the LL-BP related to the GL-BP 'GL_Analysis_for_Cyto2_CP', what are the related LL Riva-driven CP, CMP, CSP, Is_Active Values, UOW, 1st_Cut_PAD and 2nd_Cut_PAD?	
Elements	Instance
Related LL-BP	LL_Analysis_for_Cyto2_CP
Related LL-Riva-CP	Analysis_for_Cyto2_Handle_LLBPA
LL-Riva-CP Related Is_Active Value	True

Related LL-Riva-CMP	Analysis_for_Cyto2_ManageTheFlowOF_LLBPA
LL-Riva-CMP Related Is_Active Value	False
Related LL-Riva-CSP	Analysis_for_Cyto2_Maintain_aStrategicViewOF_LLBPA
LL-Riva-CSP Related Is_Active Value	False
Related LL-Riva-UOW	Analysis_for_Cyto2_LLBPA
Related LL-Riva-1st-Cut-PAD	CTAG_Cyto_PA_1st_Cut_Diagram_1_LLBPA
Related LL-Riva-2nd-Cut-PAD	CTAG_Cyto_PA_2nd_Cut_Diagram_1_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ25: For the LL-BP related to GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Process (CP) that has Request Relations? In addition, what are the CP related Request Relations and their Is_Active values, Sources and Destinations?

Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-CP	Analysis_for_Cyto2_Handle_LLBPA
LL-CP Related Request Relations	G14_AnalforCyto2_Generates_ApprovforCyto2_Request_LLBPA
Request Relations Is_Active Values	False
Request Relations Sources	Analysis_for_Cyto2_Handle_LLBPA
Request Relations Destinations	Approval_for_Cyto2_ManageTheFlowOF_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ26: For the LL-BP related to GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Process (CP) that has Start Relations? In addition, what are the CP related Start Relations and their Is_Active values, Sources and Destinations?

Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-CP	Analysis_for_Cyto2_Handle_LLBPA
LL-CP Related Start Relations	Approval_for_Cyto2_Start_Modified_LLBPA
Start Relations Is_Active Values	True
Start Relations Sources	Analysis_for_Cyto2_Handle_LLBPA
Start Relations Destinations	Approval_for_Cyto2_Handle_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ27: For the LL-BP related to GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Processes (CP) that has Deliver Relations? In addition, what are the CP related Deliver Relations and their Is_Active values, Sources, and Destinations?

Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-CP	Analysis_for_Cyto2_Handle_LLBPA
LL-CP Related Deliver Relations	G05_FinCov_Generates_AnalforCyto2_Deliver_LLBPA
Deliver Relations Is_Active Values	True
Deliver Relations Sources	Analysis_for_Cyto2_Handle_LLBPA
Deliver Relations Destinations	Financial_Coverage_Cyto_Handle_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ28: For the LL-BP related to GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Management Process (CMP)? In addition, what are the CMP related Is_Active Value and Start Relation alongside the Start Relations Is_Active values, Sources and Destinations?

Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-CMP	Analysis_for_Cyto2_ManageTheFlowOF_LLBPA
LL-CMP Related Is_Active Value	False
LL-CMP Related Start Relation	Analysis_for_Cyto2_Start_LLBPA
Start Relation Related Is_Active Value	False
Start Relation Related Source	Analysis_for_Cyto2_ManageTheFlowOF_LLBPA
Start Relation Related Destination	Analysis_for_Cyto2_Handle_LLBPA

GL-Business Process Test Case 'GL_Analysisis_for_Cyto2_CP'

CQ29: For the LL-BP related to GL-BP 'GL_Analysis_for_Cyto2_CP', what is the related Riva-based GL-Case Strategy Process (CSP)? In addition, what are the CSP related Is_Active Value and Relations alongside the Relations Is_Active values, Sources and Destinations?

Elements	Instance
GL-BP Related LL-BP	LL_Analysis_for_Cyto2_CP
LL-BP Related LL-CSP	Analysis_for_Cyto2_Maintain_aStrategicViewOF_LLBPA

LL-CSP Related Is_Active Value	False
LL-CSP Related Guide_CP Relation	Analysis_for_Cyto2_GuideCP_GLBPA
Guide_CP Relation Related Is_Active Value	False
Guide_CP Relation Related Source	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
Guide_CP Relation Related Destination	Analysis_for_Cyto2_Handle_GLBPA
LL-CSP Related Direct_CMP Relation	Analysis_for_Cyto2_DirectCMP_GLBPA
Direct_CMP Relation Related Is_Active Value	False
Direct_CMP Relation Related Source	Analysis_for_Cyto2_Maintain_aStrategicViewOF_GLBPA
Direct_CMP Relation Related Destination	Analysis_for_Cyto2_ManageTheFlowOF_GLBPA