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A Semantically-Enriched Goal-Oriented Requirements Engineering Framework for Systems of Systems Using the i* Framework Applied to Cancer Care

(OntoSoS.GORE)

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Abstract

In recent years, monolithic systems are being composed into bigger systems as Systems of Systems (SoSs). This evolution of SoS raises several software engineering key challenges, such as the management of emerging inconsistent goals and requirements, which may occur among the various Constituent Systems (CSs) themselves, as well as between the entire SoS and the participating CSs. Another significant challenge is that Systems of Systems Engineering (SoSE) involves more stakeholders than traditional systems engineering, i.e. stakeholders at the SoS-level and the CS-level, where each CS has its own needs and objectives which establish a complex stakeholder environment. To respond to these challenges, this research is aimed at investigating the implications of applying a goal-oriented requirements engineering approach in identifying, modelling and managing emerging goals and their conflicts in SoS context. The key artefact of this research is the development of a Semantically-Enriched Goal-Oriented Requirements Engineering Framework for Systems of Systems using the i* framework, namely the OntoSoS.GORE framework.

The OntoSoS.GORE is a three-layered framework designed, developed, demonstrated and then evaluated through following multiple iterations of the Design Science Research Methodology (DSRM) phases, to accomplish the following main objectives: (1) identifying and modelling the SoS global goals and the CSs local goals at different levels of an SoS using the i* framework, in which a new process to extract i* modelling elements from existing user documentation is proposed; (2) maintaining the consistency and integrity of SoS goals at multiple levels through developing a semantic Goals Referential Integrity (sGRI) model in SoS context which consists of an SoSGRI model and an ontology-based model; and (3) managing any conflicts that may occur amongst goals at both the SoS-level and the CS-level, by developing and applying a new goal conflict management approach in SoS context, which consists of two main processes: goal conflict detection and goal conflict resolution.

The research framework has been instantiated and validated by applying a real Cancer Care case study at King Hussein Cancer Center (KHCC), Amman, Jordan. Results revealed the effectiveness of applying the framework compared to the current approach applied at KHCC, in terms of addressing higher consistency, completeness and correctness with regard to goal management and conflict management in SoS context. Moreover, the framework

provides automation of the processes of following the satisfaction of goals and goals' conflict management at multiple SoS levels, instead of the manual approach applied currently at KHCC. This automation is accomplished through developing a strategic goal-oriented management tool that is anticipated to be delivered and utilised at KHCC, as well as applying it to other SoS organisations as a proposed solution for goal and conflict management. Another contribution to the Cancer Care and SoS domains is developing a reference i* goal-oriented model for access to Cancer Care which provides a wider system engineering perspective and offers an accessible level of abstraction about Cancer Care goals and their dependencies for stakeholders and domain experts. The reference model provides standardisation of common generic concepts about the domain, in which other Cancer Care organisations can considerably reuse to facilitate the process of capturing and specifying goals and requirements for their practice and validating choices among alternative designs.

To My Dad and My Mum

To My Father-in-law and Mother-in-law

To My Husband and Beloved Children

To My Brothers and Sister

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Abbreviations

3Cs: Consistency, Completeness and Correctness

ADT: Admission, Discharge and Transfer

BMT: Bone Marrow Transplantation

BS: Business Strategy

CM: Context Models

COO: Chief Operating Officer

CRC: Chair of Research Council

CRUD: Create, Read, Update and Delete

CS: Constituent System

DB: Database

DBMS: Database Management System

DDB: Distributed Databases

DG: Director General

DSRM: Design Science Research Methodology

EER: Extended Entity Relationship

FK: Foreign Key

GG: Global Goal

GGOM: Global Goal-Oriented Models

GORE: Goal-Oriented Requirements Engineering

GRI: Goals Referential Integrity

GRL: Goal-oriented Requirements Language

HR: Human Resources

HSD: Highest Strategic Dependency

ICU: Intensive Care Unit

IMU: Intermediate Care Unit

iStarML: iStar Markup Language

IT: Information Technology

ITU: International Telecommunication Union

JCR: Jordan Cancer Registry

KAOS: Knowledge Acquisition in autOmated Specification

KHCC: King Hussein Cancer Center

KPI: Key Performance Indicator

LG: Local Goal

LGOM: Local Goal-Oriented Models

LHS: Left-Hand Side

MaCoRe_SoS: Managing Conflicting Requirements in Systems of Systems

MDC: Multi-Disciplinary Clinic

MOH: Ministry of Health

MR: Medical Records

NFR: Non-Functional Requirements

NLP: Natural Language Processing

OntoiStar: Ontology-based metamodel of the i* framework

OntoSoS.GORE: Ontology-Based Goal-Oriented Requirements Engineering Framework for Systems of Systems

OPS5: Official Production System, version 5

OR: Operational Room

OWL: Web Ontology Language

OWL-DL: Web Ontology Language-Description Logic

PK: Primary Key

QMO: Quality Management Office

RDF: Resource Description Framework

RE: Requirements Engineering

RH: Research Hypothesis

RQ: Research Quesion

SD: Strategic Dependency

SGG: Sub-Global Goal

sGRI: semantic Goals Referential Integrity

SoS: System of Systems

SoSE: System of Systems Engineeering

SoSGORE: System of Systems Goal-Oriented Requirements Engineering

SoSGRI: System of Systems Goals Referential Integrity

SQL: Structured Query Language

SR: Strategic Rationale

SWRL: Semantic Web Rule Language

TAGOOn+: Tool for the Automatic Generation of Organisational Ontologies and Integration from i* models

UFO: Unified Foundational Ontology

URN: User Requirements Notation

URN: User Requirements Notation

WHO: World Health Organisation

XML: Extensible Markup Language

List of Research Publications

1) AlHajHassan, S., Odeh, M., and Green, S., (2016). "Aligning Systems of Systems Engineering with Goal-Oriented Approaches Using the i* Framework". In IEEE International Symposium on Systems Engineering 2016, Edinburgh, Scotland, (pp. 41-47). IEEE Systems Council.

2) AlHajHassan, S., Odeh, M., Green, S., and Mansour A., (2018, November). "Goal-Oriented Strategic Modelling for Cancer Care in Systems of Systems Context Using the i* Framework". In 2018 1st International Conference on Cancer Care Informatics (CCI), Amman, Jordan, (pp. 100-109). IEEE.

3) AlHajHassan, S., Odeh, M., Green, S., and Mansour A., (2018). "A Semantically Enriched Goal-Oriented Referential Integrity Model in Systems of Systems Context". In 2018 19th International Arab Conference on Information Technology (ACIT), Lebanon, (pp. 1-10). IEEE.

4) AlHajHassan, S., Odeh, M., Green, S., and Mansour A., (2019). "An Ontology-based i* Goal-Oriented Referential Integrity Model in Systems of Systems Context". International Arab Journal of Information Technology (IAJIT), 16(3 A), (pp. 565-576).

Chapter 1

Introduction

This chapter provides the rationale behind the research work. It states the research problem and justifies the need to develop a goal-oriented requirements engineering framework in systems of systems context using the i* framework. This chapter is expected to cover the first phase in the adopted Design Science Research Methodology (DSRM) (Hevner et al., 2004) by identifying the research problem and sustaining the motivation to state the research aim and objectives. Thereafter, the research hypothesis and associated research questions are derived. Finally, the research main outcomes and contributions are summarised, and the chapter ends with presenting the thesis structure.

1.1 Context of the Research Problem

There has been a growing recognition that today's complex information systems are not single entities, but instead are independent parts that function together (Haley and Nuseibeh, 2008). The independent parts are themselves complex systems, often having a lifespan, purpose, requirements, and architecture of their own, separated from whatever role they play in the larger context. Easterbrook (2007) perceives that the collection of parts forms a complex System of Systems (SoS) that includes a wide-ranging technological infrastructure alongside a wide set of human activities. A System of Systems (SoS) is "a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities" (ODUSD (A&T) SSE, 2008).

In software engineering, it is acknowledged that capturing requirements that accurately reflect users' needs is crucial to the success of a system development process (Yu, 2011). A major obstacle to getting the requirements right is the difficulty in obtaining a deep enough understanding of the application domain. It is often necessary to identify the different ways in which technical system solutions can serve users' needs during the early stages of Requirements

Engineering (RE). Current requirements models that describe an organisational environment only in terms of entities and activities do not capture other concerns that users have about the implications of taking on one solution over another, such as rationales behind solutions and other alternatives (Yu, 2011).

A model that covers the aspects of the organisational environment like the *i** framework would facilitate the requirements engineering effort (Yu, 2011). Requirements that are consistent, complete, correct and well-aligned with the stakeholders' needs, lead to better and faster design and implementation of the software system. Also, with explicitly capturing motivations, rationales and alternatives in a requirements model, it will be easier to evolve a system which meets changing user needs.

The *i** framework is a Goal-Oriented (GO) approach that attempts to introduce social modelling and to provide an understanding of the reasons that underlie system requirements (Yu, 2009). Unlike traditional systems requirements engineering methods which strive to abstract away stakeholders' concerns, *i** recognises the importance of social actors. It focuses on early understanding of business organisations through determining and modelling the relationships and the intentions among the social actors in the organisation or the business domain, and focuses on how the goals of various actors are achieved. Therefore, the *i** framework is considered as a modelling approach that can assist in analysing and redesigning organisations (Chung et al., 2000).

1.2 Research Problem

In recent years, monolithic systems are being composed into bigger systems as SoSs that are capable of delivering unique functionalities that span more complex operating environments. This evolution of SoSs raises a number of software engineering challenges regarding their specification, design, construction, and operation. Among these challenges, one important challenge is concerned with the management of emerging inconsistent requirements. In an SoS, the various participating constituent systems are often from different domains; are developed by different teams of people under different circumstances and time; have distinct functionalities; and are used by different stakeholders. Therefore, the various constituent systems may present conflicting requirements among themselves, as well as emerging conflicting requirements between the whole SoS and the participating constituent systems (Viana et al., 2017).

Systems of Systems Engineering (SoSE) involves more stakeholders than traditional systems engineering, i.e. stakeholders at the SoS-level and at the constituent systems-level, each having their own needs and objectives. Competing stakeholders' interests and goals establish a complex stakeholder environment, which many traditional requirements engineering methods do not appropriately address (ODUSD (A&T) SSE, 2008). However, goal-driven approaches can be used to drive the requirements engineering process to explore the objectives of different stakeholders and the activities performed by them to achieve these objectives (Rolland, 2005), in order to derive purposeful system requirements at both the SoS-level and the constituent systems-level.

The *i** goal-oriented framework (Yu, 2011) has been used in the requirements specifications and goals specifications of monolithic systems, but has not been engaged so far in the derivation of goals specifications and goal-oriented modelling in SoS context. Thus, this research aims to utilise the i* framework together with semantic ontologies in an attempt to address the current challenges of managing emerging inconsistent goals and requirements in complex SoS arrangements.

1.3   Research Aim and Objectives

This research aims to investigate the usefulness of applying Goal-Oriented Requirements Engineering (GORE) approaches in SoS context using the i* framework in the identification, modelling and management of SoS goals, and how beneficial are GORE approaches when applied during the early phases of the requirements engineering of SoS.

The proposed framework, namely **_"OntoSoS.GORE"_**, involves eliciting, specifying, analysing, modelling, validating and modifying requirements that are well-aligned with the users' concerns and needs with minimal conflicts in SoS context.

In order to achieve the research aim, the following research objectives have been identified:

1. To identify the SoS-level goals and the constituent systems-level goals using the i* framework.

2. To maintain the referential integrity of the SoS goals and the constituent systems' goals at all levels in an operational context.

3. To be able to check the satisfaction of both the SoS-level goals and the constituent systems-level goals by applying the OntoSoS.GORE framework.

4. To manage conflicts that may occur amongst goals at the following three levels:
   a) between individual local goals of constituent systems;
   b) between SoS global goals; and
   c) between SoS global goals and constituent systems local goals.

1.4 Research Hypothesis and Associated Questions

This research hypothesises that *"Utilising the i* framework with semantic ontologies in driving the goal-oriented requirements engineering process for systems of systems, with applying appropriate conflict management and resolution strategies, leads to deriving goals specifications that satisfy both the SoS-level and the constituent systems-level stakeholders."* In order to investigate and test the research hypothesis to be accepted or rejected, the following research questions have been identified:

RQ1: How should the SoS-level goals and the constituent systems-level goals be identified at several levels of the SoS arrangement using the i* framework?

RQ2: Can the referential integrity of the SoS goals and the constituent systems' goals be maintained at all levels in an operational context?

RQ3: To what extent can the satisfaction of both the SoS-level goals and the constituent systems-level goals be checked and verified by applying the OntoSoS.GORE framework?

RQ4: How to manage conflicts that may occur amongst goals at the following three levels:
   a) between individual local goals of constituent systems;
   b) between SoS global goals; and
   c) between SoS global goals and constituent systems local goals?

Identifying the research hypothesis and associated research questions, led to the design and development of the research framework. In this research, we propose a novel approach by utilising the i* framework along with ontologies in developing an Ontology-based Goal-Oriented Requirements Engineering framework for Systems of Systems (OntoSoS.GORE). Using this

approach, the SoS goals of different stakeholders have been modelled and managed at two levels: the SoS high-level goals and the constituent systems-level individual goals.

1.5 Summary of Research Contributions

The following list summarises the main research contributions:

1. The development of **the research framework OntoSoS.GORE**; an Ontology-based Goal-Oriented Requirements Engineering framework for Systems of Systems, that aims at modelling and managing SoS goals at different levels, maintaining the consistency and integrity of these goals at both the SoS-level and CS-level, as well as detecting and resolving any conflicts that may occur amongst goals at both levels.

2. The development of a new **process to extract i* modelling elements from user documentation**. The extraction method was expressed as heuristics that describe which element of user documentation can be typically transformed into which i* modelling element. The extracted i* elements were used afterwards in the i* goal modelling.

3. The development of an **SoS strategic goal-oriented modelling metamodel**, that defines the multiple goal-levels in an SoS arrangement, as well as the relationships and linkages between these goal levels and corresponding components such as constituent systems, actors, i* models, and the organisation's policy documents.

4. The development of a proposed **reference i* goal-oriented model for access to Cancer Care**, which provides the most generic concepts in Cancer Care domain with reference to the case of the Admission, Discharge and Transfer (ADT) at KHCC, KHCC's strategic plans and requirements retrieved from domain experts.

5. The development of a **semantic Goals Referential Integrity (sGRI) model** in SoS context, which consists of two parts: First, the SoSGRI model that intends to keep the integrity and consistency of both the SoS-level goals and the constituent systems-level goals. Second, an ontology-based model developed to semantically represent the i* goal modelling in SoS context and inform the satisfaction and achievement of the SoS goals at multiple levels.

6. The development of a new **conflict management approach** in SoS context, which consists of two main processes: conflict detection and conflict resolution. The newly proposed approach aims at detecting any conflicts that might occur at the different levels of SoS goals, and then resolve these conflicts based on analysing the complexity of the conflicting goals, their priority and specificity values.

7. The development of a **strategic goal-oriented management tool** in SoS context, which consists of two main parts: (1) Goal satisfaction panel; and (2) Conflict management panel. First, the goal satisfaction panel enables stakeholders to track down the progress and satisfaction of goals at multiple levels of an SoS arrangement, where the satisfaction of upper-levels goals can be inferred automatically depending on the achievement status of lower-level local goals. Second, the conflict management panel enables stakeholders to detect and resolve conflicts that may occur amongst goals at multiple levels of the SoS, and advise the stakeholders to apply the goal with the highest conflict resolution outcome.

1.6   Thesis Structure

After this chapter, the literature review and research gap analysis are discussed in **Chapter 2**. In particular, the notion of Systems of Systems (SoSs), Goal-Oriented Requirements Engineering (GORE) and the i* framework, as well as semantic representation of the i* framework using ontologies. **Chapter 3** presents: (1) the main research artefact "the OntoSoS.GORE Framework", its architecture and main components, and (2) the Design Science Research Methodology (DSRM) utilised in this research. **Chapter 4** presents the first DSRM iteration that is related to the design, development, demonstration and evaluation of the first component of the OntoSoS.GORE: goal-oriented modelling in SoS context. The chapter also includes a new process to extract i* concepts from existing user documentation and the development of the SoS goal modelling metamodel. **Chapter 5** presents the second DSRM iteration that is related to the design, development, demonstration and evaluation of the second layer of the research framework: the sGRI model in SoS context. This includes the Goals Referential Integrity (GRI) Model and the semantic enrichment of SoS i* goal modelling using ontologies. **Chapter 6** presents the third DSRM iteration that is related to the design, development, demonstration and evaluation of the third layer of the research framework: conflict

management approach in SoS context, including two main processes: goals conflict detection and goals conflict resolution. Finally, in **Chapter 7,** the research outcomes and main contributions, the fulfilment of the research hypothesis and research questions, along with suggested future research directions, are presented. In addition, various appendices are presented at the end of the thesis.

Chapter 2

Literature Review

This chapter reviews the current state of the art on the following topics related to this research: the notion of Systems of Systems (SoSs); characteristics and taxonomies of systems of systems; Systems of Systems Engineering (SoSE); Goal-Oriented Requirements Engineering (GORE) approaches and in particular, the * framework; semantic representation of the i* framework using ontologies, and finally it provides a research gap analysis by discussing some existing frameworks and approaches in the systems of systems requirements engineering field.

2.1 The Notion of Systems of Systems (SoSs)

An SoS is an arrangement of independent and useful systems which are integrated into a larger system that is capable of delivering new functionalities and capabilities which span more complex operating environments (ODUSD (A&T) SSE, 2008). SoSs face many obstacles in relation to RE, e.g. defining the boundary of an SoS as it changes over time (Ncube et al., 2013), and the management of emerging inconsistent goals and requirements of SoS (Viana et al., 2017).

2.1.1 Characteristics and Taxonomies of Systems of Systems

There are substantial differences between monolithic systems which are considered complex, such as an aircraft, and SoS such as an airport (Ncube et al., 2013). An airport is considered an SoS as it consists of several constituent systems that can operate and be managed independently, such as a baggage handling system. On the other hand, an aircraft cannot operate successfully unless all its components collaborate together in a sensible harmony. Systems of systems possess specific features that identify the challenges of SoS engineering. *First*, operational independence, which means that each constituent system is a self-contained system that can operate independently. *Second*, managerial independence, which means that each constituent system is managed independently and can normally choose to join or leave the SoS. *Third*, evolutionary nature, which reflects the continuously changing goals of the SoS. *Fourth*, emergent behaviour,

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which implies that the entire SoS performs functions and has purposes that do not reside in any constituent system. And *fifth*, the geographical distribution of elements, which is an obstacle against communication of constituent systems (Maier, 1998). Furthermore, DeLaurentis (2005) introduced other SoS characteristics in a study for modelling and analysing transportation System of Systems challenges, which are: inter-disciplinary study, heterogeneity of the constituent systems and networks of systems. Recently, SoSs have become more complex and difficult to manage due to all the previously mentioned characteristics.

SoSs operate in different ways and exist in different problem domains. It is important to understand the architectural taxonomy of an SoS while planning its development life cycle (Gideon and Dagli, 2005). In their study, Gideon and Dagli (2005) claimed that a systems engineering approach that is used to build a system with a specific taxonomy classification may be unsuited for building a system that follows another classification. SoSs are categorised as either: *directed, acknowledged, collaborative,* or *virtual* (Dahmann and Baldwin, 2008). A *directed* SoS is built and managed to fulfil specific purposes, where central management of the SoS exists. An *acknowledged* SoS has recognised objectives, resources and management, while the constituent systems retain their independent objectives, ownership, funding and development approaches. In a *collaborative* SoS, constituent systems decide how to provide or deny service, and voluntarily collaborate to achieve a determined central purpose of the SoS. And finally, a *virtual* SoS has no centrally agreed purpose or central management authority.

In this thesis, the research framework is applied only to the first two categories of SoSs; i.e. *directed* and *acknowledged*. The rationale behind that boils down to the following; in order to apply the framework's components efficiently, the SoS is required to be centrally managed, and the objectives and purposes of the SoS and its constituent systems need to be recognised. In *directed* and *acknowledged* SoSs, the component systems maintain an ability to operate independently; however, their normal operational mode is subordinated to the centrally managed purpose. Moreover, the Cancer Care research case study falls into the category of *acknowledged* SoS.

Misclassifying an SoS incorrectly as a 'monolithic system' or misclassifying the type of the SoS as 'directed, acknowledged, collaborative, or virtual' may lead to problems in design, development, and the use of these systems (Maier, 1998). Hence, the taxonomy of the SoS-of-

interest should be understood and planned for during the initial stages of the SoS development lifecycle.

A simple process for determining the type of an SoS was proposed by (Dahmann and Baldwin, 2008), and a taxonomy for a requirements engineering approach for each type of SoSs was suggested by (MacDiarmid and Lindsay, 2010) as presented in Table 2.1.

Table 2.1: Taxonomy for a RE Approach (MacDiarmid and Lindsay, 2010)

SoS Type	RE Approach
Directed	- Classical RE methods; - Each SoS element clearly defined by central RE authority; - SoS RE evolution controlled and coordinated by a central authority; - Central allocation of requirements.
Acknowledged	- RE performed by SoS central authority; - RE also performed independently by SoS elements (sic); - Infrequent collaboration of RE artefacts.
Collaborative	- RE performed by SoS elements (sic); - Central authority limited to the expression of global SoS goals; - High levels of RE collaboration.
Virtual	- No central authority RE input; - SoS element RE informal and irregular, if at all (sic).

2.1.2 Systems of Systems Engineering (SoSE)

Systems of Systems Engineering (SoSE) aims to overcome the inadequacy of traditional systems engineering methods applied to monolithic systems which do not scale up well when applied to the size and complexity of integrated SoS (Dahmann and Baldwin, 2008). Unlike traditional systems engineering, which concentrates mainly on building the right system, SoSE focuses on selecting the right combination of constituent systems and their interactions to satisfy a set of frequently changing goals and requirements (Ncube et al., 2013), as well as on building the right system. Thus, SoSE requires a different mindset, a different set of skills, different techniques, tools, methods and processes than currently used in requirements engineering approaches.

SoSE also involves more stakeholders than traditional systems engineering. In an SoS, there are stakeholders at the SoS level and the constituent system level, each having their own objectives. Competing stakeholders' interests and goals establish a complex stakeholder environment, which many traditional requirements engineering methods do not appropriately address (ODUSD (A&T) SSE, 2008). Interoperation between constituent systems requires stakeholders – at the SoS level and the constituent systems level – to play an important role in determining policies that make goals of the SoS and the constituent systems achievable.

The emergence of SoSE presents a significant development from single-system-centric approaches; and thus, it may be necessary to re-think current practices (Northrop et al., 2006). Traditional requirements engineering approaches, therefore, need to evolve and new RE processes, methods, and techniques will be required to handle challenges posed by Systems of Systems.

A further challenge to RE for SoS is specifying the boundary of an SoS as it may change over time. As SoS boundaries are dynamic, this poses significant challenges to managing risks correlated with several interactions across organisations, domains, policies and regulations (Ncube et al., 2013).

2.2 Goal-Oriented Requirements Engineering (GORE)

Goals represent, at different levels of abstraction, the various states the system under consideration should maintain or avoid. A *goal* is a prescriptive assertion representing a state about some system whose satisfaction, in general, requires the cooperation of some of the agents forming that system (Van Lamsweerde, 2003). Agents are active components such as humans, devices, legacy software or software-to-be components that play some role or act to achieve goal satisfaction. Goals may refer to a wide variety of prescriptive assertions. *Functional goals* refer to services the system is expected to provide; and *non-functional goals* refer to the quality of service, development objectives or architectural constraints.

The RE approach that pays explicit attention to the strategic context of system requirements is *Goal-Oriented Requirements Engineering* (GORE) (Poels et al., 2013). GORE is defined as a RE approach that is "concerned with the identification of goals to be achieved by the system, the use of goals for eliciting, elaborating, structuring, specifying, analysing, negotiating, documenting, and modifying requirements, the operationalisation of such goals into services and constraints, and the assignment of responsibilities of resulting requirements to agents as humans,

devices and software" (Van Lamsweerde, 2000 & 2001). GORE is a promising approach in the SoS context as goals can be considered as a key starting point for the requirements engineering of an SoS (MacDiarmid and Lindsay, 2010).

It is generally argued that goal models are built during the early phases of the RE process (Yu, 2011; Van Lamsweerde, 2001). The basis for the argument is the driving role played by goals in that process; the sooner a goal is identified and validated, the more efficient is the RE process. Goal-oriented RE, after all, mainly intends to let goals help with elaborating the requirements supporting them (Van Lamsweerde, 2001).

One of the main aims of goal-driven approaches is to overcome the major drawbacks of traditional requirements engineering approaches in developing systems that are technically acceptable, but are unable to respond to the needs of their users in an appropriate way (Rolland, 2005). When business requirements are elicited and articulated in terms of goal models, several benefits for the RE process result: (i) the organisational goals provide a criterion for deciding when meeting the specified requirements is adequate to achieve the stated goals; (ii) the goal decomposition allows evaluating the impact of organisational changes on system requirements of lower levels; (iii) system design choices could be explored by alternative goal decompositions; and (iv) inconsistent requirements can be traced back to conflicting goals for which mechanisms can be devised to resolve them (Poels et al., 2013; Rolland, 2005).

The literature presents several well-known frameworks and approaches for modelling the goals of systems, such as KAOS (Darimont and Van Lamsweerde, 1996), i* (Yu, 2011), and GRL (Amyot et al., 2010). A set of main common concepts are shared among these approaches, namely: (i) actors, which are active entities representing a stakeholder and/or a system whose goals are to be achieved; (ii) goals, which are functional objectives of actors that can be fully achieved; (iii) softgoals, which refer to qualities of the system or non-functional objectives that may not be fully satisfied; and (iv) links, which refer to different relationships and interactions among actors, goals, etc (Cavalcante et al., 2015).

2.2.1   The *i** Framework

As systems become increasingly more complex and closely entangled with the human social environment, models that reflect the social characteristics of complex systems are needed (Yu, 2009). A broad understanding of the organisational environment and goals is usually needed

when developing systems (Santander and Castro, 2002). The *i** framework (Yu, 2011) is a Goal-Oriented (GO) approach that attempts to introduce social modelling and to provide an understanding of the rationales that underlie system requirements. The name *i** refers to the concept of distributed intentionality. The *i** framework focuses on the early understanding of business organisations through determining and modelling the relationships and the intentions among the social actors in the organisation or the business domain. Therefore, the *i** framework is considered as a modelling approach that assists in analysing and redesigning organisations (Chung et al., 2000).

Unlike traditional systems requirements engineering methods which strive to abstract away stakeholders' involvement with systems, *i** recognises the importance of social actors, who are viewed to have intentional behaviour, i.e., they have goals, beliefs, abilities, and commitments (Yu, 2009). Actors can be humans, hardware or software, or may be a combination of these. Actors are considered to be autonomous: their behaviours are not perfectly knowable or fully controllable. The *i** modelling focuses on intentional properties and relationships rather than actual behaviour, and on how well the goals of various actors are achieved through some configuration of relationships and on dependencies among human and system actors, and on what reconfigurations of those relationships can help actors improve their strategic interests and achieve their goals and needs (Yu, 2009).

The *i** framework offers two types of strategic models to represent organisational requirements: The *Strategic Dependency (SD)* and the *Strategic Rationale (SR)* models (Yu, 2011), as described and presented in the following subsections.

2.2.1.1 The Strategic Dependency (SD) Model

The *Strategic Dependency* model (e.g. shown in Figure 2.1) is a network of directed dependency relationships among actors. It focuses on external relationships between several actors and depicts what actors want from each other and the freedoms that each actor has. A dependency link indicates that one actor (the *depender*) depends on another (the *dependee*) for something (the *dependum*). There are four well-known types of dependencies (Yu, 2009):

- *Goal dependency:* the dependum is stated as an assertion. The depender wants the dependee to make the assertion true, without specifying how it is to be achieved.

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- *Softgoal dependency:* the dependum is a quality, such as fast, cheap, reliable, secure, etc. A softgoal dependency is similar to a goal dependency except that the criteria for achievement of the quality goal are not sharply defined.
- *Task dependency:* the dependum is stated as an activity. The depender wants the dependee to perform the task as specified by the description of the activity.
- *Resource dependency:* the dependum is an entity, which can be information or a material object that the depender wants the dependee to provide.

For example, in Figure 2.1 below, one can see that the patient depends on the healthcare provider to satisfy the **hard goal** of the sickness being treated. On the other hand, the healthcare provider depends on the patient for completing the **task** of following the treatment plan. Also, the patient depends on the healthcare provider for providing the **soft goal** of having a flexible treatment plan, and the monitoring agent depends on the patient for the **resource** of vital signs (e.g. heart beating).
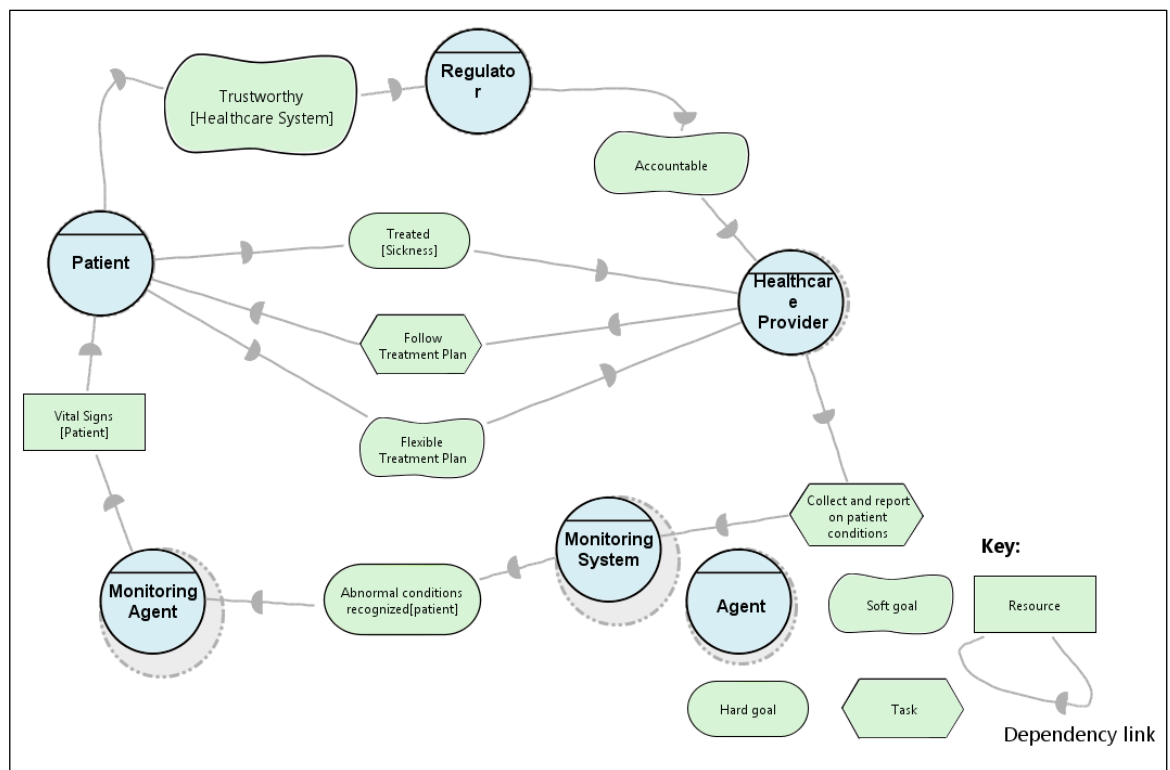
Figure 2.1: A Strategic Dependency (SD) Model (Adapted from Yu, 2011)

2.2.1.2   The Strategic Rationale (SR) Model

On the other hand, the *Strategic Rationale* model (e.g. shown in Figure 2.2), focuses on the internal description of actors' intentional relationships, the rationale behind them and the space of alternatives for each actor. Goals, softgoals, tasks, and resources, are attributed to each actor, this time as internal intentional elements that the actor wants to achieve. In addition to SD semantics, SR's semantics include the following which can also link back to SD models (Yu, 2009):

- A *means-end link* to connect one task to another task or a goal, indicating different alternatives to achieve the goal or the task. This is known as an OR decomposition.
- A *task decomposition link* to indicate the subtasks, sub-goals, resources, and soft goals that a task can be decomposed to and need to be performed or satisfied in order for the task to succeed. This is also known as an AND decomposition.
- *Contribution links* to link tasks to softgoals indicating how they contribute to achieving those qualities (positively or negatively, and with what strength).
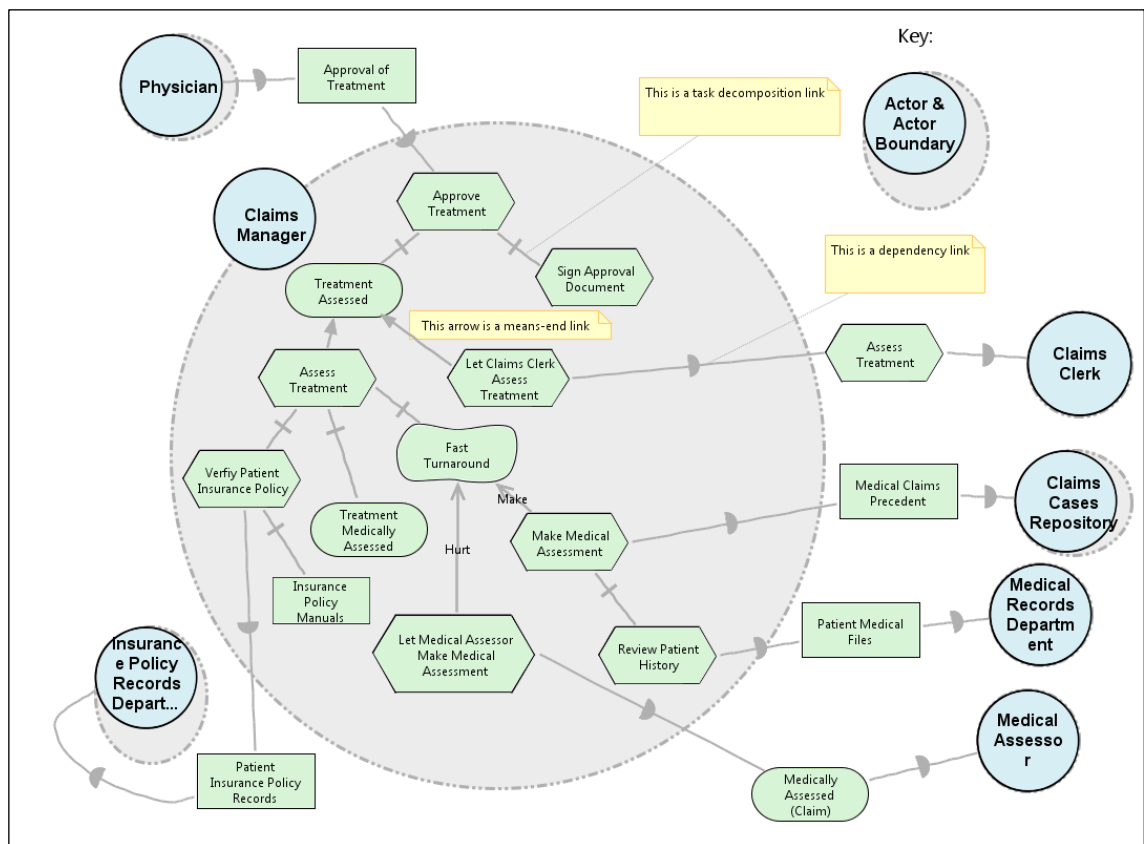
Figure 2.2: A Strategic Rationale (SR) Model (Adapted from Yu, 2011)

2.2.2   Other Goal-Oriented Approaches in Requirements Engineering

Over the past two decades, much effort was devoted to the development of goal-oriented languages and support tools. This subsection presents an overview and several key comparison points between the i* framework and some of the goal languages closest to i* including GRL, KAOS, NFR, and Tropos (Citrigno et al., 2014, Amyot et al., 2010). This section also highlights the advantages of the i* framework and the rationale behind using it, particularly in this research.

GRL (Goal-oriented Requirements Language)

GRL (Goal-oriented Requirements Language) is part of the URN (User Requirements Notation) (Z.151, 2012), it is a standard notation for goal modelling. GRL is a simplified version of i* which enables requirements engineers and business analysts to describe stakeholders (actors) and intentions (e.g., goals, softgoals, and tasks), together with their decomposition structure, dependencies, and contribution levels. GRL is supported by an established tool support (jUCMNav; Amyot et al., 2012).

GRL shares many concepts with the i* framework. However, i* contains many types of actors (e.g., agents, roles, and positions) and associations (e.g., generalisation, instantiation, and is part of) that GRL does not differentiate. For the links that are defined in both languages, there are more restrictions on using them in i* than in GRL. On the other hand, GRL brings in strategies, a combination of qualitative and quantitative contributions, actor evaluations, generic URN links, and metadata. GRL also makes no distinction between strategic and rationale models, although both views can be articulated in different diagrams of the same GRL model (Amyot et al., 2010).

KAOS (Knowledge Acquisition in autOmated Specification)

KAOS (Knowledge Acquisition in autOmated Specification) is a goal-oriented requirement engineering approach with a rich set of formal analysis techniques used to capture requirements in terms of objects, goals, actions, constraints and agents (Lapouchnian, 2005; Van Lamsweerde, 2009). KAOS supports the definition of goals at a different level of abstraction by introducing suitable refinement relations among goals. Goals can be assigned to agents, refined by other goals through AND/OR links, and operationalised by actions (Citrigno et al., 2014). Formal models and informal ones can be created. A quantitative algorithm can be used to evaluate the

partial satisfaction of goals by computing the weighted average of the sub-goals' satisfaction (Amyot et al., 2010).

Unlike the i* framework, KAOS does not provide a method for evaluating the impact of alternative design decisions on non-functional requirements (Lapouchnian, 2005).

The NFR Framework

The NFR (Non-Functional Requirements) framework (Chung et al., 2000) is a process-oriented approach that focuses on the modelling of non-functional requirements (softgoals) and on the identification of the influences (positive or negative) among them. Softgoal refinements and influences are represented in a softgoal interdependency graph, which allows evaluating the contributions of more specific goals concerning higher level ones, and identifying and evaluating different alternatives (Citrigno et al., 2014). The NFR framework also has concepts for intentional elements and qualitative contributions, as well as qualitative, forward propagation algorithm. However, it lacks the concepts of actors and dependencies found in i* and GRL. OME is a tool that supports the NFR algorithm (Amyot et al., 2010).

Tropos

Tropos (Giorgini et al., 2005) is an agent-oriented language and software development methodology founded on intentional and social concepts (includes the concepts of agents and goals), and is considered as an i* variant. Tropos is intended to support four phases of software development: early requirements analysis, late requirements analysis, architectural design, and detailed design. In the early requirements analysis phase, Tropos adopts i*'s modelling concepts and diagrams. There are four qualitative contribution levels in Tropos (-, --, +, ++). The language also supports both qualitative and quantitative relationships between goals and can perform forward and backward propagation. Three types of conflicts (weak, medium, and strong) can be detected during qualitative evaluations, but they are left unresolved (Amyot et al., 2010).

There are several tools that support i* modelling (www.istarwiki.org), but none have been found that supports Tropos, except the tool T-Tool that supports Formal Tropos (Ayala et al., 2005). Many examples of case studies in different domains have applied i* goal modelling and illustrated its use, e.g., healthcare, security analysis, and eCommerce (Ayala et al., 2005). Also, the i* framework is part of an international standard received from the International

Telecommunication Union (ITU), which is the UN agency for information and communication technologies.

2.3 Formalisation of the i* Framework and Ontologies

The *i** framework has been recognised as both a goal-oriented and an agent-oriented modelling framework since it combines goals and agents altogether. Several extensions and variants of the original framework have been defined in order to handle different modelling situations, such as GRL (Amyot et al., 2010), Tropos (Giorgini et al., 2010) and Service-Oriented *i** (Estrada et al., 2008). This has led to a diversity of *i** applications being developed by a wide range of research communities (Cares et al., 2008).

Since models are created with particular variants, sharing information and integrating models expressed in different *i** variants may lead to interoperability problems (Najera et al., 2011). Interoperability has been approached at different levels, e.g. through the definition of a unified metamodel (Cares et al., 2010; Lucena et al., 2008), or with the introduction of an interchange format for representing *i** models such as iStarML (Cares et al., 2011), or through an ontology-based metamodel to realise the integration of models expressed in *i** variants such as OntoiStar (Najera et al., 2011), bringing the advantages of ontologies to the organisational modelling domain; e.g. representing domain knowledge, data standardisation, and the use of detecting and resolving semantic heterogeneities.

The literature includes several attempts at presenting a formal description of the *i** language (Horkoff and Yu, 2016; Horkoff et al., 2014; López et al., 2012). Reviewing the state of the art, several attempts have been made at formalising the *i** language using ontologies, but none yet from systems of systems point of view. For example, Odeh Y. (2015) had proposed the siGoal ontology within the GQ-BPAOntoSOA framework to represent the conceptualisation of the *i** framework, including its SD and SR models, using Semantic Web Rule Language (SWRL) and Web Ontology Language-Description Logic (OWL-DL), to produce the formal semantic representation of interrelated goal-oriented models for an organisation. This research was implemented from a monolithic system perspective only and linked to business process architecture domain, but not applied to the SoS area.

In this section, the potential of using ontologies to formalise the *i** framework and its core concepts in a Systems of Systems (SoS) context are investigated, and potential approaches to map between *i** models and ontologies are explored.

2.3.1 OntoiStar Metamodel and TAGOOn+ Tool

In (Najera, 2011) and (Najera et al., 2013a), ontologies have been used both for supporting the integration of models expressed in *i** variants, and for tackling the *i** variants interoperability problem. Najera et al. (2011) developed an ontology-based metamodel of the i* framework named OntoiStar, which corresponds to the ontological representation of the *i** metamodel; developed a methodology (Najera et al., 2013b) for guiding the process of integrating additional concepts of *i** variants into OntoiStar; and also developed a tool called TAGOOn+ (Tool for the Automatic Generation of Organisational Ontologies and Integration from i* models) to automatically transform an *i** model (both the Strategic Dependency and the Strategic Rationale models) to instances of OntoiStar and thus generate organisational ontologies (Najera et al., 2013c).

OntoiStar has been built using the standard Web Ontology Language (OWL) (Dean et al., 2004). A practical guide to building OWL ontologies is provided in (Horridge et al., 2009). OWL allows one to define axioms in OntoiStar for defining the semantics of each *i** variant and the definition of syntactic constraints, which helps in analysing the syntactic correctness of *i** models. OntoiStar was implemented using the ontology editor and knowledge-base framework Protégé (Gennari et al., 2003), where a set of transformation rules between constructs from the *i** metamodel to the OWL language was proposed.

TAGOOn+ (Najera et al., 2013c) is a tool that automatically generates *i** organisational ontologies and automates their integration with other ontologies. It has two main purposes: First, it supports the automatic generation of organisational ontologies from organisational models expressed with *i**, Tropos and Service-Oriented *i**, using the OntoiStar+ ontological metamodel. The *i**-based models should be represented in the iStarML format (Cares et al., 2011), iStarML is an Extensible Markup Language (XML)-based format for representing i* models (See Section 2.3.2). Second, TAGOOn+ supports the automatic integration of enriched organisational models with general or domain ontologies (Vazquez et al., 2013). The TAGOOn+ tool, brings

the advantages of ontologies such as querying and reasoning, to the organisational modelling domain. An overview of the tool is presented in Figure 2.3.

In other recent research (Abad et al., 2016), the OntoiStar meta-ontology has been selected as the main schema for representing *i** models, and Protégé software was used to generate Resource Description Framework (RDF) files from *i** models. They have defined a mapping between OntoiStar and Context Models (CM) elements in order to generate a semantic repository of *i**-based CMs, which is used to discover relations between different *i** models and extract pattern from them. They are also planning as future work to link the OntoiStar ontology with domain ontologies, which will allow the enrichment of the *i** models.
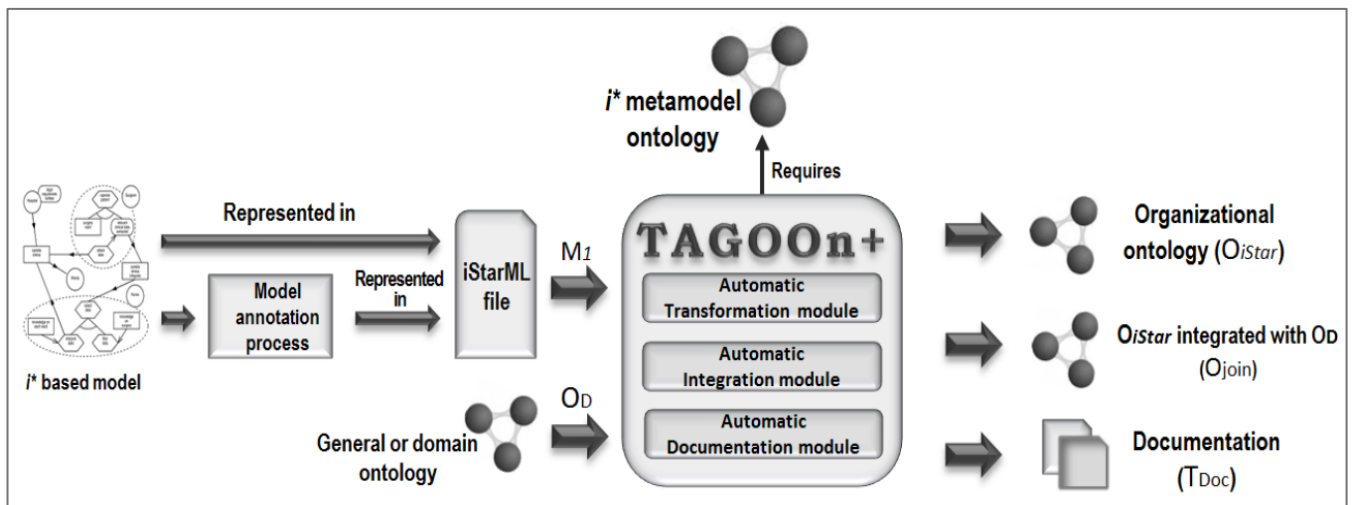
Figure 2.3: Overview of *TAGOOn+* Tool (Najera et al., 2013c)

2.3.2   The i* Reference Metamodel and iStarML

There are several tools for representing *i** models currently available in the *i** community, and models are expressed in different *i** variants. This situation poses both benefits and difficulties. Benefits, because different groups may be able to share their models and results among their tools, and even connect different tools in order to perform complex processes. Difficulties, because most of these tools differ either in the underlying metamodel of the language, or the format in which they store the models, or in both. To overcome the difficulties and exploit the benefits, the iStarML (iStar Markup Language) model interchange format has been developed as a practical solution to this problem (Cares et al., 2008, 2011).

Cares et al. (2010) have proposed an *i** reference metamodel, including many *i** variation commonalities; see Figure 2.4. They have extracted a core set of abstract and common concepts; this has been the platform for defining an XML-based language for representing *i** models named iStarML. iStarML is a textual specification, and it aims to offer an interchange format for SD and SR i* models' interoperability among different *i** variants.

Moreover, Cares et al. (2011) have developed a tool called "OME to iStarML" to transform i* models into iStarML format, which is available through the following link: http://www.upc.edu/gessi/istar/tools/istarml/ometoistarml-remoto/online_tools.html. Table 2.2 shows the *i** core concepts and their corresponding iStarML tags, besides some of the main options to illustrate how particular *i** constructs can be represented in iStarML (Cares et al., 2008, 2011).

Table 2.2: Core Concepts of i*-Based Modelling Languages and Proposed XML Tags for iStarML
(Cares et al., 2008)

i* core concept	iStarML Tag	Main attributes or subtags
Actor	<actor>	*type* attribute to specify different types of actors (e.g. agent)
Intentional element	<ielement>	*type* attribute to specify different kind of intentional elements (e.g. goal)
Dependency	<dependency>	Can contains two subtags: <dependee> and <depender>
Boundary	<boundary>	*type* attribute for representing future variations on boundary conceptualizations
Intentional element link	<ielementLink>	*type* attribute to specify types of intentional relationships (e.g. contribution) *value* attribute to specify values related to the relationship (e.g. +,++,-,++)
Actor association link	<actorLink>	*type* attribute to specify different types of actors' associations (e.g. is_part_of)
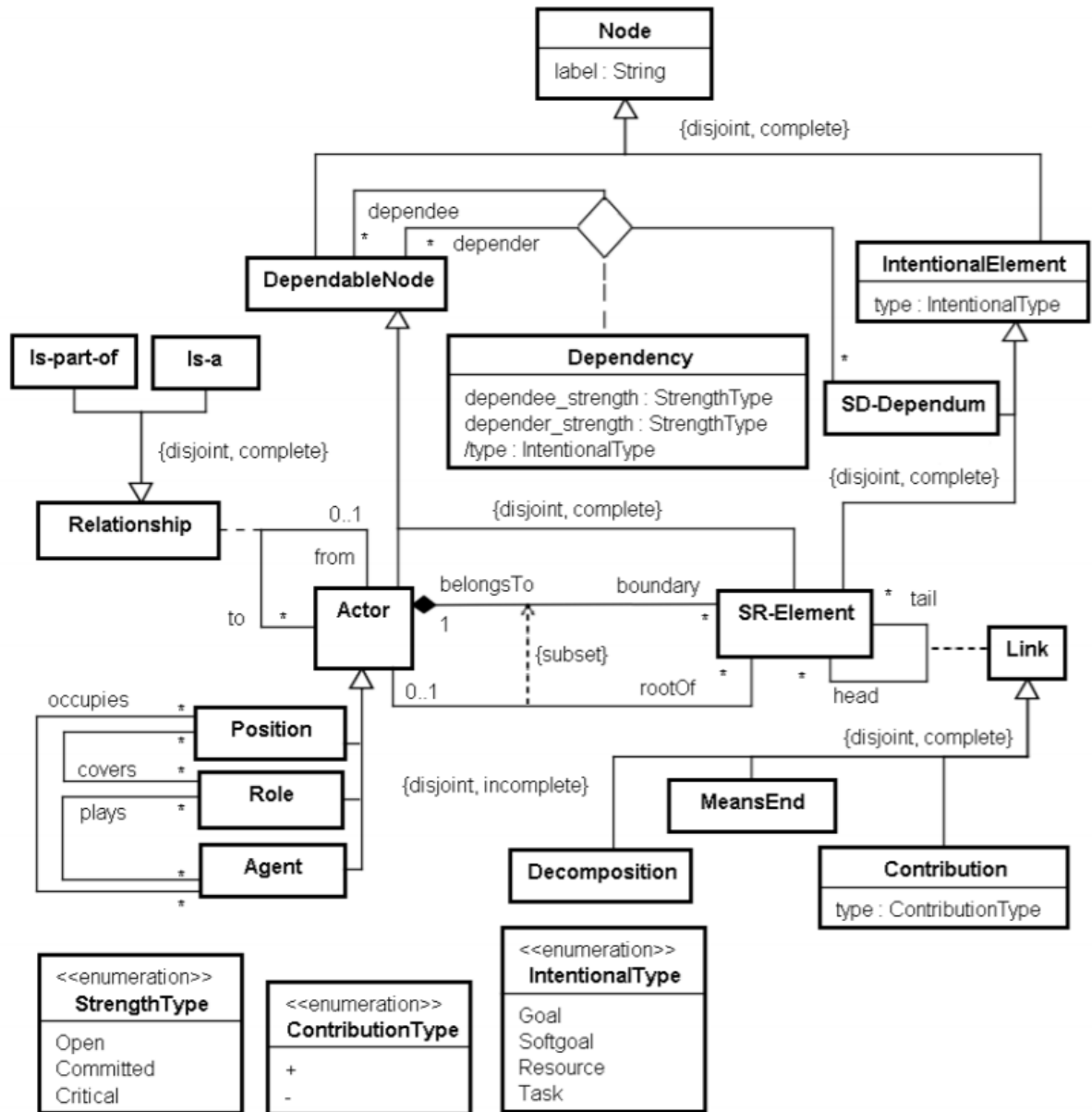
Figure 2.4: The i* Reference Metamodel (Cares et al., 2010)

2.3.3 Ontological Guidelines to Support i* Modelling

In (Guizzardi et al., 2012), (Guizzardi et al., 2013a), and (Guizzardi et al., 2013b), some ontological guidelines for *i** modelling were proposed, based on the Unified Foundational Ontology (UFO) (Guizzardi and Wagner, 2005), in an attempt to provide a solution for the problem of non-uniform use and interpretation of *i**. This involved defining a common ontology for the core concepts of the *i** language to assist in clarifying the semantics of the language's

concepts, understanding the meaning of *i** intentional element links and enhancing the language's usability to promote interoperability among the different existing *i** variants.

Following on from the previous ontological research, Gomes et al. (2015) presented an empirical study, to evaluate the ontological guidelines that they had developed earlier (Gomes et al., 2015). The hypothesis of the study was that "the ontological guidelines enhance the capability of the subjects to create *i** models". Results showed that for more experienced conceptual modellers, the ontological guidelines were useful and indeed supported *i** modelling. However, results were not as positive for non-experienced conceptual modellers.

In their work, Guizzardi et al. (2013a) started with an analysis of the semantics of the core *i** intentional elements, such as ***actor, goal, task*** and ***resource***. The study also took into consideration the concepts of ***agent, role*** and ***position***, along with the ***dependency*** relation. Then, they proposed some modelling guidelines for the ***means-end link***, ***OR-decomposition***, and ***contribution links*** based on UFO's semantic interpretation. According to UFO, a goal is the propositional content of an agent's intention. Thus, ontologically, a goal is in itself a proposition, and decomposition relations reflect logical relations between propositions.

The *i** literature shows that there was some confusion in interpreting i* notations in general, and modellers sometimes use ***OR-decomposition*** and ***means-end*** to express the same phenomenon. However, Guizzardi et al. (2013a) argued that ***means-end link*** and ***OR-decomposition*** are two different relations. For example, a goal as mentioned is a proposition, thus it is not possible to decompose a goal into tasks or resources. A goal may be only decomposed into subgoals. The ***means-end link***, on the other hand, is generally applied between ***tasks*** and ***goals***. They also provided a clear distinction between the use of the ***means-end*** and ***contribution links*** according to the causing *intention* behind the execution of the task (Guizzardi et al., 2013b).

Table 2.3 presents a formal description of some of the core concepts of *i** using the UFO foundational ontology, and Table 2.4 summarises some of the ontological guidelines that had resulted from the previous research.

Table 2.3: Formal Description of Some i* Concepts According to UFO (Guizzardi et al., 2013a)

AND-decomposition	$G \leftrightarrow G1 \wedge G2 \wedge G3 \wedge \dots Gn$
OR-decomposition	$G \leftrightarrow G1 \vee G2 \vee G3 \vee \dots Gn$
Means-end link (ME)	$task(a) \wedge goal(G) \wedge ME(a, G) \rightarrow deliberately\text{-}achieves(a, G)$
Make contribution link (MakeCont)	$action(a) \wedge goal(G) \wedge MakeCont(a, G) \rightarrow$ $achieves(a, G) \wedge \neg deliberately\text{-}achieves(a, G)$
Deliberately achieving a goal	$task(a) \wedge goal(G) \wedge deliberately\text{-}achieves(a, G) \leftrightarrow$ $achieves(a, G) \wedge (\exists i: intention(i) \wedge is\text{-}reason\text{-}for(i, a)$ $\wedge implies(propositional\text{-}content(i), G))$

Table 2.4: Some Ontological Guidelines on the Semantics of i* Links
(Guizzardi et al., 2013a, and Gomes et al., 2015)

Hardgoals G ---*OR-decomposition*-→ hardgoals G1, G2 for an actor A iff 1. By accomplishing either G1or G2, G is accomplished
Action *a* ---*means-end*-→ hardgoal G for an actor A iff 1. By choosing to perform *a*, it was A's intention to achieve goal G, 2. Performing *a* causes situation S and 3. Situation S satisfies G
Action *a* ---*make contribution*-→ hardgoal G for an actor A iff 1. By choosing to perform *a*, it was NOT A's intention to achieve goal G, 2. Performing *a* causes situation S and 3. Situation S satisfies G
A *decomposition link* can only be applied between elements of *the same kind*. E.g. goal->goal, task->task.
A *means-end link* can only be applied between elements of *different kinds*. E.g. task->goal, resource->task.
Taking task T and goal G, if the intention behind the execution of task T is to accomplish G, T and G should be related via *means-end link*. On the other hand, if by executing T, G is unintentionally achieved (i.e., as a side-effect of the execution of T), then T and G should be related via *make-contribution*.

2.4 Alternative Requirements Engineering Approaches in SoS Context

This section introduces a few existing frameworks in the field of requirements engineering of systems of systems, in order to highlight some gaps in the literature that motivated the researcher to develop this research framework.

Haley and Nuseibeh (2008) introduced an interdisciplinary approach for bridging between requirements analysis of an SoS and its architecture, with a focus on analysing the information systems requirements for SoS. They proposed a combination of tools for analysing requirements of systems of systems, that could provide the analyst with high-quality information early and help with analysing requirements for monitoring and managing SoSs. Within their proposed combination of tools, they used the i*/Tropos requirements engineering methodologies to help in understanding the interplay between the components from an agent, action, and intention point of view.

A key limitation to Haley and Nuseibeh's (2018) approach, that it was only applied to and tested through a hypothetical small-sized case study. They did not carry on further research in this area or apply their approach, in order to test its effectiveness, to a real case study example which scales up to the complexity of the SoS domain.

In other recent research work regarding goal-oriented models for self-aware systems of systems, Cavalcante et al. (2015) purported that a successful requirements engineering approach for SoS would require a combination of both top-down and bottom-up approaches. They proposed an approach structured upon two-goal levels for modelling goals in the SoS context: the SoS Goal Level; which encompasses the representation of global goals of the SoS itself, and the Systems Goal Level; which encompasses the representation of goals of the individual constituent systems. They claimed that with this approach, it is possible to express the global goals of the SoS as well as to handle the collaboration of independent systems and their respective goals. Figure 2.5 depicts these two goal levels for modelling goals of an SoS and its constituent systems.

Cavalcante's (2015) approach was promising from a theoretical point of view, but a key limitation is that it was not tested through applying it to a real example or a case study, and no

evaluation outcomes were published. The approach also lacks the application of a proper goal modelling language, hence no goal-modelling from SoS context was performed.
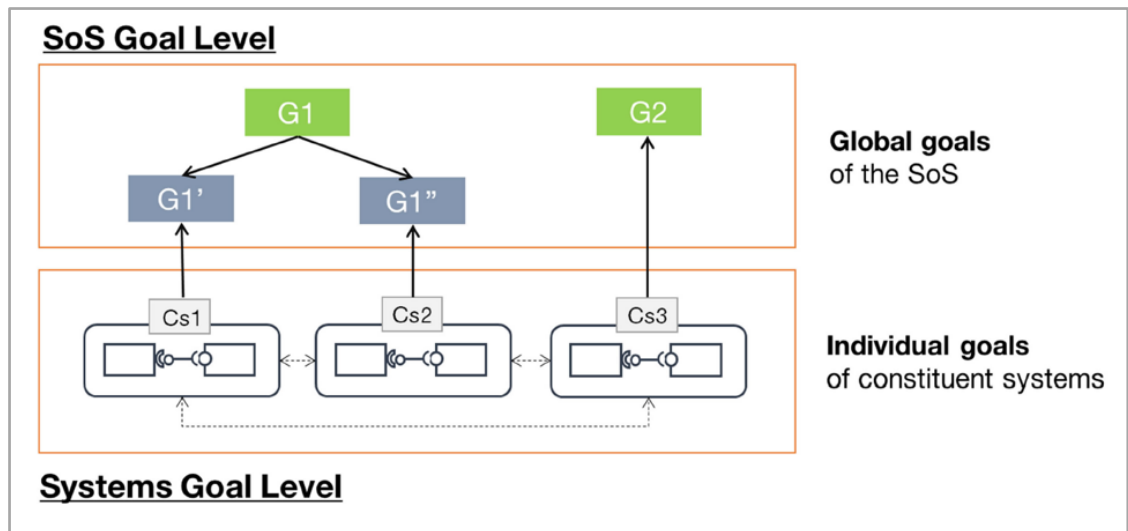
Figure 2.5: Goal levels for goals of SoS (Cavalcante et al., 2015) © 2015 IEEE

Viana et al. (2017) have presented a framework called MaCoRe_SoS (Managing Conflicting Requirements in Systems of Systems) to support conflict management in SoS arrangements between resource-based requirements (i.e. requirements concerned with the consumption of different resources). The framework includes three main steps: (1) conflict identification, with activities, overlap detection and conflict detection; (2) conflict diagnosis, and (3) conflict resolution.

Their results suggested that the framework is able to help an SoS to manage their resources by identifying conflicting requirements at runtime. However, a key limitation is that the results are based on a simulated environment of an example of limited size and, therefore, it is not possible to claim generalisability or evaluate the scalability of the framework yet. The authors are still improving their work and analysing other domains with realistic workloads.

2.5   Research Gap Analysis and Conclusions

This chapter has provided a state-of-the-art review of the notion of systems of systems, goal-oriented requirements engineering approaches and in particular the i* framework, the formalisation of the i* language semantically, and finally, existing requirements engineering approaches in SoS context. The chapter is also linked to the first and second phases of the DSRM

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process (i.e. problem identification and motivation, and objectives of a solution, respectively), which reveal the significance of addressing the research problem. See Section 3.3 for more details regarding the research methodology DSRM phases.

After having reviewed the literature, several limitations and gaps were revealed that need to be addressed through developing an effective GORE framework in SoS context. These gaps are summarised as the following: (i) lack of frameworks in SoS context that aim to manage the continuously changing and evolving goals at both the local and global levels of an SoS arrangement; (ii) lack of research work that is concerned with not only the technical features, but also the social aspects of SoS requirements engineering which focus on the actors and their roles as a vital part of the process; (iii) the i* goal-oriented approach has been used in the requirements and goals specifications of monolithic systems, but has not been applied yet in deriving goals specifications and goal-oriented modelling in SoS context; (iv) complex stakeholder environment and various participating constituent systems in an SoS present more conflicting requirements and goals that are not properly tackled in the literature; (v) existing research work in the SoS domain did not test the effectiveness of their proposed approaches through conducting proper-sized practical real case studies (e.g. Cavalcante et al., 2015); and (vi) lack of research work that tackled the area of Cancer Care goal requirements engineering from an SoS point of view, as Cancer Care is the chosen case study for this research. See Section 3.4.

SoS engineering is largely driven by stakeholders' goals and needs and involves more stakeholders than traditional systems engineering, each having their own needs and objectives, thus, establishing a complex stakeholder environment, and leading to more conflicts that might occur in all SoS levels. It is acknowledged that GORE is a promising approach for requirements engineering for monolithic systems, and this research aims to extend the potential validity of this fact in the SoS context.

The above-identified gaps in the literature raise the need for a Goal-Oriented Requirements Engineering framework that incorporates the nuances exhibited by SoS, models and manages their local and global goals in SoS context, and provides effective mechanisms to resolve conflicts and inconsistencies amongst goals and their owning stakeholders. This proposed framework, the main artefact of this research, and its components are introduced in the next

chapter, along with the adopted research methodology; the DSRM process of Peffers et al., (2007), and how its phases are linked to the thesis chapters.

Chapter 3

Research Design and Framework

This chapter starts by providing the motivations behind the design of the research framework and highlighting the significance of the research in Section 3.1. Then, in Section 3.2 the design of the research framework, its components and layers are introduced. The adopted research methodology for this research, with the research main phases and iterations, are presented in Section 3.3. In Section 3.4, an overview and the rationale behind selecting the KHCC Cancer Care case study are introduced. Finally, the chapter is concluded in Section 3.5.

3.1 The Motivations Behind the Research Framework Design

The evolution of SoSs raises a number of software engineering challenges regarding their specification, design, construction, and operation. Among these challenges, one important challenge is concerned with the management of inconsistent emerging requirements. In an SoS, the various participating constituent systems are often from different domains; are developed by different teams of people under different circumstances and at different times; have distinct functionalities; and are used by different stakeholders. Therefore, the various constituent systems may present conflicting requirements among themselves, as well as emerging conflicting requirements between the whole SoS and the participating constituent systems (Viana et al., 2017).

In software engineering, it is acknowledged that capturing requirements that accurately reflect users' needs is crucial to the success of a system development process (Yu, 2011). The emerging interdisciplinary area of SoS and SoSE is largely driven by stakeholders' goals and needs. SoSE involves more stakeholders than traditional systems engineering, i.e. stakeholders at both the SoS level and the constituent systems level, each having their own needs and objectives. Competing stakeholders' interests and goals establish a complex stakeholder environment, which many traditional requirements engineering methods do not appropriately

address (ODUSD (A&T) SSE, 2008). However, goal-driven approaches can be used to drive the requirements engineering process to explore the objectives of different stakeholders and the activities performed by them to achieve these objectives (Rolland, 2005), in order to derive purposeful system requirements at both SoS-level and constituent systems-level.

The *i** framework is a goal-oriented approach that attempts to introduce social modelling and provide an understanding of the reasons that underlie system requirements (Yu, 2009). The *i** framework recognises the importance of social actors and focuses on how the goals of various actors are achieved. It focuses on an early understanding of business organisations through determining and modelling the relationships and the intentions among the social actors in the organisation or the business domain.

This research aims to apply Goal-Oriented Requirements Engineering (GORE) in the SoS context using the i* framework to identify, model and manage SoS goals, and as the starting point for deriving associated requirements. The i* goal-oriented approach has been used in the requirements specifications and goals specifications of monolithic systems, but has not been used so far in the derivation of goals specifications and goal-oriented modelling for SoS.

Identifying the research hypothesis and associated research questions, presented earlier in Section 1.4, led to the design and development of the research framework. In this research, we propose a novel approach that combines the i* goal-oriented framework with an ontological approach to develop an Ontology-based Goal-Oriented Requirements Engineering framework for Systems of Systems (OntoSoS.GORE). OntoSoS.GORE framework is introduced in the next section. Using this approach, the SoS goals of the involved stakeholders have been modelled and managed at two levels: the SoS high-level goals and the constituent systems-level individual goals.

The i* goal-oriented models developed for the SoS are ontologised to check for any inconsistencies or conflicts that might occur amongst goals. The significance of using an ontology-driven approach within the framework, is that the use of detecting and resolving semantic heterogeneities and maintaining the consistency of goals at both local and global levels are enabled, as well as informing the satisfaction of goals by linking the several goals levels together. Ontologies are largely used for representing domain knowledge, and a common use of ontologies is data standardisation. Accordingly, ontologies are applied to represent and clearly

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distinguish between the global and local i* goal models, their concepts and elements, and the links between these models.

Conflicts occurring amongst goals at any level of the SoS arrangement are detected and resolved using conflict management strategies and mechanisms. The usage of OWL and SWRL as modelling languages (Horrocks et al., 2004), provide different ways to detect and resolve conflicts in the knowledge base, in order to produce a set of consistent goal-oriented models which are well-aligned with and best satisfies users' goals, needs and concerns.

In addition, the research framework is applied to the health care domain, and in particular Cancer Care for demonstration and validation purposes. This research looks into Cancer Care in a new and innovative way from systems of systems perspective, as Cancer Care consists of many independent constituent systems. One of the contributions of this research is introducing a proposed *Reference i* Goal-Oriented Model for Access to Cancer Care* presented in Chapter 4 and published in (AlHajHassan et al., 2018a), developed following international standard practices and general certified regulations. This reference model contributes to informing the validity and generality of the research framework in the SoS requirements engineering context, and is intended to be applied to different Cancer Care organisations and provide them with a model covering the most generic goals, concepts and stakeholders' relationships in Cancer Care system of systems at both global and local levels.

3.2 The Research Framework OntoSoS.GORE

This research work aims to utilise the i* framework goal-oriented approach along with semantic technologies, in developing an **Onto**logy-based **G**oal-**O**riented **R**equirements **E**ngineering framework for **S**ystems **o**f **S**ystems, namely the "**OntoSoS.GORE**"; the main artefact of this research work. A previous work initiating the development of this research framework was published in (AlHajHassan et al., 2016). Applying the OntoSoS.GORE framework to an SoS arrangement or organisation involves eliciting, specifying, analysing, modelling and validating local and global goals that are well-aligned with the users' concerns and needs.

The research framework OntoSoS.GORE is anticipated to be used in three main ways: (i) for evaluating and, if necessary, refining (i.e. improving by removing existing conflicts) an existing SoS, where all of the constituent systems have already been engineered and have also

been organised into a centrally managed SoS; (ii) for engineering all of the constituent systems from scratch and organising them into an SoS, in the case where the constituent systems are not engineered or formed into an SoS yet; and (iii) for addressing SoSs that fall in between the previous two extremes. This would be the case where some constituent systems still had to be engineered, or the constituent systems still needed to be organised into a managed SoS. The Cancer Care case study applied for this research is classified to fall into the last case, since some of the existing constituent systems that comprise the Cancer Care still need to be organised into a managed SoS, as will be discussed later in Chapter 4.

The framework's main components and layers are introduced in the following subsections and illustrated in Figure 3.1.

Figure 3.1: The OntoSoS.GORE Framework Layers and Main Components

The diagram content (OntoSoS.GORE Framework):

First Layer — Developing Local and Global Goal-Oriented i* Models

- SoS Strategic Documents, Policies, & Procedures
  - Identify the SoS High-Level Global Goals → Develop i* GGOM for SoS (Reference i* SD Model)
  - Identify the Constituent Systems-Level Local Goals → Develop i* LGOMs for CSs (SDs + SRs)
  - Develop a Conceptual Metamodel for SoS i* Goal Modelling

Second Layer — GRI model and Ontologising the i* Goal Modelling

- Develop Goals Referential Integrity (GRI) Model
- Develop an Ontology-based Model for i* SoS Goal Modelling

Third Layer — Conflict Management

- OWL-DL Reasoning
- SWRL Rules
- Conflict Detection → Conflict Set → Conflict Resolution
- Maintain Goals Referential Integrity (GRI)

Revisit & Refine the i* Local & Global Models

OntoSoS.GORE Framework

Key:
LGOMs: Local Goal-Oriented Models, GGOM: Global Goal-Oriented Model
CS: Constituent System, SD: Strategic Dependency Model, SR: Strategic Rationale Model

3.2.1 First Layer: Developing Local and Global i* Goal-Oriented Models for the SoS and its Constituent Systems

An SoS is engineered to create operational capabilities and functionalities that are beyond that which the constituent systems can provide autonomously (Ncube et al., 2013). Goals are delineated as either Systems of Systems goals, which are the global missions of the SoS-of-interest as a whole, or as constituent system-level goals, which are assigned to a particular constituent system as local goals (i.e. SoS-level goals and constituent systems-level goals).

The main objective of this layer is to develop Global Goal-Oriented Models (GGOMs) for the SoS as a whole, and Local Goal-Oriented Models (LGOMs) for its constituent systems, using the i* framework. In order to accomplish this, the SoS-level goals and the constituent systems-level goals should be identified as well as the actors at these global and local levels.

Furthermore, a conceptual metamodel for SoS strategic goal modelling using the i* framework is developed, see Chapter 4, in order to define the multiple goal-levels in an SoS arrangement, and the relationships between these goal-levels and corresponding components such as constituent systems. This metamodel is also linked to the second layer of the research framework; the sGRI model that provides the enforcement of goals referential integrity in SoS context.

The Constituent Systems (CSs) that comprise the SoS should be determined and understood. These constituents must be discovered, selected, and composed in order to identify suitable arrangements of these systems to contribute to: (i) the realisation of the global goals established for the SoS, and (ii) the accomplishment of the global goals of the SoS based on their capabilities (Cavalcante et al., 2015).

At this phase, a proper understanding of the individual goals of the participating constituent systems and the capabilities that they provide should be addressed, as well as an understanding of the SoS, the identification and specification of its global goals, and the identification of the SoS interactions. Moreover, the actors and stakeholders who own these local and global goals, and the relationships and dependencies between them should be identified and understood. This will be done through analysing and studying the strategic documents, policies and procedures of the SoS organisation and its comprised constituent systems, and also by meeting with and interviewing the organisation's key stakeholders and domain experts.

Applying the i* framework, Local Goal-Oriented Models (LGOMs) consisting of Strategic Dependency (SD) models and Strategic Rationale (SR) models are developed for the SoS organisation's constituent systems. The stakeholders' needs and goals of each constituent system and the external relationships between them are modelled in SD models. On the other hand, the internal description of actors' intentional relationships, the rationale behind them, the space of alternatives for each actor, and how hard goals and tasks contribute to achieving softgoals (i.e. qualities) are modelled in SR models.

Likewise, Global Goal-Oriented Models (GGOMs) for the entire SoS are developed, see Section 4.1.3. The high-level global goals of the SoS plus the most generic goals and concepts extracted from the local models are expressed in a Strategic Dependency (SD) model, representing the strategic external relationships among actors on the SoS-level and their wished-for goals. The first layer of the framework and its components are presented in more details in Chapter 4.

3.2.2 Second Layer: Goals Referential Integrity (GRI) Model and Ontologising i* Goal-Oriented Modelling in the SoS context

1) *Developing a Goals Referential Integrity (GRI) Model in the SoS context*

The term *integrity* was introduced in the context of database development. It refers to the correctness or validity of the data in a database, as defined explicitly by means of integrity rules or constraints, i.e. rules that define properties to be satisfied by the database (Grefen and Apers, 1993). *Referential integrity* as a concept in database systems represents the "cement" that keeps relational database components together. In a relational database, such components are tables and the link between two tables is a foreign key. Referential integrity ensures that relationships between tables remain consistent (Ordonez et al., 2007).

In this research, a new term in SoS and GORE context is introduced, namely **Goals Referential Integrity (GRI)** and is defined as *"the capability to maintain the integrity of the SoS goals with the evolving local goals of the constituent monolithic systems"*. **GRI** intends to preserve the integrity and consistency of both the SoS-level goals and the constituent systems-level goals, if either any goal at any of the two levels has been changed, updated, deleted or a

new goal has been identified. The integrity of goals should be kept both ways: top-down (from the SoS to the constituent Systems); and bottom-up (from constituent systems to the SoS).

Three types of constraints on goals are identified and should be considered in order to maintain and enforce Goals Referential Integrity in an SoS arrangement: insert constraints, update constraints, and delete constraints. These constraints and the proposed GRI model are discussed in further detail in Chapter 5.

2) *Ontologising the i* Goal-Oriented Modelling in the SoS context*

In this component of the framework, an ontology-based model is developed using OWL to semantically enrich the GRI model and represent the *i** strategic goal modelling in SoS context, towards maintaining the consistency and referential integrity of goals, and form, together with the proposed GRI model, the semantic Goals Referential Integrity (sGRI). The semantics of the *i** modelling concepts should be well understood, and the formal ontological representation of the *i** elements and the strategic goal modelling in SoS context will provide the mean to check for inconsistencies or conflicts that may occur in the resulting *i** models developed for the SoS-of-interest, as well as informing the satisfaction of the goals at different levels. This component will be discussed in more detail in Chapter 5.

3.2.3   Third Layer: Applying Conflict Management at the Constituent Systems-Level (Local Level) and the SoS-Level (Global Level)

Systems of systems are the most difficult to handle compared to other classes of systems, especially because of their complexity. Conflicts may occur amongst goals in the local level between several constituent systems, as they may occur amongst goals in the SoS-level, and also between these in the SoS-level and these in the CSs level; and therefore, there is a need for conflict management mechanisms. Conflict management consists of two main stages: conflict detection and conflict resolution (Van Lamsweerde, 2001). In this layer of the research framework, two main components are addressed regarding conflict management in SoS goal-oriented modelling: goals conflict detection and goals conflict resolution as well as the maintenance of goals referential integrity while applying the conflict management process. This layer of the framework and its components are discussed in more detail in Chapter 6 of the thesis.

1) *Conflict Detection*

On the one hand, an SoS global goal could be satisfied by one or more of the constituent systems local goals, but on the other hand, individual goals at the CSs level may conflict with a global goal at the SoS-level. Conflicts amongst goals at the different levels should be detected and may arise for several reasons, such as (Cavalcante et al., 2015): (i) the existence of a broader range of stakeholders including stakeholders at the SoS level and at the CS level, each having their own objectives and interests; (ii) conflicts in the relationship between constituent systems and the SoS; (iii) conflicts arisen from interactions among constituent systems; and (iv) knowing that a given constituent system might simultaneously belong to more than one SoS.

The usage of OWL and SWRL as modelling languages, where rule conflicts may appear, provide different ways to detect conflicts in the knowledge base. Since the developed local and global i* models are translated and described in OWL, which is based on Description Logic (DL), a DL reasoner is used to deal with inconsistent knowledge bases. When two contradictory facts are held in the knowledge base, it is considered inconsistent, and reasoners detect these situations. Thus, the consistency checking process of DL reasoners can be used to detect semantic conflicts and will alert about the detection of the conflicts (Calero et al., 2010).

2) *Conflict Resolution*

This step focuses on providing strategies either to resolve conflicting goals that may occur at any level of the SoS arrangement or to mitigate conflicts. Conflict resolution could be achieved by returning to the stakeholders who own conflicting goals to see whether they would be prepared to accept a compromise (Van Lamsweerde, 2001). Perhaps one new goal would satisfy both stakeholders, to a reasonable extent, a process known as *satisficing*.

Another strategy involves analysing the complexity of goals and selecting the goal with the highest priority. Priority is an important attribute that can be attached to goals, which is often used for resolving conflicts amongst goals (Van Lamsweerde, 2001). Prioritisation technique allows the resolution of conflicts that might appear between two goals by assigning a priority to each goal, in order to decide which is applied in case of conflict.

Goal specificity is also another significant factor that should be determined when analysing the complexity of goals. Specificity refers to the level of precision and explicitness of the goal,

which relates to the definition of a target level of performance (Wofford, 1982; Leung and Liu, 2003). Higher goal specificity leads to a higher priority of the goal in the case of goal conflict.

Furthermore, conflict resolution often requires negotiation (Boehm et al., 1995). Goal-based negotiation is an iterative process which includes identifying all stakeholders together with their wished-for goals (called *win conditions)*, identifying conflicts between these goals together with their associated risks and uncertainties, and then reconciling goals through negotiation to reach a mutually agreed set of goals, constraints, and alternatives for the next iteration. In this research, the conflict resolution process focuses on analysing the complexity of goals in terms of their priority and specificity as will be discussed later in Chapter 6.

3.2.4 Revisit the Developed Local and Global i* Models to be Refined and Modified

New goals might be identified from interactions between the constituent systems or by resolving conflicts among goals or obstacles to goal achievement. Thus, the global goals of the SoS should be managed and redefined more thoroughly according to the outcomes and consequences of the conflict management process. This will also be accomplished by applying a key feature of the OntoSoS.GORE framework which is maintaining the referential integrity of the SoS goals as was revealed earlier.

The identification of any new goals and the outcomes of the conflict detection and resolution processes along with enforcing the referential integrity constraints should be reflected on the design of the LGOMs developed for the constituent systems level as well as the GGOMs developed for the SoS level, conforming to the local and global goal management process. In this phase, the SD and the SR models of the constituent systems are modified as needed and then finalised. Besides, the integration process of the LGOMs in order to generate the refined proposed Reference i* GGOM for the SoS-of-interest is part of this phase.

In the proposed OntoSoS.GORE approach, the integration process is dependent on the schematic information stored and inferred from the local models to create the global view. This method also focuses on resolving any structural discrepancies amongst the local models. Moreover, the GGOMs generated will be refined continuously as the goals of the SoS are evolving and changing over time.

In the next section, the research methodology adopted for this research is introduced, and justification of choosing this particular methodology and how it suits the nature of the research and the design of the research framework is presented.

3.3 The Design Science Research Methodology (DSRM) in Action

Information systems research has been criticised for having little influence on practice. One approach to achieving more relevance is to conduct research using appropriate research methods that balance the interests of both researchers and practitioners (Cole et al., 2005). A well-known research method that is employed in the information systems field is design science research, which directly intervenes in real-world domains and effects changes in these domains.

Design Science Research (DSR) is a problem-solving research paradigm aiming at answering questions relevant to human problems via the creation of innovative artefacts, which are both useful and fundamental in understanding the problem. DSR thereby contributes new knowledge to the body of scientific evidence by constructing, implementing and evaluating an artefact. The importance of DSR has been recognised to improve the effectiveness and utility of IT artefacts in the context of solving real-world problems (Hevner and Chatterjee, 2010).

Due to the nature of this research in developing an *Ontology-Based Goal-Oriented Requirements Engineering Framework for Systems of Systems,* the Design Science Research Methodology (DSRM) has been adopted (Hevner et al., 2004), as it is well-aligned with the development, performance enhancement and evaluation of innovative and purposeful artefacts in the field of Information Systems (IS), and DSRM's iterative nature is anticipated to contribute to developing a reasonably well-constructed version of the framework and expected to be well-aligned with the Cancer Care case study selected at KHCC, that will be conducted through multiple iterations.

Moreover, DSRM emphasises the rigour and the relevance of the research accomplishments by bearing in mind the vital relationships between the environment and knowledge base domains. In particular, DSRM utilises a problem-solving process where research artefacts are designed, implemented, and evaluated in cycles (i.e. Relevance cycle, Design cycle, and Rigour cycle) as shown in Figure 3.2, to reveal to what extent the proposed aims and objectives of the research have been fulfilled.
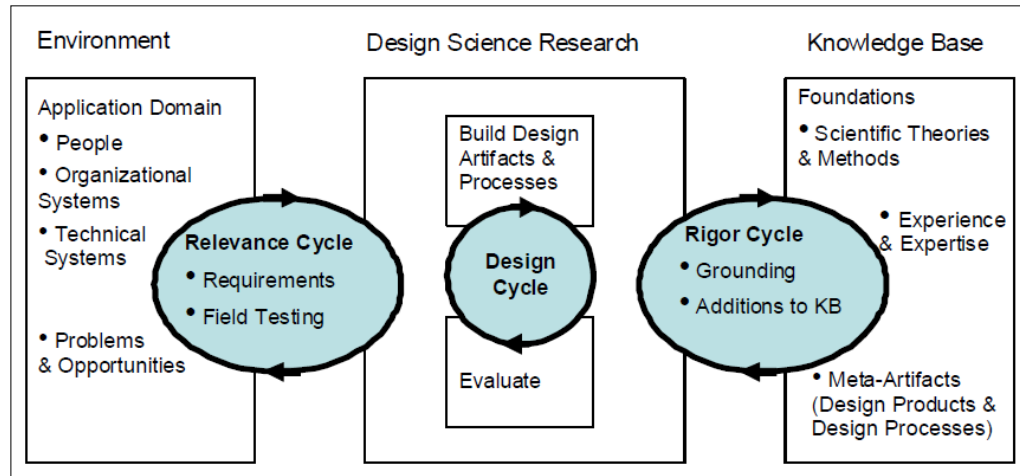
Figure 3.2: Hevner's Design Science Research Cycles (Hevner, 2007)
© Scandinavian Journal of Information Systems, 2007

One of the widely-accepted frameworks that is proposed for the production and presentation of design science research in information systems domain following Hevner's (2004) guidelines is the DSRM process model of Peffers et al. (2007) shown in Figure 3.3, which has been adopted for this research. The proposed DSRM process model comprises six main phases: problem identification and motivation, objectives of a solution, design and development, demonstration, evaluation, and communication.

The DSRM process is structured in a formally sequential order; however, phases 2-6 have an iterative nature, so that one might move forward or backwards to any step when needed in order to develop a reasonably well-constructed version of the OntoSoS.GORE framework. The current research work is expected to go incrementally through at least three iterations to effectively assess and evaluate the framework, but may need more or fewer iterations depending on the requirements of applying the research case study.
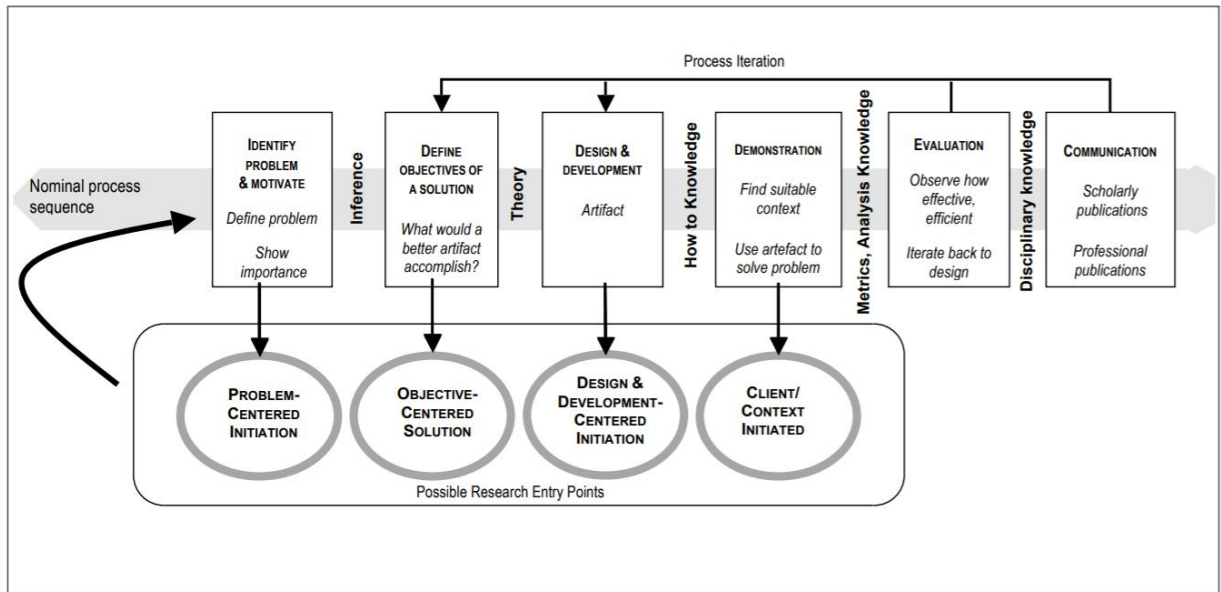
Figure 3.3: Design Science Research Methodology (DSRM) Process Model
(Peffers et al., 2007), Licensed under CC-BY-SA 3.0

The adopted research methodology of the DSRM process model shown in Figure 3.4, presents all the phases and iterations that are performed to develop, assess and evaluate the main artefact of this research; the OntoSoS.GORE framework. Figure 3.4 also illustrates the linkages between each DSRM phase/ iteration and the thesis chapters. A further description of the anticipated iterations and their phases and how each phase is being conducted is now introduced.

3.3.1   Problem Identification and Motivation

In this phase, the main motivation for this research is identified, and the research problem is defined justifying the value of a solution. The research is defined by stating the research hypothesis and identifying a set of associated research questions while clearly stating the research aim and objectives. This is presented in Chapter 1 of this thesis; "Introduction".

Also, in this phase, the current state of the art in relation to the models, methods, techniques, and frameworks utilised in the fields of Systems of Systems RE, Goal-Oriented RE, $i*$ modelling and ontologising the i* framework have been critically reviewed and presented in Chapter 2, leading to the research gap analysis, and identifying areas in traditional RE that need enrichment to be fit for SoS context.
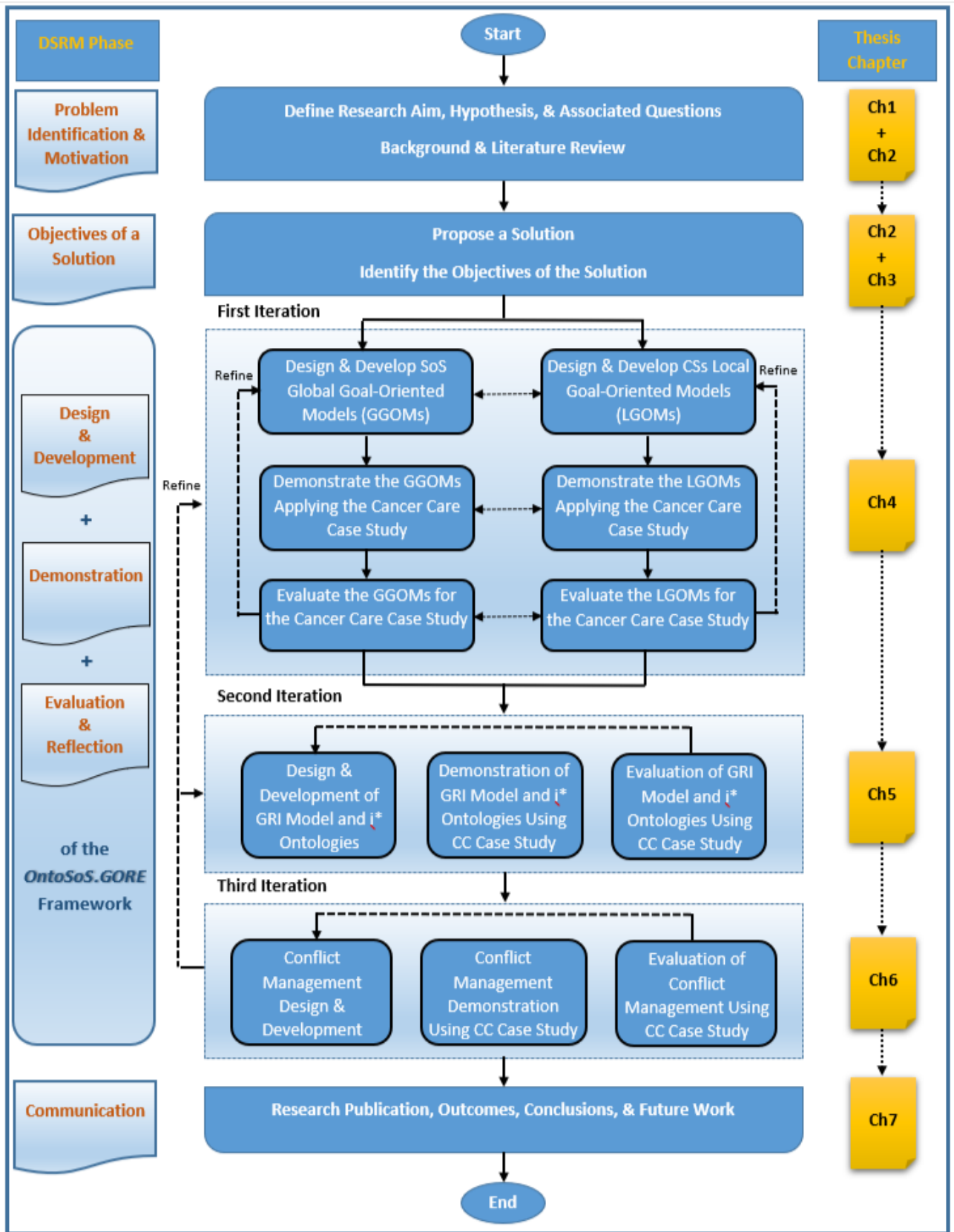
Figure 3.4: Adopted Research Methodology of the DSRM Process Model

3.3.2 Objectives of a Solution

In this phase, the initial objectives of the OntoSoS.GORE framework, the main artefact of this research, are recognised and defined, and then refined iteratively throughout the research lifecycle in phases 3-5. The research framework produces a new solution in providing goal modelling and management in SoS and GORE context, and fulfilling the research objectives which were identified in Section 1.3.

Furthermore, the requirements for the proposed research framework (OntoSoS.GORE) that can be used in the design phase are presented in this phase, as well as the evaluation methods.

3.3.3 Design, Development, Demonstration and Evaluation of the Research Framework OntoSoS.GORE

Conducting the comprehensive literature review and identifying the research aim, objectives, hypothesis and related questions led to the design and development of the research framework. Since the framework consists of multiple layers and components, which was introduced in Section 3.2, this research adapted applying the phases 3-5 of the DSRM iteratively for developing each component, and incremental segments of the Cancer Care case study at KHCC were applied during the demonstration and evaluation phases for each component. Accordingly, phase 3 the design and development; phase 4 the demonstration; and phase 5 the evaluation of the framework, are all performed within incremental iterations in order to reach a well-constructed version of the framework, as described hereunder.

3.3.3.1 First Iteration of the Design, Development, Demonstration and Evaluation of the Research Framework

The first DSRM iteration involves the development, demonstration, and evaluation of the first layer of the research framework: global and local goal-oriented modelling in SoS context. In the design and development phase, a new process to extract and elicit i* elements from existing user documentation and a conceptual metamodel for i* strategic goal-oriented modelling in the SoS context are developed.

In the demonstration and evaluation phases, this component of the framework is instantiated and validated through conducting the Cancer Care case study at KHCC. Local Goal-Oriented

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Models (LGOMs) and Global Goal-Oriented Models (GGOMs) for the SoS and its constituent systems consisting of a set of SD and SR models are developed using the i* framework, then validated. Developing and validating KHCC's goal models went through three sub-iterations incrementally, each covering a particular set of KHCC's strategic documents, policies and procedures. In each sub-iteration, several elicitation techniques are applied to elicit needed requirement from KHCC's documents: (1) analysing existing user documentation; (2) requirements workshops; (3) structured and semi-structured interviews.

At the end of each sub-iteration, the correctness and completeness of the developed set of i* goal models are validated by the main stakeholders and domain experts at KHCC, and missing requirements which are needed to go through and complete the next sub-iterations are determined. Moreover, refinements on the developed goal models are performed based on the outcomes of the evaluation process of the previous iteration and the next set of goal models are produced until all the i* goal models are developed and validated for the selected part of KHCC's strategic documents, policies and procedures.

Furthermore, a proposed reference i* goal-oriented model for access to cancer care is developed and validated during the first DSRM iteration going through several sub-iterations. The proposed reference model provides the most generic concepts in Cancer Care domain with reference to the case of the Admission, Discharge and Transfer (ADT) at KHCC, KHCC's strategic plans, and feedback and requirements retrieved from domain experts. Detailed description of the first DSRM iteration, its outcomes, developing and validating the first component of the framework are provided in Chapter 4 of the thesis.

3.3.3.2 Second Iteration of the Design, Development, Demonstration and Evaluation of the Research Framework

The second DSRM iteration involves the design, development, demonstration, and evaluation of the second layer of the research framework: the semantic Goals Referential Integrity (sGRI) model in SoS context. This layer includes two components: (1) a Goals Referential Integrity (GRI) model in SoS context; and (2) an ontology-based approach for SoS goal-oriented modelling, where each is developed and evaluated following multiple sub-iterations. The first sub-iteration is related to developing and evaluating the GRI model, and the

second sub-iteration presents the development and evaluation of the semantic enrichment of SoS goal-oriented modelling using ontologies.

This layer of the framework and its components are described in more detail in Chapter 5 of the thesis.

3.3.3.3 Third Iteration of the Design, Development, Demonstration and Evaluation of the Research Framework

The third DSRM iteration involves the design, development, demonstration, and evaluation of the third and last layer of the research framework: goals conflict management in SoS context. This layer includes two components: (1) goals conflict detection; and (2) goals conflict resolution. Multiple sub-iterations are needed to develop and evaluate the components of this layer of the framework and to apply the conflict management strategies on the developed i* goal models. This layer of the framework and its components are described in more detail in Chapter 6 of the thesis.

Conducting small-scale parts of the case study to assess and evaluate the framework in initial iterations, followed by more comprehensive parts of the case study in further increments, aims at verifying the sufficiency of the developed framework in relation to goal-oriented requirements engineering in SoS context. The research hypothesis, along with associated research questions and research objectives inform the evaluation of this research. The research aim and objectives are incrementally evaluated through the iterations and phases of the DSRM, and the overall hypothesis of the research is evaluated and assessed through assessing the outcomes of answering the research questions in a bottom-up perspective.

This leads to a methodological approach to determine the extent to which the research hypothesis is true, and the extent to which the research artefact is effective, achieved by the end of the third iteration. At the end of this increment, a decision will be made as to whether to iterate back to phase 3 to enhance the effectiveness and efficiency of the framework, or to continue to communication phase.

3.3.4   Communication

In this phase, the rigour of the framework's design and development, and results from the cycles of phases 2-5 will be communicated incrementally as thesis chapters, journal and conference papers, technical reports, as well as related seminars and workshops. Suggested future research directions and research limitations will be presented. The completion of this phase will be accomplished by the completion of the thesis writing and conducting the final viva exam.

3.4 Overview and Background of the KHCC Case Study

The OntoSoS.GORE framework, the main artefact developed in this research, is applied to the Cancer Care domain, namely King Hussein Cancer Centre (KHCC) in Jordan. Previous research work has applied their work to Cancer Care at KHCC as the key research case study (Aburub, 2006; Yousef, 2010; Odeh Y., 2015; and Ahmad, 2016), with a focus on Cancer Care and Registration (CCR) processes and from a business process perspective. However, this research investigates Cancer Care in a new and innovative way: from systems of systems perspective.

This case study has been particularly nominated by the researcher and considered sufficient and representative enough to assess and evaluate the research framework and main artefacts, for the following reasons:

(i) Cancer Care is considered an SoS, as it consists of many independent constituent systems – which are complex systems themselves – such as Jordan's Cancer Registry System, Treatment Centres, Patients Management System, Laboratory System, Pharmacy System, etc;

(ii) KHCC's documents used in this research, including strategic plans, policies and procedures are well-structured hierarchically and well-aligned with the research framework global and local levels. The documents are also sufficient to apply the i* extraction method (discussed in Chapter 4) on, in order to extract i* elements which are used in goal-oriented modelling;

(iii) KHCC's exceptionally high standard of care is evident in their knowledge-based and person-centred approach. The centre has earned many accreditations from leading hospital

quality evaluators – both local and international – which have been consistently renewed. Thus, it is anticipated that the goal-oriented models developed through this research with reference to KHCC's strategic documents, plans, policies and procedures are aimed to be generic enough to be applied to other cancer care organisations meeting their requirements and goals;

(iv) KHCC applies sets of Key Performance Indicators (KPIs) on their strategic goals and objectives. These KPIs contribute to informing the satisfaction of hard goals and softgoals, and provide measurements to such satisfaction using representative test cases provided by KHCC's stakeholders and domain experts;

(v) KHCC's main stakeholders are willing to be engaged in this research project and validating the goal models developed as well as providing the researcher with any missed requirements or documents through several interviews and workshops conducted at the different stages of the research;

(vi) KHCC has signed agreements with global cancer centres and institutions which provide access to the largest network of top oncology research, education and clinical cancer care in the world. KHCC has established programs that focus on all stages of comprehensive cancer care: from prevention and early detection, through diagnosis and treatment, to palliative care. KHCC treats over 3500 new cancer patients each year, from Jordan and the region. It is equipped with state-of-the-art medical equipment and services. KHCC core competency stems from its qualified oncologists and consultants (http://www.khcc.jo); and

(vii) KHCC has earned a number of national and international accreditations and acknowledgements that testify to the exceptional high standards of comprehensive care that KHCC offers its patients: (1) received Joint Commission International (JCI) accreditation for its ongoing pursuit of excellence; (2) the sole centre in the Arab world and the sixth in the world to receive disease-specific accreditation from the JCI for its oncology program; (3) KHCC department of Pathology and Laboratory Medicine earned international accreditation from the College of American Pathologists (CAP), confirming the exceptional high quality of KHCC's pathology and laboratory services; (4) earned accreditation by the Health Accreditation Council of Jordan (HCAC) affirming that KHCC applies and enforces the national healthcare quality standards for patient care, patient safety, and organisational excellence; (5) KHCC's Training Centre was accredited as a provider of continuing nursing education by the American Nurses

Credentialing Centre (ANCC); (6) received accreditation from the World Health Organisation (WHO) as a regional collaborative and training centre for the Eastern Mediterranean region; and (7) has been granted the approval of The Arab Board for Health Specialisations in regards to the breast imaging fellowship program, being the first centre in the Arab world to become accredited in this program.

KHCC Cancer Care global and local goal modelling and the development of the Reference i* Cancer Care Goal-Oriented model, one of the main contributions and artefacts of this research, are further discussed in Chapter 4.

3.5 Chapter Summary

This Chapter introduced the research framework OntoSoS.GORE, the main artefact of this research, with its components and layers. The design, development and evaluation of the research framework are performed through multiple iterations by adopting the DSR methodology and by applying the KHCC Cancer Care case study, to effectively assess and evaluate the sufficiency of the framework in the context of SoS goal-oriented requirements engineering, and to produce a well-constructed version of the framework.

The research hypothesis, along with associated research questions and research objectives inform the evaluation of this research. The research aim and objectives are incrementally evaluated through the iterations and phases of the DSRM process, and the overall hypothesis of the research is evaluated and assessed through assessing the outcomes of answering the associated research questions. Thus, determining the extent to which the research hypothesis is true, and the extent to which the research artefact is effective.

In the following chapter, the components of the first layer of the developed research framework presenting the first increment of the DSRM process are discussed in more detail; a new process to extract i* goal modelling elements and concepts from existing user documentation is proposed prior to presenting the development of global and local i* goal-oriented modelling in SoS context and a conceptual metamodel for SoS i* goal-oriented modelling.

Chapter 4

The Research Framework OntoSoS.GORE – DSRM First Iteration: Goal-Oriented Modelling in SoS Context

In this chapter, the components of the first layer of the developed research framework OntoSoS.GORE are presented, which are related to global and local goal-oriented modelling in SoS context. Prior to developing the global and local i* goal-oriented models for the SoS-of-interest, a process to elicit and extract i* goal modelling elements and concepts from existing user documentation was needed and hence developed. A conceptual metamodel for SoS i* goal-oriented modelling presenting the multiple levels of goals and their linkages with constituent systems, i* models, the organisation's policy documents among other entities was developed. These elements represent the design and development phase of the first iteration of the DSRM process, articulated in Section 4.1.

In the demonstration phase of the DSRM process first iteration presented in Section 4.2, the i* extraction process and the goal modelling in SoS context are applied to the Cancer Care case study at KHCC, which led to the development of global and local goal models for KHCC's strategic documents, plans, policies and procedures, followed by proposing a Reference i* Goal-Oriented Model for Access to Cancer Care. Furthermore, a requirements elicitation approach including analysis of existing user documentation, requirements workshops, structured and semi-structured interviews, is presented and applied to the Cancer Care case study.

In Section 4.3, the evaluation phase of the DSRM process first iteration is presented. The validation and evaluation of the developed Cancer Care i* models including the proposed reference i* model is discussed with reference to stakeholders and domain experts' feedback. Moreover, the satisfaction of hard goals and softgoals are partially measured through hierarchical goal networks and by linking these goals to KHCC's KPIs.

As will be revealed through this chapter, the development, demonstration and evaluation of the first layer of the research framework in an SoS context answers the first research question (RQ1) addressed in the thesis, which is formulated as follows:

RQ1: How should the SoS-level goals and the constituent systems-level goals be identified at several levels of the SoS arrangement using the i* framework?

4.1 Design and Development of i* Goal-Oriented Modelling in SoS Context

This section describes the design and development phase of the first layer of the OntoSoS.GORE framework, i.e. the i* goal-oriented modelling in SoS context. It begins by introducing a new process to elicit and extract i* goal modelling elements from existing user documentation to be utilised in i* goal modelling, followed by presenting the global and local goal-oriented modelling using the i* framework in SoS context and providing a conceptual metamodel for SoS i* goal-oriented modelling that represents the multiple levels of SoS goals and their relationships with other entities in the SoS organisation.

4.1.1 A Process to Extract i* Elements from User Documentation

Several methods in the literature had described how to elicit information from existing documents. In particular, (John and Dorr, 2003) have presented an elicitation approach based on a conceptual model for eliciting requirements artefacts from user documentation. With their approach, they can elicit common and variable features, Use Case elements, tasks describing user activities in an interactive system and textual requirements, from documents such as user manuals. The approach was applied in different case studies with real documentation in three domains: automotive, telecommunication, and civil engineering, but was not related to i* modelling concepts nor applied to goal-oriented modelling domain.

On the other hand, Yu (2009) has provided definitions of the four main types of dependencies used in i* SD modelling: goal, softgoal, task and resource, as well as the additional links employed in i* SR modelling: means-end, task decomposition and contribution links, as was pre-mentioned in Section 2.2.1. In addition, formality and domain terms were raised by Yu (2009) as i* research issues. Formality is more difficult to attain in social modelling, and

linguistic terms chosen by developers to represent and rephrase domain concepts that reflect stakeholder perspective can also present difficulties in modelling and interpreting the i* models.

Building on John and Dorr's (2003) elicitation approach and Yu's (2009) definitions and guidelines, in this research, a new elicitation process is developed and expressed by heuristics to elicit and extract i* goal modelling concepts from existing user documentation.

After analysing KHCC's strategic documents, policies and procedures, appropriate textual requirements were extracted for i* goal modelling, i.e. depender and dependee actors and the four types of i*dependencies; goal, softgoal, task, and resource. The extraction method and transition from user documentation into i* elements shown in Figure 4.1, were expressed as heuristics. These heuristics describe, which element of user documentation can be typically transformed into which i* element as follows:

- Nouns that represent roles, job titles and departments are translated into **actors**; dependers and dependees, e.g. physician, surgeon, and pharmacy.
- A role with a specialised adjective indicates an **ISA** relationship between two actors, e.g. patient and emergency patient, physician and attending physician.
- Noun phrases that represent services are translated into **hard goal** dependencies, e.g. diagnosis of patient, consultation of specialist physician.
- Verbs and verb phrases that represent activities are usually translated into **task** dependencies, e.g. order a test, write a prescription.
- Physical or logical entities that need to be delivered from one actor to another are translated into **resource** dependencies, e.g. reports, prescriptions, and information.
- **Qualities** or **softgoals** cannot be determined explicitly in user documentation, but hints to qualities can be found:
    - Adverbs and adjectives, e.g. quick and safe, represent qualities and softgoals, especially if a sentence appears in the user documentation once with the adverb/adjective, and once without, e .g. diagnosis and quick diagnosis, reporting and timely reporting.
    - Numbers, i.e. size, can be a hint for softgoals, e.g. plan discharge with up to 7 days' notice.

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- Also, nouns that refer to qualities, can be translated into softgoals, e.g. empathy, safety.

- Description of multiple possibilities or alternative ways is usually translated into **OR decompositions**.

- Numbered lists, bulleted lists, or description of several needed steps are usually translated into **AND decompositions**.
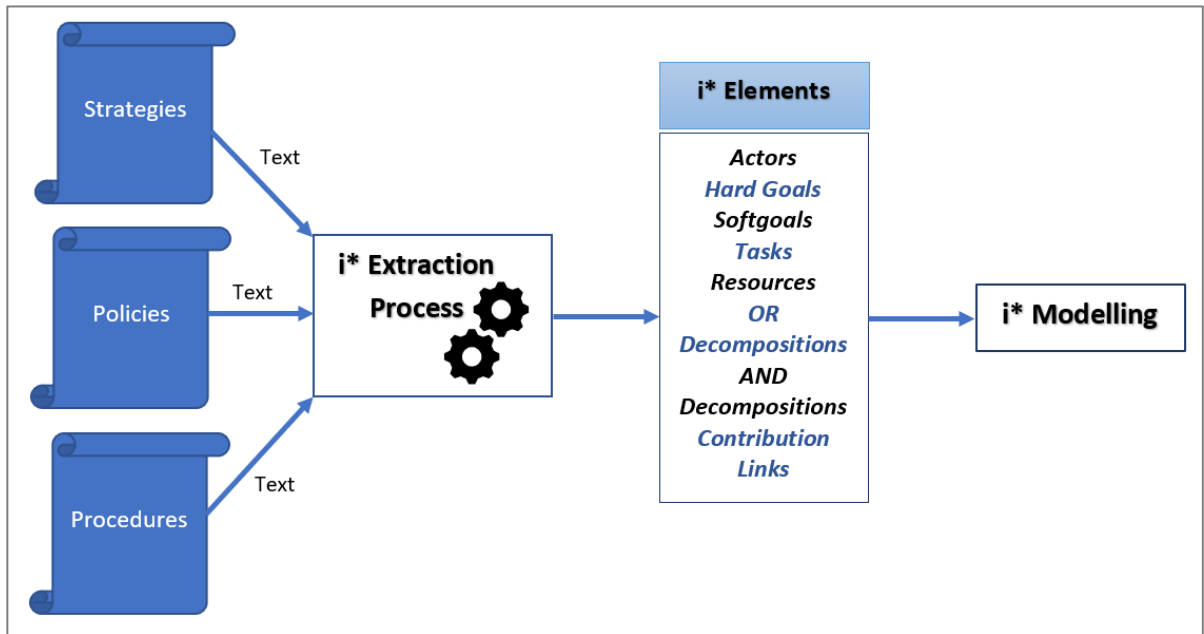
Figure 4.1: The i* Extraction Process

The i* extraction process has been validated with input from domain experts while conducting interviews at KHCC and applied to KHCC's strategic documents and policies to extract Cancer Care i* elements in order to perform goal modelling for Cancer Care as SoS, as will be presented and discussed in Sections 4.2 and 4.3.

Figure 4.2 shows an example of implementing the proposed i* extraction process to a textual description as an input, followed by analysing the text and extracting the i* modelling elements, and resulting of developing an i* model as an output. This example is part of the Cancer Care case study goal-oriented modelling at KHCC, and is related to the procedures of patient's medically-advised discharge, and in particular the part related to the actor "Nurse in charge", its tasks and goals, and its associations with other correlated actors.

Step (1): Input→ Text

Procedures of Medically-Advised Discharge:
Nurse in charge:
- The nurse in charge of a patient's discharge shall perform the following:
- Follow up on discharge instructions, as documented in the patient's medical record.
- Provide notification to attending physician about any significant teaching needs that may not be met prior to the planned time of discharge.
- Schedule with the appropriate clinic follow up appointments and provide the appointment slip to the patient or the accompanying adult.
- Provide notification of patient's discharge to the ward clerk, who should as well provide notification of discharge to the A&D Office.
- If discharge is cancelled, the nurse shall notify IMMEDIATELY the ward clerk office.
- Provide notification of patient's discharge to housekeeping personnel, in order to make the room ready for the next patient.
- Prepare the patient's medical record for collection by the Medical Records.
- Send prescriptions to the Pharmacy to be prepared.

Step (2): Analysing Text

Procedures of Medically-Advised Discharge:

Actor
Nurse in charge:

          Actor   *Actor*
- The nurse in charge of a patient's discharge shall perform the following:

          Task   *Actor*
- Follow up on discharge instructions, as documented in the patient's medical record.

       Hard Goal   *Actor*   *Task*
- Provide notification to attending physician about any significant teaching needs that may not be met prior to the planned time of discharge.

          Task
- Schedule with the appropriate clinic follow up appointments and provide the

      Resource   *Actor*
appointment slip to the patient or the accompanying adult.

        Hard Goal   *Actor*
- Provide notification of patient's discharge to the ward clerk, who should as well provide

      Hard Goal   *Actor*
notification of discharge to the A&D Office.

          Actor   *Softgoal*   *Actor*
- If discharge is cancelled, the nurse shall notify IMMEDIATELY the ward clerk office.

       Hard Goal   *Actor*   *Task*
- Provide notification of patient's discharge to housekeeping personnel, in order to make

      Actor
the room ready for the next patient.

        Resource   *Actor*
- Prepare the patient's medical record for collection by the Medical Records.

      Resource   *Actor*   *Task*
- Send prescriptions to the Pharmacy to be prepared.

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Figure 4.2: Steps of Applying the i* Extraction Method to a Textual Description Example

4.1.2 Implementing a Hybrid Design Approach

The design of the anticipated SoS goal-oriented modelling provided by the research framework can be performed in two ways: top-down or bottom-up; the former approach is typical of a Global Goal-Oriented Model (GGOM) developed from scratch based on the requirements specifications (from the SoS to the constituent systems), while the latter approach is typical of the development of a GGOM as the aggregation of existing Local Goal-Oriented Models (LGOMs) (from constituent systems to the SoS). However, a common misunderstanding about goal-oriented approaches is that they are inherently just top-down or just bottom-up (Van Lamsweerde, 2001); this is by no means the case as a goal-based elaboration typically consists of a hybrid of top-down and bottom-up processes.

A more comprehensive requirements engineering approach for SoS would require a combination of both top-down and bottom-up approaches, as a top-down approach (from the SoS to constituent systems) used in isolation might not be able to effectively consider aspects related to the constituent systems. On the other hand, a bottom-up approach (from constituent systems to the SoS) may not be able to capture important concerns related to the SoS as a whole (Cavalcante et al., 2015).

Top-down and bottom-up approaches have been already applied extensively in the design of Distributed Databases (DDB) (Özsu and Valduriez, 2011). Building on what has been evolving in the DDB design and the GORE fields, a hybrid of top-down and bottom-up approaches has been adopted in the development of the OntoSoS.GORE framework for modelling goals for an SoS and its constituent systems as depicted in Figure 4.3. The development of the Global Goal-Oriented Models (GGOMs) at the SoS-level will result from the integration of the Local Goal-Oriented Models (LGOMs) at the CS-level. The generic global goal model and the local goal-oriented models are further revisited and refined through the multiple DSRM iterations followed and through applying incremental parts of the Cancer Care case study at KHCC to mature and validate the framework and its components.
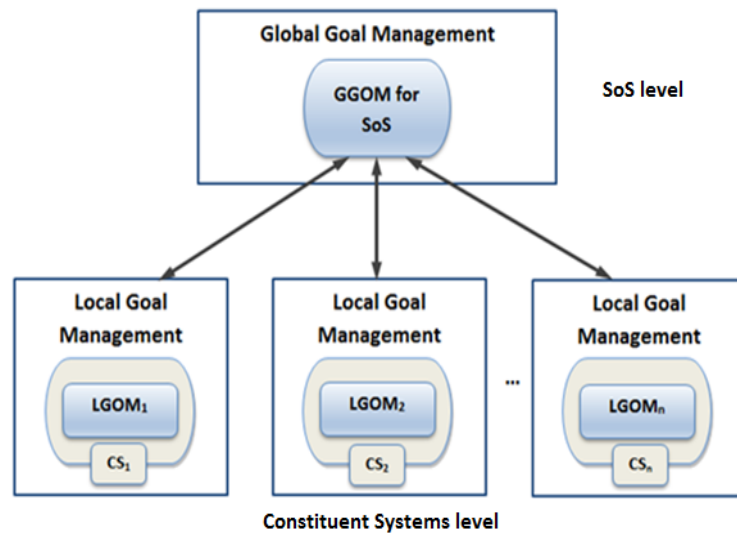
Figure 4.3: The OntoSoS.GORE Framework Goal-Levels

4.1.3 Global and Local i* Goal-Oriented Modelling in SoS Context

In SoS requirements engineering, goals are delineated as either SoS-level goals, which are the global missions of the SoS-of-interest as a whole, or as CS-level goals, which are assigned to a particular constituent system as local or individual goals.

The main objective of the first layer of the research framework is to develop Global Goal-Oriented Models (GGOMs) for the SoS as a whole, and Local Goal-Oriented Models (LGOMs) for its constituent systems, using the i* framework. In order to accomplish this, the SoS-level goals and the CS-level goals should be identified as well as the actors at these global and local levels.

The constituent systems that comprise the SoS should be determined and understood. These constituents must be discovered, selected, and composed in order to identify suitable arrangements of these systems to form the whole SoS arrangement and determine their contribution to the realisation and accomplishment of the SoS global goals based on their capabilities. This could be done by analysing and studying the user documentation and the organisational structure of the SoS-of-interest, and through brainstorming and interviewing the main stakeholders and domain experts at both the SoS and CS levels.

At this phase, a proper understanding of the individual goals of the participating constituent systems and the capabilities that they provide should be addressed, as well as an understanding of the SoS, the identification and specification of its global goals, and their interactions. Moreover, the actors and stakeholders who own these local and global goals, and the relationships and dependencies between them should be identified and understood. This will be done through analysing and studying the strategic documents, policies and procedures of the SoS organisation and its comprised constituent systems.

Applying the i* framework, SD and SR models are developed representing the LGOMs for the local levels and the constituent systems. The stakeholders' needs and goals of each constituent system and the external relationships between them are modelled in SD models. On the other hand, the internal description of actors' intentional relationships, the rationale behind them, the space of alternatives for each actor, and how hard goals and tasks contribute to achieving softgoals (i.e. qualities) are modelled in SR models.

Two approaches could be followed to develop the LGOMs for the local levels: (1) Developing a LGOM for each constituent system in the SoS arrangement, or (2) Developing a LGOM for each policy document of the SoS organisation, where each policy document includes one or more constituent system(s). Determining which approach to follow depends on the SoS arrangement itself, its organisational structure, and the existing or accumulated requirements. Analysing and understanding the SoS organisation, its constituent systems, its strategic documents, policies and procedures lead to identifying the most appropriate approach for developing the LGOMs.

In the case of developing an LGOM for each constituent system; for each CS$_i$, where $1 \leq i \leq n$ and n is the number of the constituent systems, there is an LGOM$_i$ which is a set of the SD$_i$ and the SR$_i$ models, as in (1):

$$LGOM_i.CS_{i\ =} SD_i.CS_i \cup SR_i.CS_i \quad , 1 \leq i \leq n \qquad (1)$$

For each CS$_i$, there is an SD$_i$, which consists of a set of actors and different types of dependencies between them as presented mathematically in (2):

$$SD_i.CS_i = \sum_{j=1}^{m} A_{ji} + GD_{ji} + SGD_{ji} + TD_{ji} + RD_{ji} , 1 \leq i \leq n \quad \text{and} \quad 1 \leq j \leq m \quad (2)$$

Where:

n: number of constituent systems, m: number of dependencies between actors

A_{ji} : $Actor_j$ in $SD\ Model_i$

GD_{ji} : $Goal\ Dependency_j$ in $SD\ Model_i$

SGD_{ji} : $SoftGoal\ Dependency_j$ in $SD\ Model_i$

TD_{ji} : $Task\ Dependency_j$ in $SD\ Model_i$

RD_{ji} : $Resourse\ Dependency_j$ in $SD\ Model_i$

Also, for each CS$_i$, there is an SR$_i$ to be modelled as presented mathematically in (3):

$$SR_i.CS_i = \sum_{j=1}^{m} A_{ji} + AB_{ji} + GD_{ji} + SGD_{ji} + TD_{ji} + RD_{ji} + MEL_{ji} + TDL_{ji} + CL_{ji} ,$$

$$1 \leq i \leq n \quad \text{and} \quad 1 \leq j \leq m \quad (3)$$

Where:

n: number of constituent systems, m: number of dependencies between actors

A_{ji} : $Actor_j$ in $SR\ Model_i$

AB_{ji} : $Actor_j\ Boundary$ in $SR\ Model_i$

GD_{ji} : $Goal\ Dependency_j$ in $SR\ Model_i$

SGD_{ji} : $SoftGoal\ Dependency_j$ in $SR\ Model_i$

TD_{ji} : $Task\ Dependency_j$ in $SR\ Model_i$

RD_{ji} : $Resourse\ Dependency_j$ in $SR\ Model_i$

MEL_{ji} : $Means - ends\ Link_j$ in $SR\ Model_i$

TDL_{ji} : $Task\ Decomposition\ Link_j$ in $SR\ Model_i$

CL_{ji} : $Contribution\ Link_j$ in $SR\ Model_i$

In addition, GGOMs for the entire SoS are developed. One part of developing the global models is concerned with modelling the high-level global goals of the SoS and the strategic relationships among actors at the SoS-level. Another part following, is modelling the most generic goals, dependencies and concepts in the domain extracted from the previously developed global and local models to be expressed in a global generic SD model, towards proposing a *Reference i* Goal-Oriented Model* for the SoS-of-interest. The development of the integrated GGOM is given in (4):

$$GGOM.\ SoS = \bigcup_{i=1}^{n} CS_i \quad ,\ 1 \le i \le n \qquad (4)$$

The integration process followed to develop the GGOMs is dependent on the schematic information stored and inferred from the local models to create the global view. This method also focuses on resolving any structural discrepancies amongst the local models. Moreover, the GGOM generated will be refined continuously as the goals of the SoS are evolving and changing over time.

In order to define the multiple goal-levels in an SoS arrangement, besides the relationships and linkages between these goal levels and corresponding components such as constituent systems; a conceptual metamodel for SoS strategic goal modelling using the i* framework has been developed. As illustrated in Figure 4.4, the metamodel describes the relationships and links between the SoS, its constituent systems, the global and local goals at multiple levels, besides links to the i* goal models, the organisation's actors, policy documents and KPIs. The model is also linked to the second layer of the research framework; the sGRI model that provides the enforcement of goals referential integrity in SoS context, as will be discussed in Chapter 5.

Three different levels of goals are adopted in this metamodel: (1) **SoS Global Goals**, which are the highest strategic priorities and missions of the SoS organisation; broken down into (2) **Sub-Global Goals**, which aim at achieving the global goals at the higher level and are also considered within the SoS-level; and (3) **Constituent Systems Local Goals** which are the individual goals of each constituent system at the local level, that collaborate together in order to achieve the higher-level global and sub-global goals.

According to the developed model, sub-global goals and local goals could also have sub-goals of their own -through a recursive relationship- which either contribute positively to satisfying and achieving their parent goals, or on the contrary, contribute negatively to these goals and detract from satisfying them. Determining the detraction relationships between different goals leads to goals conflict detection and resolution that will be discussed in detail in Chapter 6.

Each type of goal, whether global, sub-global or local, has two types of actors, a depender and a dependee, where actors represent stakeholders, departments, or systems. The developed i* goal models (SDs and SRs) represent one or more constituent system, and one or more policy document. Besides, there is one global SD model that represents the SoS-level and acts as a proposed reference goal-oriented model for the whole organisation.
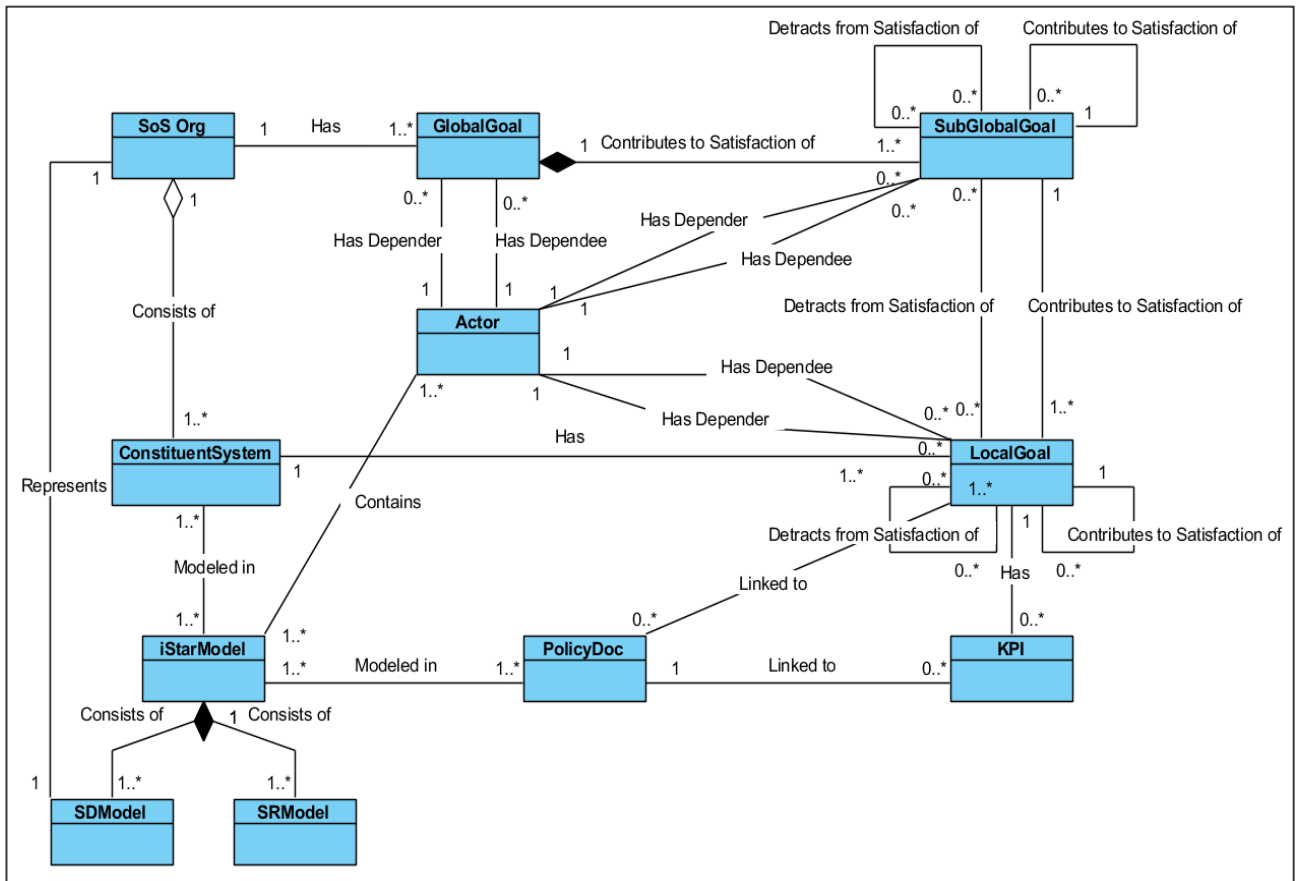
Figure 4.4: The UML Class Diagram Representing a Metamodel for i* Strategic
Goal-Oriented Modelling in SoS Context

4.2 Demonstration of i* Goal-Oriented Modelling in SoS Context: Cancer Care Case Study

This research is engaged with KHCC in Jordan and looks into Cancer Care from a new and innovative way from SoS perspective. In this section, the instantiation of the first layer of the research framework is performed by applying the i* goal-oriented modelling to the Cancer Care case study. The requirements elicitation and analysis approach consisting of several elicitation methods is first introduced, then the global and local goal modelling of KHCC's strategic plans, ADT policies and procedures are presented, followed by proposing a Reference i* goal-oriented model for access to Cancer Care.

4.2.1 Requirements Elicitation and Analysis Approach

In order to implement Cancer Care i* goal modelling in an SoS context, requirements need to be elicited and documented with regards to KHCC's strategic goals, policies, procedures and actors. During the elicitation process, different types of goals are specified, including hard and soft goals, along with different types of actors at both global and local levels of the SoS. Accordingly, several elicitation techniques have been applied in this research to collect the requirements as follows:

1) Existing User Documentation
2) Requirements Workshops
3) Structured and Semi-Structured Interviews

An outline of the elicitation approach applied is shown in Figure 4.5, and the elicitation techniques used are described in the following subsections.
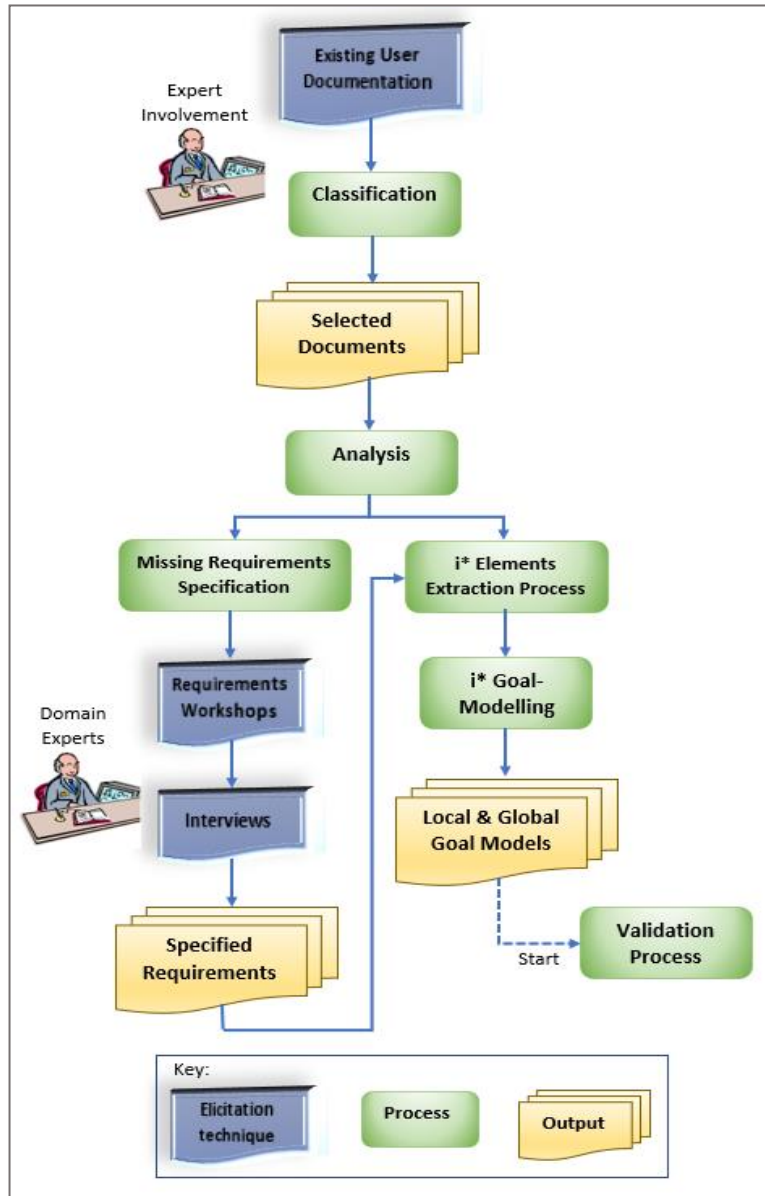
Figure 4.5: Outline of the Elicitation Approach

4.2.1.1 Existing User Documentation

Different types of user documentation have been collected from KHCC for the purposes of applying the research framework to the Cancer Care case study. Also, access to the online system used in KHCC has been gained by the researcher. The documentation was categorised into two main groups: 1) KHCC's strategic plans, and 2) KHCC's policies and procedures.

KHCC's strategic plan consists of multiple levels of goals; starting with three main strategic priorities on top of the pyramid. Under these, there are 11 strategic goals, 59 SMART objectives,

109 initiative actions performed to satisfy the higher-level goals, and over 70 stakeholders who join forces to achieve the organisation's goals. As demonstrated in Figure 4.6, relationships and linkages are established between KHCC's several goal levels, related constituent systems, policy documents and KPIs by applying the i* framework as an engine to found these linkages and perform the goal-oriented modelling in SoS context.

Figure 4.6: KHCC Strategic Goal-Modelling Elements and Linkages Following the i* Framework

On the other hand, KHCC's policy documents cover policies and procedures related to patients' Admission, Discharge and Transfer (ADT), Human Resources (HR), Medical Records (MR) and the Information Technology (IT) department. KHCC's provided user documentation was scanned, studied, and analysed to determine which documents will be selected and modelled by applying the research framework and the i* goal-oriented approach. The selection criteria applied is based on the following aspects:

1) *Cancer Care-related documents:*
   The selected documents should only be cancer care related, following Odeh's (2015) coined definition of Cancer Care Informatics "The employment of informatics to holistically empower the process of cancer care, where the cancer patient is the focus in

the cancer care journey involving all the concerned stakeholders". The selected set of documents should cover the widest variety of cancer care constituent systems, and cover the most cancer care services and concepts.

2) *Document's structure:*

The selected documents should contain concepts that can be extracted and translated into i* goal modelling elements, i.e. hard goals, softgoals, tasks, resources, and actors, following the i* extraction process presented earlier in Section 4.1.1. Also, selected documents' structure and content should enable the researcher to extract generic cancer care concepts – which will be the input to proposing the *Reference i* Goal-Oriented Model for Access to Cancer Care–.*

3) *Documents related to KPIs:*

Documents that are linked directly to KPIs are highly important and should be selected, since KPIs inform the satisfaction and level of achievement for the goals at multiple levels of the SoS, which is one of the main objectives of the research work.

4) *Research scope:*

The selected documents should be within the scope of the research and should serve the research purposes and objectives. The research scope was determined to cover KHCC's strategic plans and ADT policies and procedures.

5) *Stakeholders' feedback:*

Stakeholders' feedback and recommendation ensure that the selected documents are sufficient and representative enough for cancer care domain. Stakeholders' feedback was collected by conducting structured and semi-structured interviews through multiple iterations.

The selected KHCC's documents and the criteria behind selection are shown in Table 4.3 in Section 4.3.1, as part of the validation process. The specified documents were analysed, refined, and prioritised. Then, requirements were derived from these documents, and the i* extraction process was applied to the selected KHCC documents, to extract sufficient and valid i* elements to use them as an input to the i* goal modelling process as was explained earlier by the example provided in Figure 4.2. In addition, missing requirements that are needed and vital for goal

modelling were also specified and then gathered through conducting several requirements workshops and interviews with KHCC's domain experts as will be discussed in the following subsections.

4.2.1.2 Requirements Workshops

Requirements workshop is a structured and facilitated event for getting carefully selected stakeholders together to discover, refine, prioritise, validate and discuss requirements. As part of the incremental iterations of the DSRM, two types of intensive workshops were held at KHCC: (1) workshops for elicitation purposes and requirements gathering; and (2) workshops for validation purposes, which will be discussed in Section 4.3 as part of the evaluation phase.

The requirements workshops were conducted during the case study visits with selected stakeholders and domain experts at KHCC mainly: The Director General (DG), the Chief Operating Officer (COO), the Chair of Research Council (CRC), the Quality Management Officer (QMO), Deputy Manager of Patient Journey and Health Informatics Department and heads of departments.

The first type of workshops held for elicitation purposes as part of the demonstration phase of the first DSRM iteration, aimed mainly at presenting the concept of the i* goal-oriented modelling and the i* framework - its elements, its main features and practices - to the stakeholders. Furthermore, other aims achieved include collecting existing user documentation (i.e. KHCC's strategic plans, policies and procedures), gaining the stakeholders' consensus on the selected cancer care-related documents to be modelled, determining cancer care constituent systems, and eliciting needed requirements for i* goal-modelling which some were missed from the existing user documentation. In addition, further one to one and group interviews -discussed in the next subsection- are scheduled in order to gather any missing requirements by providing a form of surveys to stakeholders.

4.2.1.3 Structured and Semi-Structured Interviews

Several structured and semi-structured interviews were conducted with KHCC's main stakeholders and domain experts as part of the requirements elicitation process, followed by more interviews for the research validation and evaluation process. In the first DSRM iteration,

four intensive interviews, of 3 hours long each, were scheduled and conducted with KHCC's domain experts: DG, COO, CRC, QMO, Deputy Manager of Patient Journey and Health Informatics Department and other heads of departments. The interviews main objectives and outcomes are summarised in this section; however, full interviews questions and structure are provided in Appendix A.

As part of the demonstration phase of the first increment of the DSRM process, the following objectives were targeted and achieved during the conducted interviews:

1) Determine cancer care-related strategic and policy documents to be modelled.
2) Determine the constituent systems which comprise the cancer care SoS.
3) Determine the missing requirements in KHCC's strategic plan and policy documents.

- **Determine cancer care-related strategic and policy documents to be modelled:** (one interview with the director general and heads of departments)

The following questionnaire (Table 4.1) was prepared and completed by the stakeholders during the interviews to satisfy the first objective of determining only cancer care-related documents, among KHCC's strategic plan and ADT policies and procedures:

- Which of the following KHCC's documents and policies are identified as Cancer Care-Related?

Table 4.1: KHCC's Cancer Care-Related Documents

#	Name of Document	Is it Cancer Care-Related?
	KHCC Strategic Plan	
	Strategic Priority 1: "To foster person-centred care and safety"	☒
	Strategic Priority 2: "To improve and sustain KHCC institutional core competencies"	☐
	Strategic Priority 3: "Positioning KHCC as a leading regional oncology research, education and awareness centre"	☐
	ADT Committee Policies	
1	Admission of Patients	☒
2	Discharge of Patients	☒

3	Discharge Planning Process	☒
4	Medical Referrals-Transfer	☒
5	Role of Surgical Intermediate Unit	☒
6	Flow of Patient and Waiting List Management	☒
7	Physicians Handover	☒
8	Referring Patients from Paediatric Department to Adult Services	☐
9	Patient - Family Rights and Responsibilities	☒
10	Meal Provision to Hospitalised Patients	☒
11	Critical Care Unit(s) Closure	☐
12	Patient's Pass	☒
13	Patient Companion	☒
14	Patient Delay	☒
15	Patients' No Show	☒
16	Storage of Patient's Belongings	☐
17	Release of minor to other than parent/ legal guardian	☒
18	Patient and Family Complaints	☒
19	Handling Disgruntled Patients/Families	☒

Following this step, further criteria were applied, as mentioned in Section 4.2.1.1 regarding the documents' structure, research scope, and linkages to KPIs to determine the final set of documents to be goal-modelled. The results of applying the selection criteria led to deciding on the following documents to be goal-modelled and to apply the OntoSoS.GORE framework on:

a) Strategic Priority 1: "To foster person-centred care and safety", from KHCC strategic plan document.

b) The following Admission, Discharge and Transfer (ADT) committee policies:
   - Admission of Patients
   - Discharge of Patients
   - Discharge Planning Process
   - Medical Referrals-Transfer

- Role of Surgical Intermediate Unit

- Meal Provision to Hospitalised Patients

- Flow of Patient and Waiting List Management

- Patient Delay

- Patients' No Shows

- **Determine the constituent systems which comprise the cancer care SoS:** (one interview with the deputy manager of Patient Journey and Health Informatics Department and heads of departments)

A questionnaire was prepared and completed by the stakeholders during the interviews to determine the constituent systems which comprise the cancer care SoS and their categories. The questionnaire is provided in Appendix A, Section 2. Cancer Care SoS at KHCC comprises more than 40 constituent systems under five different categories, as resulted in Figure 4.7 and listed below:

1) **Patients System**
2) **Care Providers and Clinical Systems:** Physicians, Nurses, Laboratory system, Pharmacy system, Chemotherapy system, Radiotherapy system, Radiology system, Operational Room (OR) system, Intermediate Care Unit (IMU), Intensive Care Unit (ICU), Psycho-Social Services System, Physical Therapy, New Patient Clinic, Inpatient system, Outpatient system, Multi-Disciplinary Clinic (MDC), Nuclear Medicine Department, Nutrition Unit, Palliative system, Anaesthesia and Pain Management system, Bone Marrow Transplantation (BMT), Endoscopy system, Respiratory system, and Outside Treatment Facilities.
3) **Monitoring Systems:** Quality Management Office (QMO), Ministry of Health (MOH), Jordan Cancer Registry (JCR), Hospital Cancer Registry, Infection Control system, Safety system.
4) **Legislation Systems:** ADT committee, OR committee, Medical Records (MR) committee, Governmental Laws, and Accrediting Bodies.
5) **Supporting Systems:** Admission and Discharge (A&D), MR system, IT system, Finance, Food and Beverage Unit, Transportation system, Environmental Services system, Material Maintenance system.
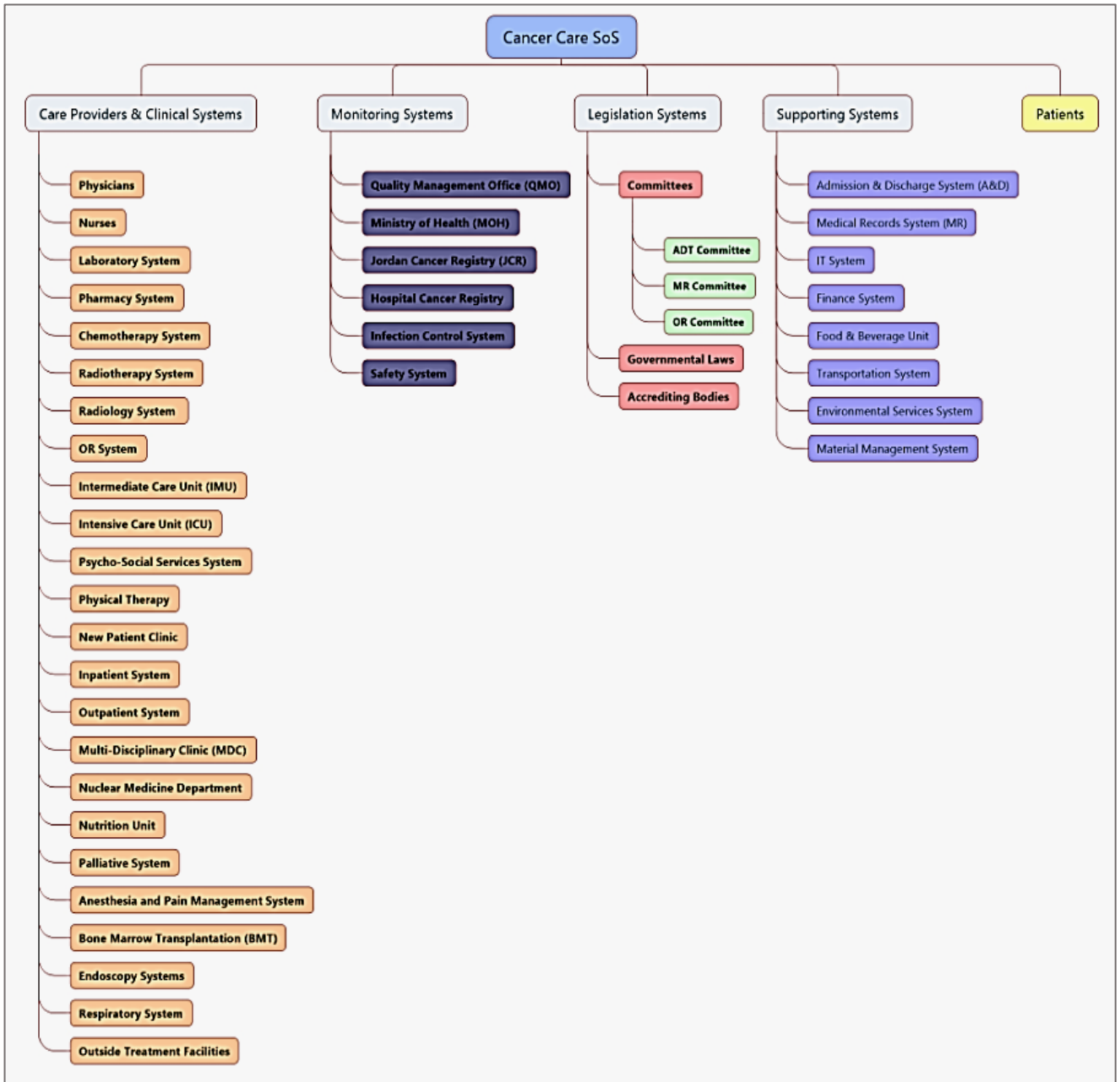
Figure 4.7: Cancer Care SoS Constituent Systems

▪ **Determine the missing requirements in KHCC's strategic plan and documents:** (two interviews with the COO)

This objective was accomplished by determining any missing requirements in KHCC's strategic plan documents and specifically determining the depender and dependee actors for all goals and sub-goals (i.e. strategic goals, SMART objectives and actions). Part of the questionnaire to determine the depender and dependee actors for goals with the stakeholders'

answers provided is shown below in Table 4.2. Full questionnaires covering all the strategic goals in KHCC's strategic plan can be found in Appendix A, Section 3. A brief introduction about i* goal modelling and concepts was provided to the user in advance as well as conducting i* goal modelling intensive workshops.

Table 4.2: Determining the Depender and Dependee Actors for KHCC's Strategic Goal 1.1:
"Improve Patient's Experience"

SMART Objectives	Strategies	Depender Actor	Dependee Actor
1.1.a Maintain and increase overall inpatient satisfaction	Strategy 1. Improve Efficiency (Utilisation) of the available beds	Patient	ADT
1.1.b Maintain and increase inpatient satisfaction per each category	Strategy 2. Improve food services	Patient	Food & Beverage Unit
	Strategy 3. Decrease environmental Noise	Patient	Nursing
	Strategy 4. Improve the satisfaction of the international patients	Patient	Head of Patient Journey Department
	Strategy 5. Launching person centred initiatives	Patient	Head of person-centred initiatives
1.1.c Increase outpatient overall satisfaction	Strategy 1. Provide mechanisms to improve patient appointment at outpatient	Patient	Outpatient Clinic Manager
	Strategy 2. Improve outpatient general environment	Patient	Outpatient Clinic Manager
1.1.d Maintain outpatient satisfaction per each category	Strategy 1. Improve outpatient pharmacy and laboratory waiting times	Patient	Outpatient Clinic Manager
	Strategy 2. Down time policy for VISTA and ATS	Patient	IT Director
	Strategy 3. Follow up of patient complaints and introduce proactive measures	Patient	QMO and IT

| 1.1.e Minimize overall patient waiting times | Strategy 1. Shadowing patients from first contact of KHCC throughout the process | Patient | QMO |

4.2.2   Cancer Care Goal-Oriented Modelling at KHCC Using the i* Framework

In the health domain, Cancer Care is considered as an SoS, which results from the collaboration of a set of independent socio and technical constituent systems. KHCC's Cancer Care goals of different stakeholders have been captured, modelled, and managed at two levels: Cancer Care SoS high-level goals (global goals) and the constituent systems-level individual goals (local goals).

In this section, as part of the demonstration phase of the first DSRM iteration, global and local goal-oriented modelling is performed on the selected documents of KHCC's strategic plans, policies and procedures.

4.2.2.1   Global and Local Goal-Oriented Modelling of KHCC's Strategic Plans

KHCC's strategic documents and plans - the first category of KHCC user documentation - were analysed and studied thoroughly, and three sub-increments of the i* global and local goal modelling were implemented. The rationale behind selecting these strategic documents as the starting point of i* goal modelling for cancer care, is that they cover the process of strategic planning and ensure the involvement of all KHCC internal and external stakeholders, including top and middle management. These strategic documents give a full view of the organisation's plan, its priorities, strategies and goals, and involve all KHCC departments and the key constituent systems of the Cancer Care SoS, e.g. patients' system, pharmacy system, laboratory system, IT system, treatment systems, nursing and others.

Valid i* concepts and elements were extracted from the documents following the approach proposed in Section 4.1.1, to be used in developing the Cancer Care i* goal models. The requirements derived from these documents and the developed Cancer Care goal models were validated through conducting the requirements workshops and interviews with KHCC's main stakeholders and domain experts. Figure 4.8 provides a key for the reader of all i* modelling concepts used in this PhD thesis.
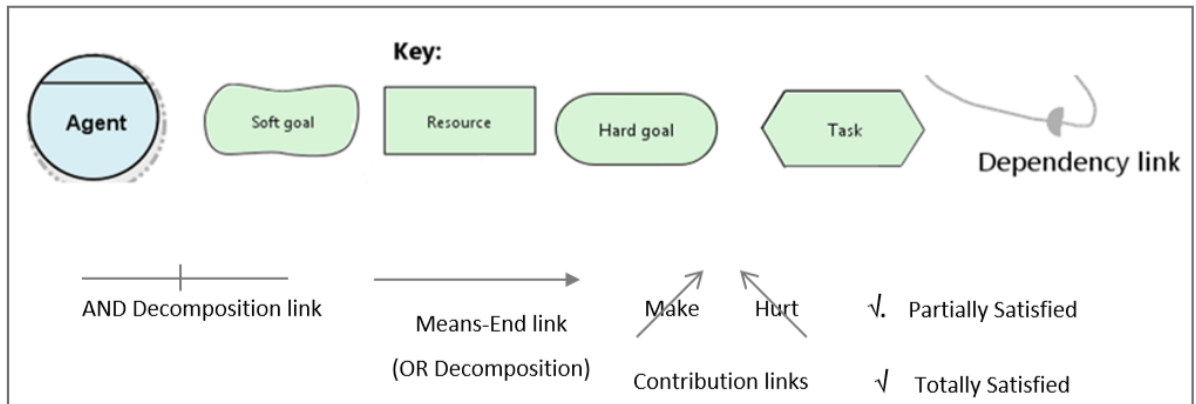
Figure 4.8: Key for i* Framework Modelling Elements

First, the three strategic priorities of KHCC were modelled within the global SoS high-level goals which resulted in "The Business Strategy" (BS) model of KHCC shown in Figure 4.9 as an abstract view. The BS model is a strategical model that comprise the organisation's highest business goals (Odeh Y., 2015). The developed BS model was further broken down into several SD and SR models both in the global and local levels of the SoS.
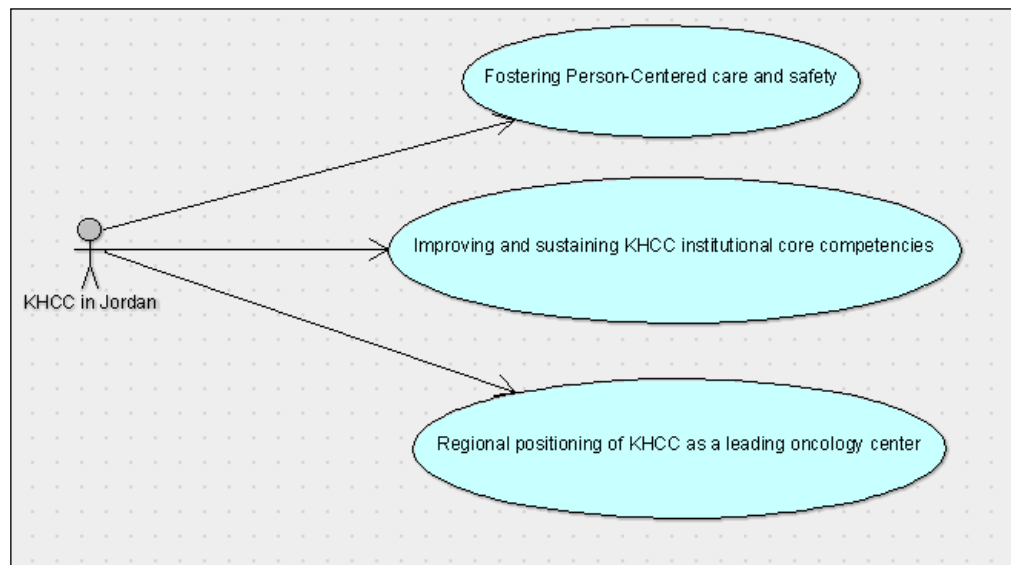
Figure 4.9: KHCC Business Strategy (BS) Model

The first strategic priority in KHCC's strategic plans aims at fostering person-centred care and safety in terms of provided cancer care services and value propositions. It is classified as cancer care-related and was chosen to be goal-modelled in this research. KHCC's first strategic priority, its associated strategic goals, objectives, actions and stakeholders were modelled during the first iteration of the DSRM.

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On the other hand, the second and third strategic priorities aim at improving and sustaining KHCC institutional core competencies including human capital and infrastructure, and positioning KHCC as a leading oncology research, education and awareness centre, respectively. These two priorities are describing the specific way KHCC aims to achieve its goals and plans, and how work should be done collaboratively. Since these two priorities are not considered cancer care specific, and not related directly to cancer care services, they are considered out of the scope of this research and are not being modelled.

A Highest Strategic Dependency (HSD) model (Odeh Y., 2015) was developed for each of the strategic priorities modelled previously in the BS model. Figure 4.10 depicts the HSD model for KHCC's first strategic priority: "To foster person-centred care and safety"; in this model the patient relies on the Cancer Care team to satisfy two high-level hard goals; "Providing the optimal portfolio of Cancer Care services" and "Improving patient's experience", besides satisfying the soft-goal "Foster patient's safety".
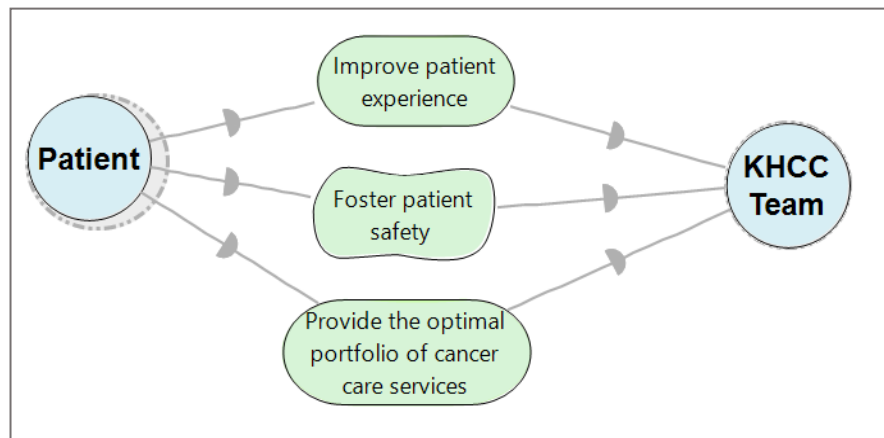
Figure 4.10: Highest Strategic Dependency (HSD) Model for KHCC's Strategic Priority 1

Further i* modelling was performed at the next goal-level representing the strategic goals that comprise the first strategic priority and their sub-goals. The SD and SR models for strategic goal 1.1: "Improve patient's experience" were modelled in the first sub-iteration of the DSRM first increment, and are shown respectively in Figures 4.11 and 4.12. The remaining developed i* models for KHCC's strategic plans, including strategic goals 1.2 and 1.3 are developed in the second and third sub-iterations of the first DSRM increment respectively and are available in Appendix A, Section 6.
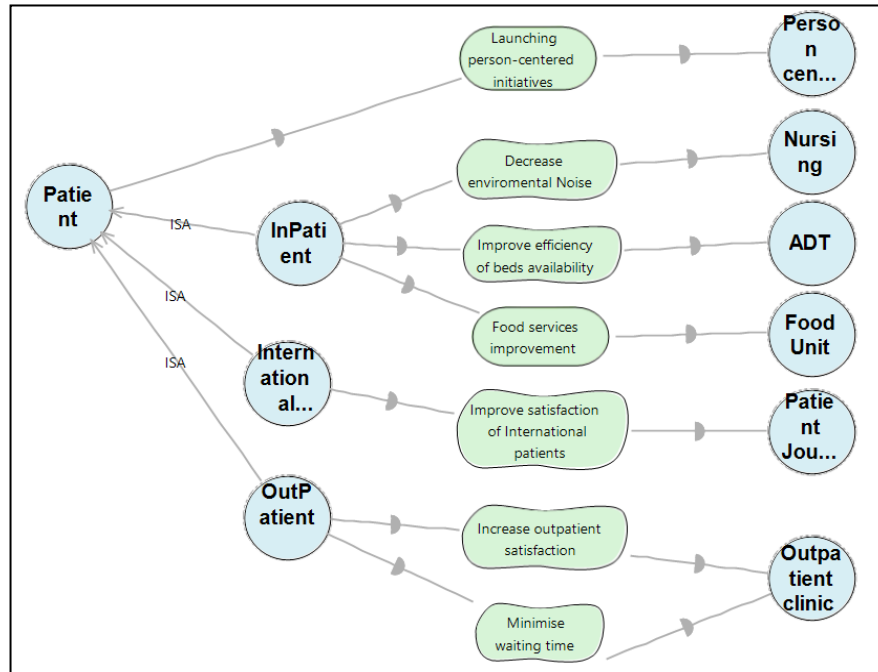
Figure 4.11: SD Model for Strategic Goal 1.1: "Improve patient's experience"
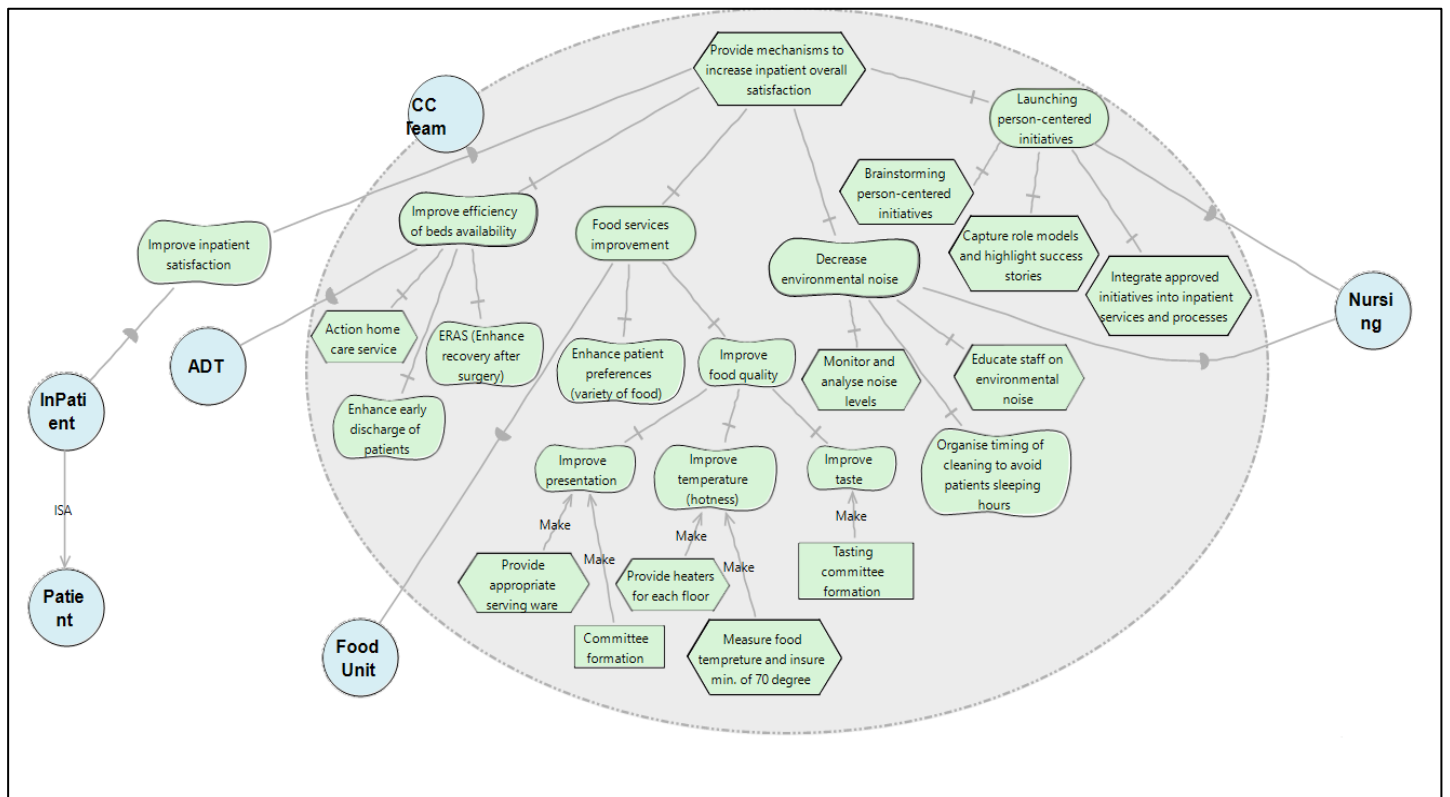
Figure 4.12: SR Model for Strategic Goal 1.1: "Improve patient's experience"

4.2.2.2 Global and Local Goal-Oriented Modelling of KHCC's ADT Policies and Procedures

KHCC's policies cover mainly the following categories and systems: 1) Admission, Discharge, and Transfer (ADT) policies and procedures 2) Medical Records (MR) policies and procedures, 3) IT policies and procedures, 4) HR policies and procedures, and also interacts with other constituent systems including pharmacy, lab, nursing, treatment systems, social services, outside treatment facilities and Jordan Cancer Registry (JCR).

This research work is focused on the case of the medical ADT at KHCC, which is related to the admission and discharge of patients, as well as their treatment and care. The ADT policies and procedures are concerned with everything related to patient's care from admission until discharge and furthermore follow-up. These policies and procedures also cover the variety of Cancer Care constituent systems and Cancer Care services. On the other hand, MR, IT and HR policies and procedures are considered not cancer care-related and will not be part of this research scope.

The first part of policies and procedures of the medical ADT Committee, which are related to the *"Admission, Discharge and Transfer of Patients"* were selected to be modelled first as they cover the variety of cancer care constituent systems and cancer care services. These documents were analysed and comprehensively studied in the first sub-iteration of the first DSRM increment of the framework's design, development, and demonstration. This led to the development of the following local-level i* goal models: SD model for 'Admission of Patients Policy', shown in Figure 4.13, SR models for 'Emergency Admission Procedures', 'Elective and Urgent Admission Procedures', 'Discharge of Patients policy', 'Patient Medically Advised Discharge Procedures', 'Patient Discharge Against Medical Advice Procedures', and 'Patient Transfer to Other Facilities Procedures'. These i* models are demonstrated in Appendix A, Section 7.

In the second sub-iteration, the second part of ADT committee policies and procedures were selected and analysed, leading to the development of the associated local-level SD and SR goal models, namely: 'Discharge Planning Process'; 'Role of Surgical Intermediate Unit'; and 'Meal Provision to Hospitalised Patients'.

And finally, through the third sub-iteration, the following SD and SR goal models were developed for the last set of ADT committee policies and procedures: 'Flow of Patients and Waiting List Management'; 'Patient Delay' and 'Patients' No Shows'. All the i* models developed for KHCC's ADT policies and procedures through the multiple incremental iterations of the DSRM process, are presented in Appendix A, Section 7.
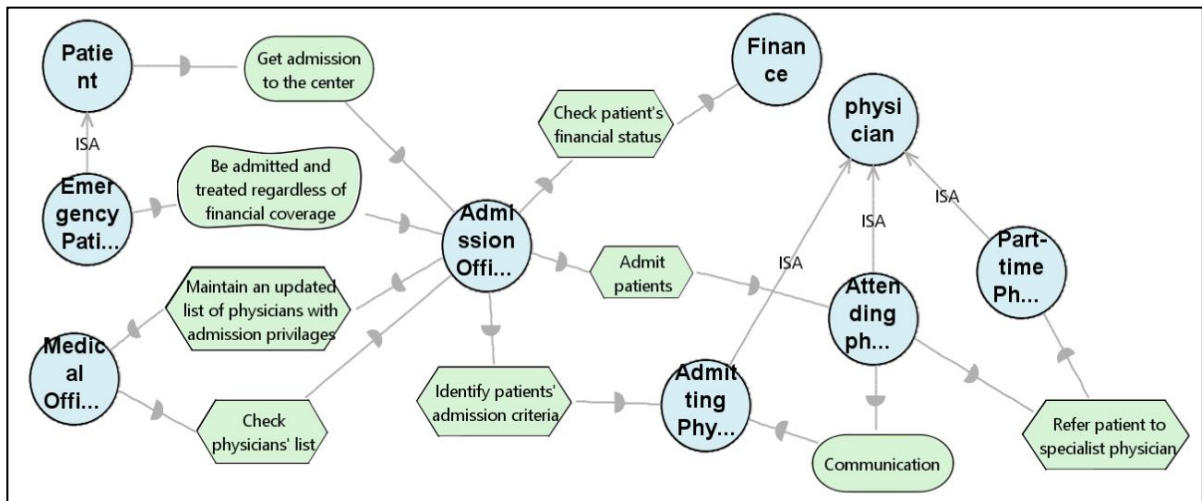
Figure 4.13: SD Model for "Admission of Patients Policy"

While modelling ADT's policies and procedures into i* goal models, KPIs related to ADT domain were mapped and traced back to their corresponding ADT policies and developed i* models, as shown in Table 4.3. Consequently, linking KPIs to policy documents was one of the criteria applied in order to select policy documents that are chosen to be goal modelled during the research, as mentioned previously in Section 4.2.1.1.

Table 4.3: Mapping between KPIs and Corresponding ADT Policies and i* Models

#	KPI	Related Policy	ADT or Not?	i* Model
1	Average length of stay (6 days)	Patient Delay	ADT	Patient Delay
2	Exceeded length of stay	Patient Delay	ADT	Patient Delay
3	Late discharge orders	Discharge Planning Process	ADT	Discharge of Patients
4	Occupancy rate	Flow of Patient & Waiting List Management	ADT	Flow of Patients
5	Average waiting time for admission	Flow of Patient & Waiting List Management	ADT	Flow of Patients
6	Missed outpatient appointments (No shows)	Patients' No shows	ADT	Patients' No shows

#	KPI	Related Policy	ADT or Not?	i* Model
7	Cancelled outpatient clinics	Patients' No shows	ADT	Patients' No shows
8	Cancelled procedures in OR	Scheduling of Operative Services	OR Committee (Not ADT)	X
9	OR utilisation	Scheduling of Operative Services	OR Committee (Not ADT)	X
10	Staff sickness absence rate	Sick leaves	HR (Not ADT)	X

4.2.2.3 Proposing a Reference i* Goal-Oriented Model for Access to Cancer Care

One of the main aims of this research is providing the SoS organisation with a generic or reference goal-oriented model that represents the most important and generic aspects, along with the relationships and dependencies among the main actors in the organisation, from a GORE perspective.

Stemmed from the Cancer Care SD and SR models developed so far, the most generic aspects of Cancer Care hard goals, qualities, tasks and resources with their main actors (i.e. departments and stakeholders) were extracted. This led to the development of a Reference i* Goal-Oriented Model for Access to Cancer Care. The proposed reference i* model was validated by KHCC's domain experts and was matured and improved through three incremental sub-iterations following the DSRM process. The evaluation and validation of the proposed model will be discussed in Section 4.3, including all the resulted incremental versions. The last validated version of the developed reference i* model is shown in Figure 4.14.

The final version of the proposed reference i* model is an SD model that consists of 72 dependency relationships of different types; goal, softgoal, task and resource, as well as 27 actors that represent several Cancer Care departments and stakeholders, as follows: Patient, Care Provider, Physician, Consultant Physician, Admission and Discharge Office, Pharmacy, Nursing, Laboratory, ER Staff, Medical Records, Surgeon, OR Manager, Bed Manager, Chemotherapy Unit, Radiotherapy Unit, Social Services, Food Unit, Nutrition Unit, Radiology Department, Physical Therapy, Jordan Cancer Registry (JCR), Intermediate Unit (IMU), Intensive Care Unit (ICU), Multi-Disciplinary Clinic (MDC), New Patient Clinic, Nuclear Medicine, and Outside Treatment Facilities.
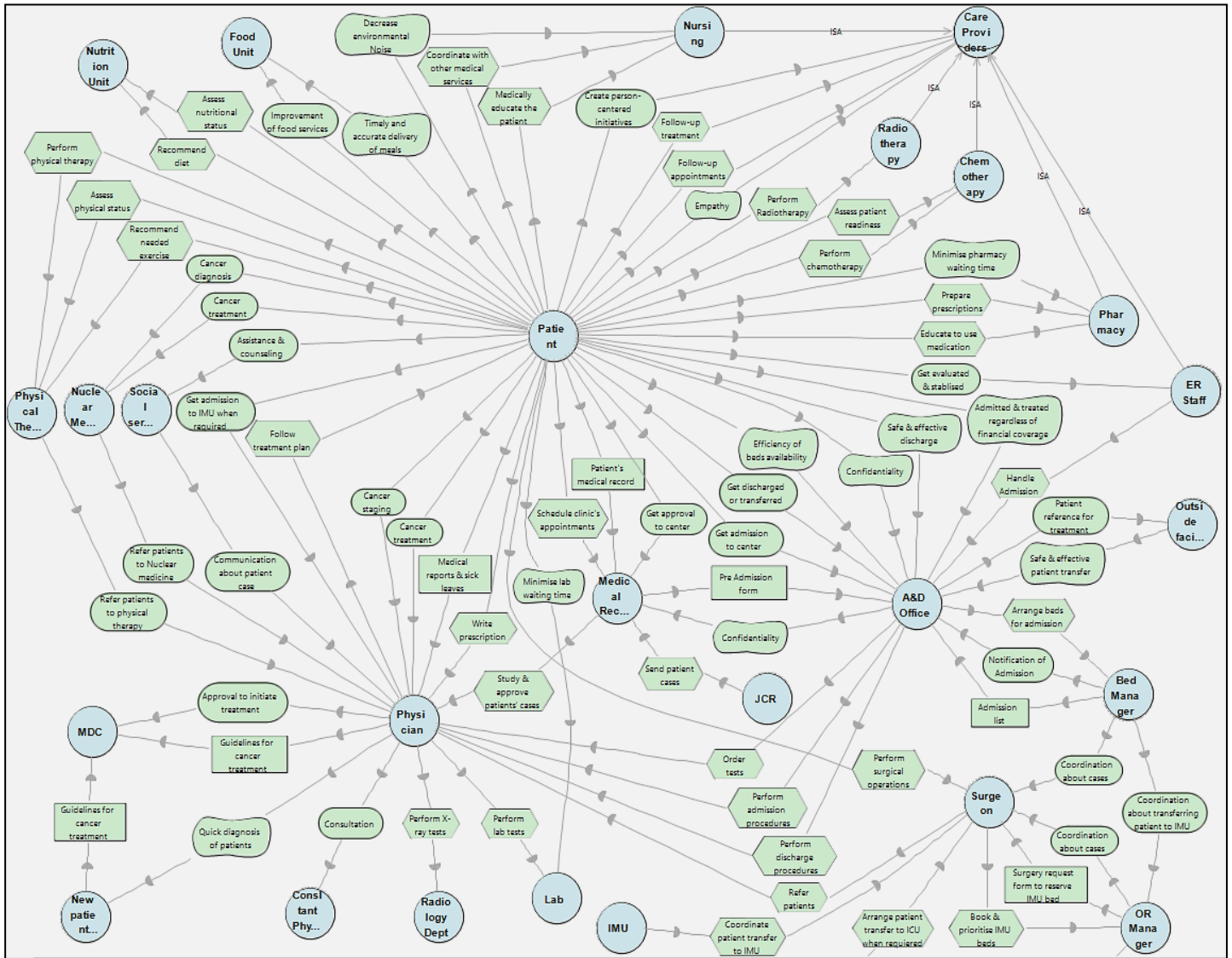
Figure 4.14: Proposed Reference i* Cancer Care Goal-Oriented Model_Last Version

4.3 Evaluation of i* Goal-Oriented Modelling in SoS Context with Input from the Cancer Care Case Study

Following the Cancer Care i* goal modelling for KHCC, more requirements workshops, structured and semi-structured interviews were conducted with KHCC's main stakeholders and domain experts as part of the research validation and evaluation phase.

The workshops and interviews main objectives and outcomes are summarised in this section, however, full interviews' questions are provided in Appendix A. The following objectives were targeted and achieved during the evaluation phase of the first DSRM iteration regarding

evaluating the first layer of the research framework and its outcomes, and will be discussed further in the following subsections:

1) Validate the selected set of KHCC documents to be goal modelled, and its completeness.

2) Validate the proposed i* extraction process developed to elicit i* elements from existing user documentation, its correctness and completeness.

3) Validate the developed i* models for KHCC strategic plans and ADT policies and procedures, their correctness and completeness (three sub-iterations).

4) Validate the proposed Reference i* Goal-Oriented Model for Access to Cancer Care (three sub-iterations).

5) Validate developed i* models of hierarchical goal networks for measuring the satisfaction of hard goals and softgoals, by linking them to corresponding KPIs.

4.3.1 Evaluating KHCC's Developed i* Goal-Oriented Models

In the first iteration of the evaluation phase, the interviews aimed at validating and evaluating the first layer of the research framework, the developed Cancer Care i* models for KHCC's strategic plans and ADT policies and procedures, presenting the research progress and outcomes, collecting stakeholders' feedback and reflecting it on the next sub-iterations of implementing the i* goal modelling. The following were achieved by evaluating the first component of the framework and KHCC's developed i* goal-oriented models through several sub-iterations.

- **Validate the selected set of KHCC documents to be goal modelled and its completeness.**
  As mentioned earlier in Section 4.2.1, a particular set of KHCC's documents were selected to be goal-modelled, and considered sufficient and representative enough with reference to multiple criteria applied during the selection. The selected set of documents, along with the associated criteria, are presented in Table 4.4. This selection was validated and approved by KHCC's domain experts, and the list is considered complete for the purposes and scope of this research.

Table 4.4: Validation of the Selected Set of KHCC's Documents to be Goal Modelled

#	Name of Selected Document	Reason(s) Behind Selection (Criteria)
	KHCC Strategic Plan	
1	Strategic Priority 1: "To foster person-centred care and safety"	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation
	ADT Committee Policies	
1	Admission of Patients	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation
2	Discharge of Patients	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation
3	Discharge Planning Process	- Cancer Care-related - Within research scope - Linked to KPI: "Late discharge orders" - Stakeholders' confirmation
4	Medical Referrals-Transfer	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation
5	Role of Surgical Intermediate Unit	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation
6	Flow of Patient and Waiting List Management	- Cancer Care-related - Within research scope - Linked to KPIs: "Average waiting time for admission" and "Occupancy rate" - Stakeholders' confirmation
7	Patient Delay	- Cancer Care-related - Within research scope - Linked to KPIs: "Average length of stay" and "Exceeded length of stay" - Stakeholders' confirmation
8	Patients' No Show	- Cancer Care-related - Within research scope - Linked to KPIs: "Missed outpatient appointments" and "Cancelled outpatient clinics" - Stakeholders' confirmation

#	Name of Selected Document	Reason(s) Behind Selection (Criteria)
9	Meal Provision to Hospitalised Patients	- Cancer Care-related - Within research scope - Useful at obtaining i* elements and cancer care generic concepts - Stakeholders' confirmation

- **Validate the proposed i* extraction process developed to elicit i* elements from existing user documentation, its correctness and completeness.**

As part of the evaluation phase, the i* extraction process proposed in Section 4.1.1 was evaluated with input from KHCC's domain experts during interviews and the walk-through example mentioned earlier in Figure 4.2. The validation interviews are provided in Appendix A, Section 4. Results of the validation process revealed the *correctness*, *consistency* and *completeness* of the heuristics that comprise the i* extraction process, and of the Cancer Care i* goal modelling elements extracted when applying the extraction process and its heuristics.

- **Validate the developed i* models for KHCC strategic plans and ADT policies and procedures, their correctness and completeness.**

The i* elements, actors, dependencies and relationships in each developed i* model for KHCC's documents were validated through several interviews conducted with main domain experts and stakeholders, following three sub-iterations of the evaluation phase of the DSRM process. The final version of i* models, and full validation interviews are provided in Appendix A, Sections 6 and 7, which aimed at determining the following:

- The correctness of each dependency type, whether it is a goal, softgoal, task, or resource.
- The correctness of the depender and dependee actors for each dependency type.
- The correctness of the dependency direction between actors.
- Identifying the generic concepts (actors and dependencies) in the Cancer Care domain, to be as input for developing the Reference i* Goal-Oriented Model for Access to Cancer Care.
- Identifying the corresponding constituent system for each dependency type.

Feedback gained from stakeholders was applied to the i* models, and modifications were implemented until a more mature and complete set of i* models was attained. The final set of i*

goal models was then ready to enter the next phases of maintaining goals referential integrity, ontologising the goal models and applying conflict detection and resolution strategies, which are discussed in Chapters 5 and 6 of the thesis.

4.3.2 Evaluating the Proposed Reference i* Goal-Oriented Model for Access to Cancer Care

The i* elements, dependencies and relationships between actors, in the proposed reference i* goal-oriented model for Access to Cancer Care, were validated through several interviews conducted with main domain experts and stakeholders following three sub-iterations of the evaluation phase of the DSRM process, until a final more mature and complete model approved by domain experts was attained. All incremental versions of the proposed reference i* model are shown in Figures 4.15 - 4.18. Full validation interviews are provided in Appendix A, Section 5, which aimed at determining the following:

- The correctness of each dependency type, whether it is a goal, softgoal, task, or resource.
- The correctness of the depender and dependee actors for each dependency type.
- The correctness of the dependency direction between actors.
- The completeness of the elements modelled, with reference to the case of ADT policies and procedures, strategic plans and access to Cancer Care at KHCC.

The main outcomes of the evaluation process of the proposed i* reference model are summarised as follows:

The proposed reference i* goal-oriented model for Access to Cancer Care provides the most generic concepts in Cancer Care domain with reference to the case of ADT at KHCC and KHCC's strategic plans. By proposing the model to KHCC, stakeholders gained the benefits of recognising and understanding the linkages and relationships with other stakeholders and departments more easily, since it concisely highlighted what actors need and expect from each other. The model developed following GORE approaches and in particular, the i* framework, provides a wider system engineering perspective and offers an accessible level of abstraction for stakeholders and domain experts in validating choices among alternative designs.

Moreover, one of the major benefits sought from developing such a goal model is that of reusability. It is intended to apply the model into other Cancer Care organisations and facilities,

to discover the benefits and impacts of reusing such a model in this area. Reusable resources not only save effort in the invention of the wheel, but promote comparability and standardisation by the use of similar models in different organisations.

The basic principle adopted by proposing this Cancer Care model is the use of knowledge and standardisation of common generic concepts about the domain, in which other Cancer Care organisations can considerably facilitate the process of capturing and specifying the goals and requirements for their practice, required systems or applications. It is contended that such knowledge can be reused several times in the development of successive specifications and that the relative advantages of using the model proposed in terms of time and cost savings might, therefore, increase over time.
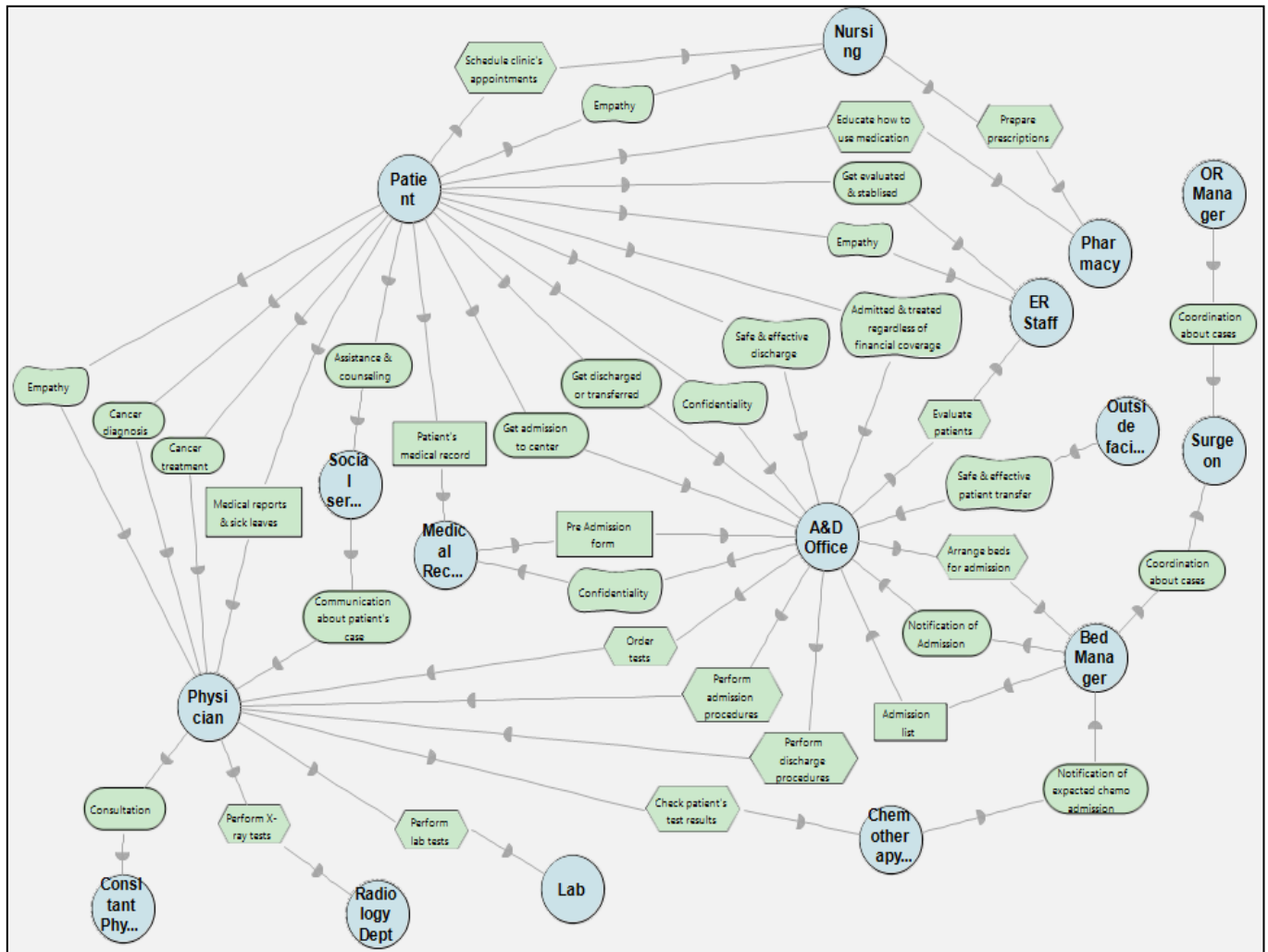
Figure 4.15: Reference i* Cancer Care Goal-Oriented Model_V1
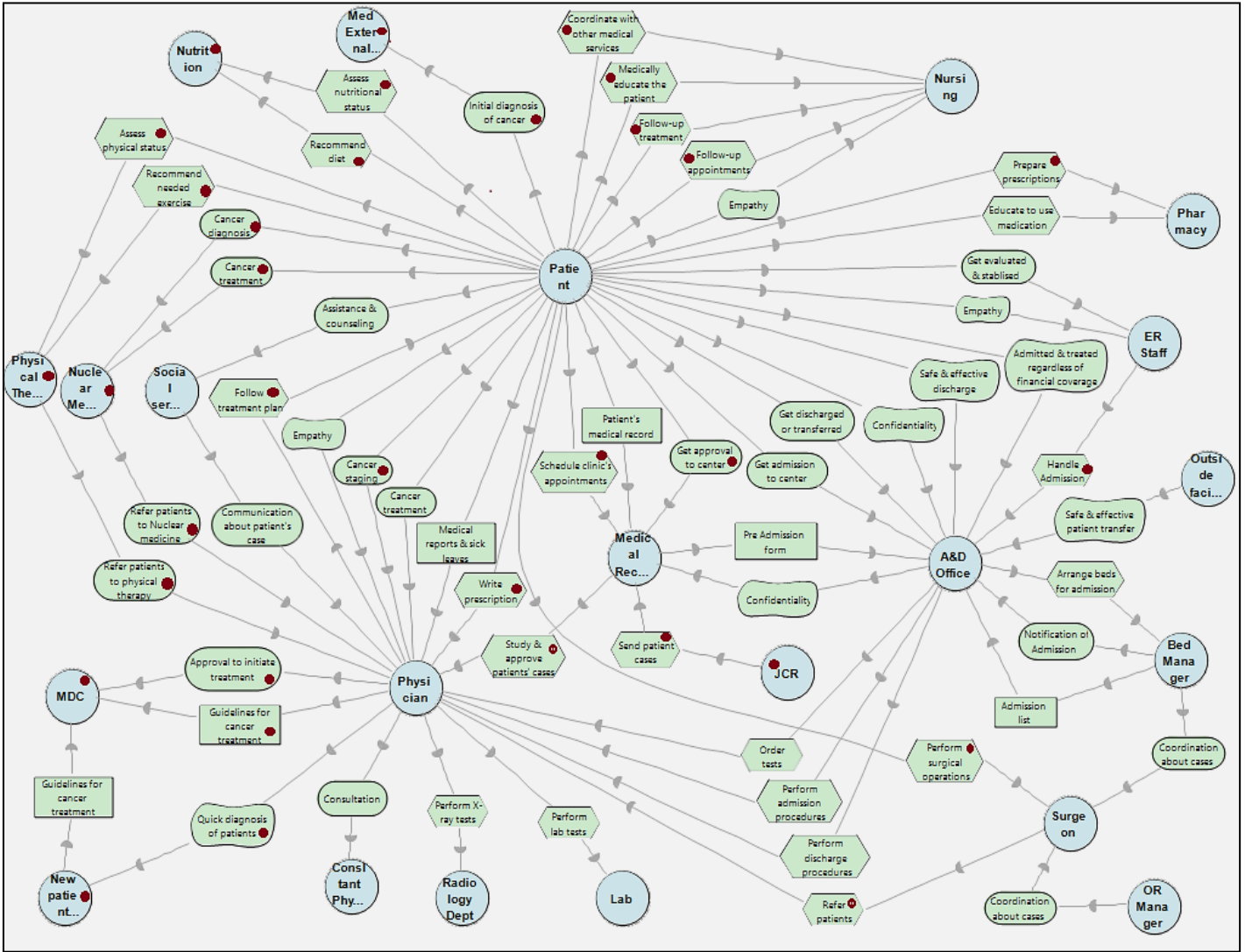
Figure 4.16: Reference i* Cancer Care Goal-Oriented Model_V2 (After 1ˢᵗ Iteration of Validation)

Figure 4.17: Reference i* Cancer Care Goal-Oriented Model_V3 (After 2nd Iteration of Validation)

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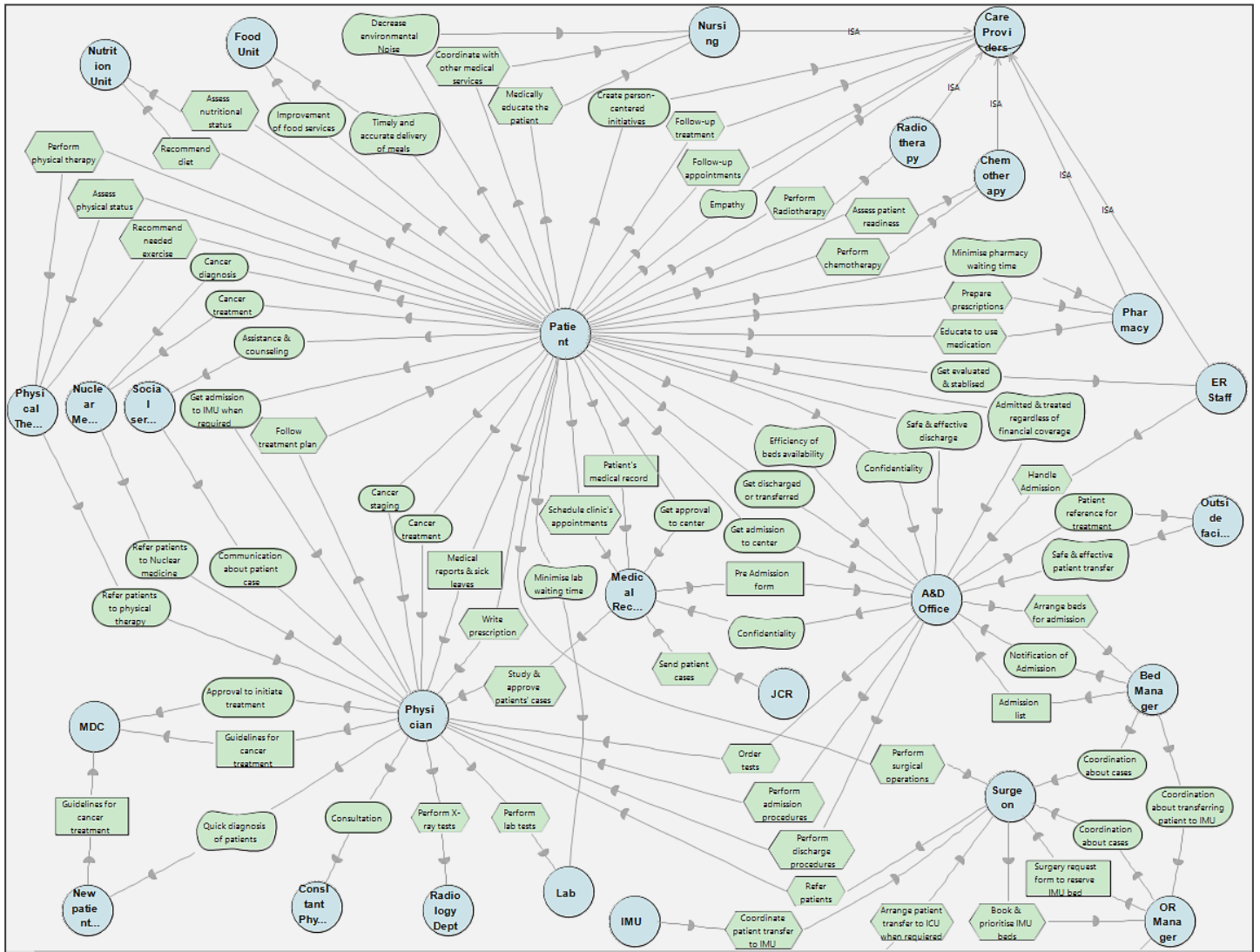
Figure 4.18: Reference i* Cancer Care Goal-Oriented Model_Last Version (After 3rd Iteration of Validation)

4.3.3 Measuring the Satisfaction of Hard Goals and Soft Goals through Hierarchical Goal Networks

Hierarchical goal networks were constructed to measure the satisfaction of Cancer Care hard goals and soft goals. The main aim of developing these goal networks is to link the local-level goals with the global high-level goals, and check which local goals were already totally achieved and satisfied, which were partially satisfied and highlight which goals still need to be accomplished in order to satisfy the goals in the global level. This provides the stakeholders with

a clear view of the progress and achievement of all goals in the local and global levels and what actions are still needed in order to satisfy the remaining unaccomplished goals.

By determining and modelling the satisfaction and achievement of local goals, the satisfaction of the global goals in the higher levels could be inferred. This was implemented through building ontologies in SoS context, besides implementing these hierarchical goal networks using Java programming language and impeded Structured Query Language (SQL) (Hursch et al., 1988), as will be discussed in Chapter 5. Examples of hierarchical goal networks are shown in Figures 4.19 and 4.20. The symbol √. is used to indicate that the hard goal or softgoal is partially satisfied, and √ indicates that the goal is totally satisfied. If the goal is not checked at all, this means it is not accomplished yet.
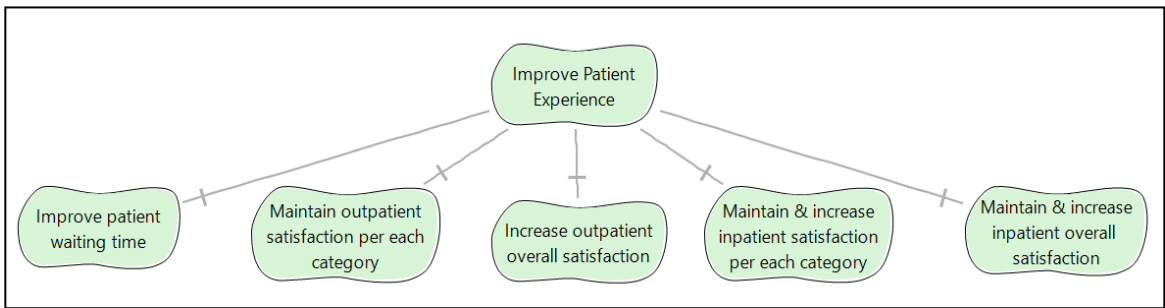
Figure 4.19: Hierarchical Goal Network of the Strategic Sub-Global Softgoal: 'Improve Patient Experience'
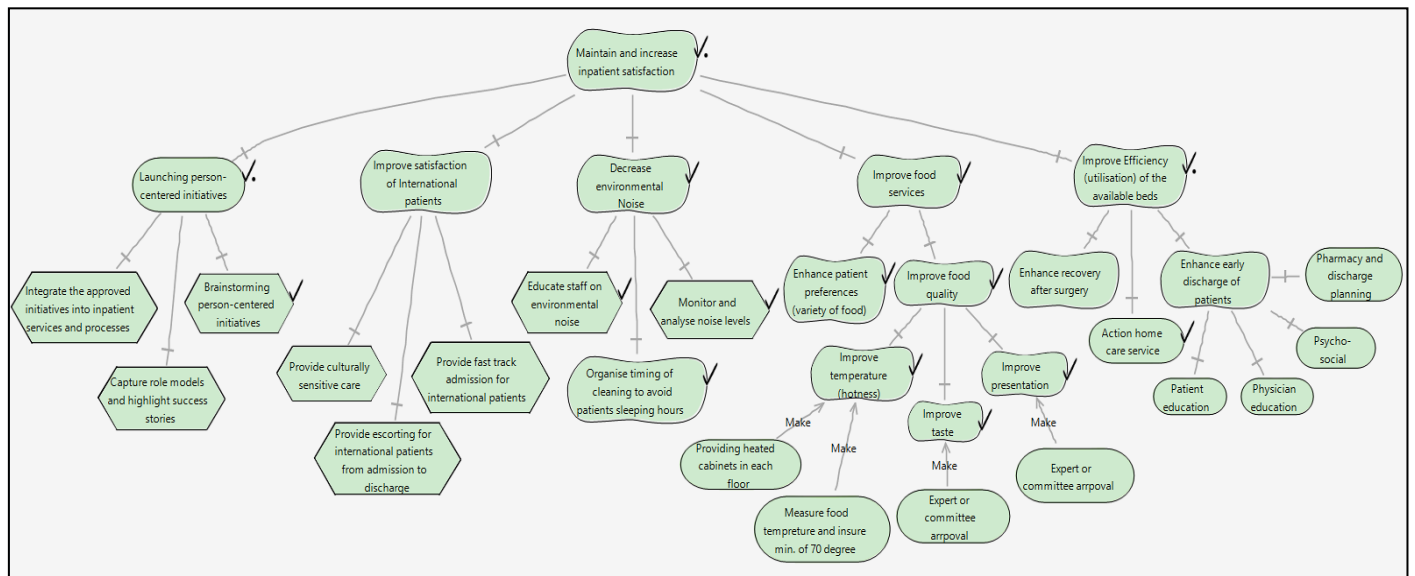
Figure 4.20: Hierarchical Goal Network for Measuring the Satisfaction of the Softgoal: 'Maintain and Increase Inpatient Satisfaction'

4.4 Chapter Summary

This chapter presented and discussed the components of the first layer of the research framework OntoSoS.GORE, which represents the first DSRM iteration, including the design and development phase, demonstration phase and evaluation phase of i* goal-oriented modelling in SoS context. Three sub-iterations were needed within each DSRM phase to complete the i* goal-oriented modelling component.

A new process to extract i* elements and concepts from existing user documentation was developed. This process, along with several requirements elicitation techniques were applied to KHCC Cancer Care case study and documents to extract i* modelling elements, prior to starting the i* goal modelling process. The extraction process and the developed i* models for KHCC's strategic plans, policies and procedures were validated through interviews with domain experts and key stakeholders.

Also, a conceptual metamodel for SoS i* goal-oriented modelling presenting the multiple levels of goals and their linkages with the SoS organisation, its constituent systems, actors, i* developed models, strategic and policy documents and other entities was developed. The model was applied to the KHCC Cancer Care case study resulting of development of global and local goal models for KHCC's selected documents and leading to proposing a Reference i* Goal-Oriented Model for Access to Cancer Care, which was also validated with associated domain experts. The proposed reference model provides the most generic concepts in Cancer Care domain with reference to the case of ADT at KHCC and KHCC's strategic plans. It provides standardisation of common generic concepts about the domain and also offers a major benefit of reusability if applied to other Cancer Care organisations.

The first research question (RQ1) was attended to and answered through this chapter. The global and local goals at multiple levels of an SoS arrangement; the goal's type whether it is, hard goal, softgoal, resource, or task; and the relationships amongst goals and their associated actors were identified and modelled using the i* framework. The developed i* goal-oriented models are going to be the input for the sGRI model and the conflict management approach developed and discussed through the next chapters.

The developed metamodel for i* goal modelling in SoS context is partially implemented to measure the satisfaction of goals in different levels, and to detect and resolve any conflicts that may occur amongst the goal levels, as will be discussed in Chapters 5 and 6, respectively. The second layer of the research framework of developing a semantic Goals Referential Integrity (sGRI) model, its demonstration and evaluation with input from the KHCC Cancer Care case study is presented in Chapter 5, representing the second iteration of the DSRM process.

Chapter 5

The Research Framework OntoSoS.GORE – DSRM Second Iteration: sGRI Model

In this chapter, the second layer of the research framework -the semantic Goals Referential Integrity (sGRI) model- is introduced by describing its two components, implemented through the second DSRM process iteration over the design and development, demonstration and evaluation phases.

First, a Goals Referential Integrity (GRI) model in SoS context is developed, in Section 5.1.1. The GRI model aims at maintaining the consistency and integrity of goals at both local and global levels, in an attempt to address the current challenges of managing evolving multiple goal-levels and their complexity in SoS arrangements. As part of the GRI model, a strategic goal-management tool is introduced and implemented with multiple goal levels in an SoS context which are employed to inform goals satisfaction and progress.

Second, in Section 5.1.2, the i* goal-oriented modelling in SoS context is semantically enriched using ontology, to represent the goal levels of an SoS organisation and their linkages with constituent systems, i* models and other entities; and to inform the satisfaction and achievement of goals in multiple levels when linked together. The sGRI model is instantiated and evaluated by applying the KHCC Cancer Care case study, in Sections 5.2 and 5.3, respectively.

This chapter aims at answering the second and third research questions (RQ2 and RQ3) addressed in the thesis, which are stated as follows:

RQ2: Can the referential integrity of the SoS goals and the constituent systems' goals be maintained at all levels in an operational context?

RQ3: To what extent can the satisfaction of both the SoS-level goals and the constituent systems-level goals be checked and verified by applying the OntoSoS.GORE framework?

5.1 Design and Development of a Semantic Goals Referential Integrity (sGRI) Model in an SoS Context

The second DSRM iteration involves the development of the second layer of the research framework, namely, the semantic Goals Referential Integrity (sGRI) model represented by the two main components: the GRI model and the ontology-based model in an SoS context, which are both discussed in this section.

5.1.1 Goals Referential Integrity (GRI) Model in an SoS Context

In database systems context, the term integrity refers to "the correctness or validity of the data in the database, as defined explicitly by means of integrity rules or constraints, i.e. rules that define properties to be satisfied by the database" (Grefen and Apers, 1993). Referential integrity as a concept in database systems represents the "cement" and controlling terms and conditions that keep relational databases semantically controlled. An SQL-based relational database has components such as tables, where a Foreign Key (FK) is the link between two tables. An FK is a field in a database table that points to a primary key (i.e. unique key) in another table, in order to create a relationship between these two tables. Referential integrity constraints ensure that relationships between tables remain consistent (Ordonez et al., 2007). Figure 5.1 shows an example of referential integrity constraints in a part of a bank database.
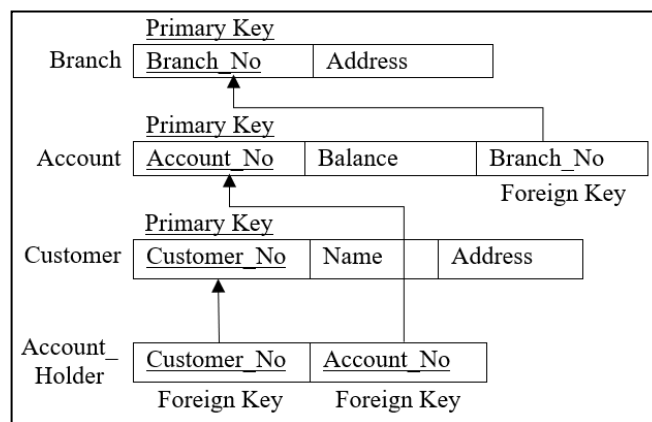
Figure 5.1: Referential Integrity Constraints Example in a Bank Database
(Adapted from Elmasri and Navathe, 2017)

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Within the OntoSoS.GORE framework, a new term in GORE context is introduced, namely the *"Goals Referential Integrity (GRI)"*. It is defined as *"the capability to maintain the integrity of evolving goals for a particular system/organisation"*. And in SoS context, the new term *"Systems of Systems Goals Referential Integrity (SoSGRI)"* is defined as *"the capability to maintain the integrity of the SoS goals with the evolving local goals of the monolithic constituent systems in an SoS arrangement"*.

SoSGRI intends to maintain the integrity and consistency of both the SoS-level goals and the constituent systems-level goals, if either any goal at any of the two levels has been changed, updated, deleted, or a new goal has been identified. The integrity of goals should be maintained both ways: top-down (from the SoS to the constituent Systems); and bottom-up (from constituent systems to the SoS).

The four basic functions typically associated with persistent storage in database applications are the Create, Read, Update, and Delete (CRUD) operations (Driesen, 2015). Alternative words are sometimes used when defining these four basic functions of CRUD, such as retrieve instead of read, modify instead of update, and destroy instead of delete.

In this research, the parallel of CRUD basic functions is reused in SoS context to maintain goals' referential integrity at multiple SoS levels. Three types of constraints on goals have been identified and specified to maintain and enforce GRI in an SoS arrangement: Insert, update, and delete constraints. The create function is linked to the GRI insert constraints; the update function matches the GRI update constraints, and the delete function matches the GRI delete constraints, where these constraints are described as follows:

1) *Insert constraints:* If a new global goal at the SoS-level is identified, this should be reflected on the local constituent systems' goals, as this new goal might need new local goals to be identified in addition to some already existing goals to be satisfied. On the other hand, if an individual goal of any constituent system is newly recognised, the impact on the SoS global goals should be investigated and managed; and this new goal should be linked clearly to other goal-levels.

2) *Update constraints:* If some updates are implemented on any of the SoS global goals, such updates should also be applied to any affected local goals to maintain their integrity

and satisfaction. Also, updates which are carried out on any local goal at constituent systems-level should be reflected on SoS global goals.

3) *Delete constraints:* If any global or local goal is no longer needed or has been removed, the effect on other goals should be identified and minimised, but ensuring the integrity of all goals in the SoS arrangement.

The deployment of the GRI model in an SoS context depends on and affects the constituent systems' participation in the SoS goals fulfilment, taking into consideration that the constituents are operationally and managerially independent. For example, on the one hand, deleting a local goal of a certain constituent system implies that this goal is no longer contributing towards achieving a corresponding global goal. If this constituent system still has other local goals contributing at the SoS global level, then it continues to participate in the SoS arrangement. Otherwise, if no other local goals of this constituent system are linked to the global level, then the constituent system is no longer participating in the SoS arrangement. On the other hand, if a high-level decision is made by an SoS-level authority to delete a global goal, then related local goals will no longer contribute towards achieving this goal anymore. Therefore, the constituent system(s) with these local goals will leave and no longer participate in the SoS arrangement, if they are not contributing towards the achievement of other global goals of the SoS.

5.1.1.1 Implementation of Goals Referential Integrity (GRI) in an SoS Context

SoSGRI is implemented by developing the database structure using MySQL database management system (Van Der Lans, 2007). Implementing the GRI model in an SoS context informs the satisfaction and progress of goals at multiple levels. In this research, SQL and Java programming language are utilised to develop a proof-of-concept prototype that plays the role of a *strategic goal-management tool* for the SoS organisation with access to its main SoS high-level strategic goals and the CS-level local goals linked to KPIs that adhere to satisfying these goals. The tool enables stakeholders to track down the progress and satisfaction of Global Goals, Sub-Global Goals, and Local Goals at multiple levels of an SoS arrangement.

The related database system is designed and implemented for SoS i* strategic goal-oriented modelling following the Extended Entity Relationship (EER) modelling (Gogolla and Hohenstein, 1991) and the database schema shown in Figures 5.2 and 5.3, respectively.

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Figure 5.2: EER Diagram for i* Strategic Goal-Oriented Modelling in SoS Context

SoSOrganisation

SoS_ID	SoS_Name	SoS_Desc	Ref_Model_ID

ConstituentSystem

CS_ID	CS_Name	CS_Desc	Related_SoS

GlobalGoal

GG_ID	GG_Name	GG_Desc	Dependency_Type	Achieved	Priority	Specificity	Actor1_Depender	Actor2_Dependee	SoS_ID

SubGlobalGoal

SGG_ID	GG_Name	SGG_Desc	Dependency_Type	Achieved	Priority	Specificity	Actor1_Depender	Actor2_Dependee	Satisfy_GG	Satisfy_SGG

LocalGoal

LG_ID	LG_Name	LG_Desc	Dependency_Type	Achieved	Priority	Specificity	Actor1_Depender	Actor2_Dependee	CS_ID	Satisfy_SGG	Satisfy_LG

KPI

KPI_ID	KPI_Title	KPI_Desc	KPI_Tagret Value	KPI_Current Value	KPI_Domain	LG_ID	P_No

PolicyDoc

P_No	P_Title	P_Desc	Orig_Entity

iStarModel

Model_ID	Model_Type	Model_Title	Model_Desc

Actor

Actor_ID	Actor_Name

CS_has_iStarModel

CS_ID	Model_ID

PolicyDoc_has_iStarModel

P_No	Model_ID

LG_Linkedto_Policy

LG_ID	P_No

iStarModel_has_Actor

Model_ID	Actor_ID

LG_Detracts_SGG

LG_ID	SGG_ID

SGG_Detracts_SGG

SGG1_ID	SGG2_ID

LG_Detracts_LG

LG1_ID	LG2_ID

Key

Primary Key	Attribute	Foreign Key

Figure 5.3: Database Schema for i* Strategic Goal-Oriented Modelling in SoS Context

An EER model is a high-level or conceptual data model incorporating extensions to the original entity-relationship (ER) model, used in the design of databases. It reflects more precisely the requirements, properties and constraints of more complex databases, and includes additional concepts other than the ones introduced by the ER model (Elmasri and Navathe, 2017).

The database schema of a database is its structure described in a formal language supported by the Database Management System (DBMS). It refers to the organisation's data as an outline of how the database is constructed into database tables in the case of relational databases (Elmasri and Navathe, 2017). A description of the database tables (i.e. entities) which comprise the SoS strategic goal-oriented EER model and their corresponding properties is provided in Appendix B.

For the purpose of dealing with the restrictions generated by a Primary Key (PK) in a parent table and the link to a Foreign Key (FK) in a child table, referential integrity of goals at different levels of an SoS arrangement should be enforced and maintained in the following three cases:

1) **Insert:** referential integrity constraints should be observed and kept when inserting a new record both in a parent or a child table. When inserting a new record, the primary key integrity constraints should always be maintained. Three PK structural integrity rules should be followed (Popescu, 2001; Tudor, 2014):

   Rule 1: uniqueness of the key – the PK must be unique and minimal.

   Rule 2: integrity of the key – the PK value must not be NULL.

   Rule 3: integrity of the reference (FK) – an FK in a child table must either be NULL or correspond to an existing value of the related PK in the parent table.

   Inserting a new record in a child table can generate errors and should be prohibited if there are no corresponding values in the PK field from the parent table. If this occurs, the insertion referential restriction is breached.

2) **Update:** referential restriction when updating a record in a parent or a child table must insure the three integrity rules for PK mentioned in 1 above, as well as provide adequate referencing between PK and FK values. For example, updating a record in a child table can generate errors and should not be allowed if the update referential restriction is breached and there are no corresponding values in the PK field from the parent table.

3) **Delete:** referential restriction when deleting a record in a parent or a child table must ensure that the link between the FK in the child table and the associated PK in the parent table is maintained. Deleting a record in a parent table can generate errors and should be prohibited if the deletion referential restriction is breached and there are still values in the

FK column of the child table with no corresponding value in the PK column of the parent table.

Examples stemmed from the KHCC Cancer Care case study, on each one of these GRI constraints in an SoS context, are provided through the demonstration phase of the second DSRM process iteration in Section 5.2.1.

The design and development of the previous EER model and SoS strategic goal-oriented database led to the design of a GRI model applied in SoS context. Besides, analysing and investigating the KHCC Cancer Care case study, and identifying the multiple levels of goals in the organisation along with their relationships with the SoS itself, and the constituent systems among other entities contributed to designing and developing the SoSGRI model.

Figure 5.4 represents a generic view of the SoSGRI model. It depicts the relationships and interactions between the SoS global goals at the SoS-level, and the constituent systems' local goals at the CS-level. It also shows how global and local goals are linked together to maintain the overall goals' referential integrity. The column GG in each constituent system's table indicates the SoS global goal to which the corresponding local goal of the constituent system contributes to satisfying. This column provides a link between the local and global goals; similar to a foreign key in relational databases.

In Figure 5.5, the goals referential integrity is maintained by defining the linkages between a subset of the entities identified earlier in the model presented in Chapter 4, wherein Figure 4.4, the SoS organisation, its constituent systems, the SoS global goals and sub-global goals, and the CS local goals are interrelated. The column "SoS" added to the "Global Goal" and "Constituent System" tables, links each global goal and constituent system with the SoS organisation they belong to. The column "GG" defined in the "Sub-Global Goal" table informs the SoS global goal to which the corresponding sub-global goal contributes to satisfying. Likewise, the columns "SGG" and "CS" in the "Local Goal" table inform the sub-global goal to which the corresponding local goal contributes to satisfying, and the constituent system where this local goal is identified, respectively.
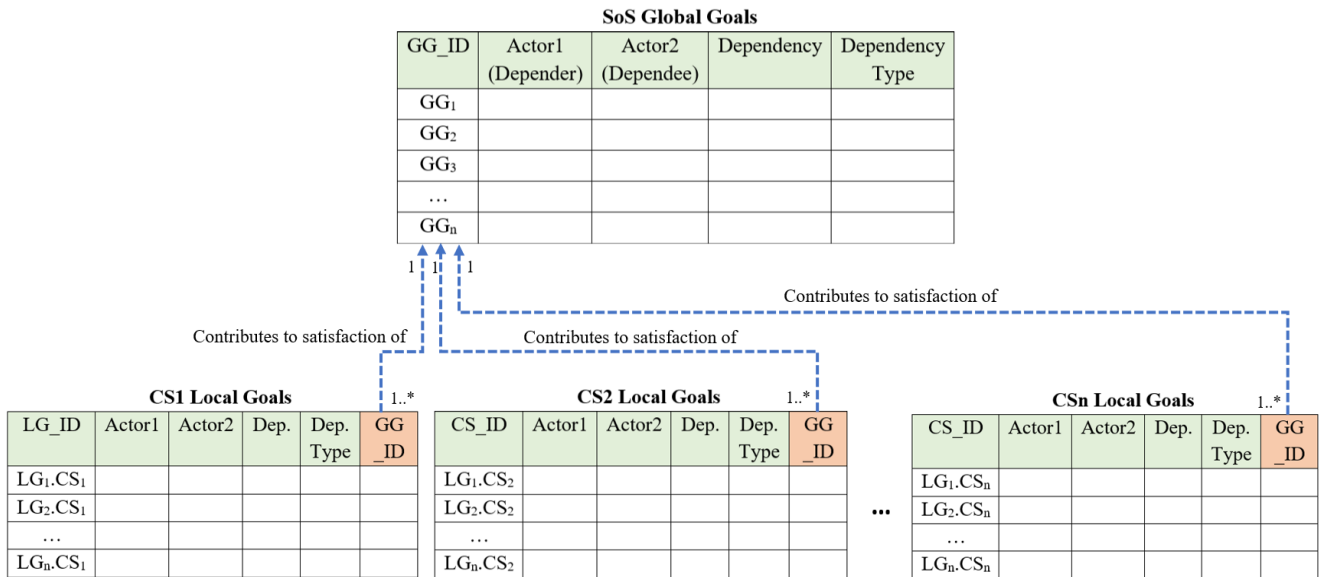
Figure 5.4: Generic View of the GRI model in SoS Context

SoS Global Goals

GG_ID	Actor1 (Depender)	Actor2 (Dependee)	Dependency	Dependency Type
GG$_1$				
GG$_2$				
GG$_3$				
…				
GG$_n$				

CS1 Local Goals

LG_ID	Actor1	Actor2	Dep.	Dep. Type	GG_ID
LG$_1$.CS$_1$					
LG$_2$.CS$_1$					
…					
LG$_n$.CS$_1$					

CS2 Local Goals

CS_ID	Actor1	Actor2	Dep.	Dep. Type	GG_ID
LG$_1$.CS$_2$					
LG$_2$.CS$_2$					
…					
LG$_n$.CS$_2$					

CSn Local Goals

CS_ID	Actor1	Actor2	Dep.	Dep. Type	GG_ID
LG$_1$.CS$_n$					
LG$_2$.CS$_n$					
…					
LG$_n$.CS$_n$					
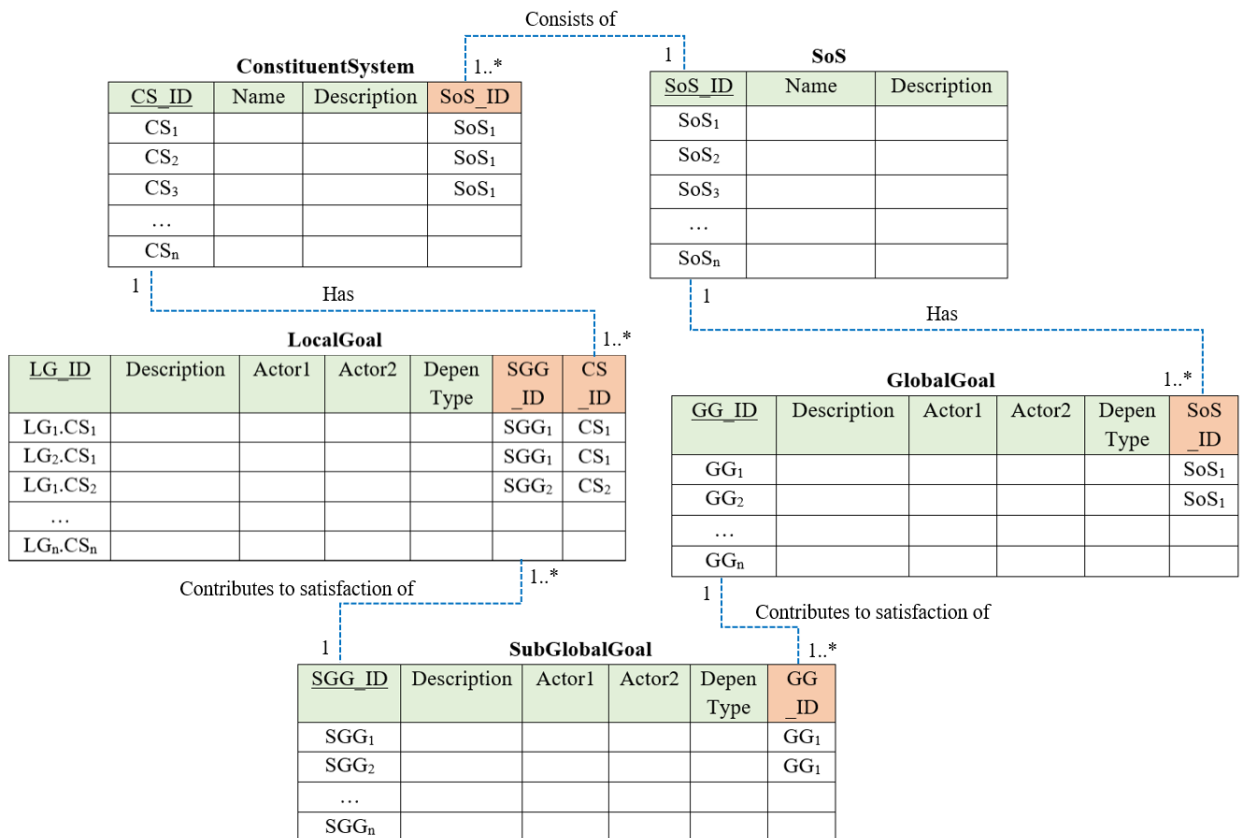
Figure 5.5: Maintaining Goals Referential Integrity at Multiple levels in SoS Goal Modelling

ConstituentSystem

CS_ID	Name	Description	SoS_ID
CS$_1$			SoS$_1$
CS$_2$			SoS$_1$
CS$_3$			SoS$_1$
…			
CS$_n$			

SoS

SoS_ID	Name	Description
SoS$_1$		
SoS$_2$		
SoS$_3$		
…		
SoS$_n$		

LocalGoal

LG_ID	Description	Actor1	Actor2	Depen Type	SGG_ID	CS_ID
LG$_1$.CS$_1$					SGG$_1$	CS$_1$
LG$_2$.CS$_1$					SGG$_1$	CS$_1$
LG$_1$.CS$_2$					SGG$_2$	CS$_2$
…						
LG$_n$.CS$_n$						

GlobalGoal

GG_ID	Description	Actor1	Actor2	Depen Type	SoS_ID
GG$_1$					SoS$_1$
GG$_2$					SoS$_1$
…					
GG$_n$					

SubGlobalGoal

SGG_ID	Description	Actor1	Actor2	Depen Type	GG_ID
SGG$_1$					GG$_1$
SGG$_2$					GG$_1$
…					
SGG$_n$					

5.1.1.2 Implementation of Goals Satisfaction at Multiple Levels in an SoS Context

The developed *strategic goal-management tool* consists of two main parts: (1) Goal satisfaction panel, presented in Figure 5.6; and (2) Conflict management panel, which will be discussed in Chapter 6. The goal satisfaction panel aims at linking SoS goals and constituent systems' goals at multiple levels in a dynamic way, where the data retrieved from lower local levels regarding the achievement and satisfaction of local goals, act as input to infer the satisfaction of upper-levels goals automatically, i.e. global and sub-global goals.

The goal satisfaction panel displays all goal levels. Any goal selected is linked to its upper-levels goals (i.e. parent goals), and lower-levels goals (i.e. child goals until reaching leaf goals), showing each goal related data such as; type of goal, depender and dependee actors and most importantly if the goal is achieved or not. A recursive relationship occurs at the sub-global and local levels between goals, illustrating the multiple goal levels in an SoS arrangement and presenting the linkages among them appropriately, e.g. a sub-global goal may have a set of sub-global goals that contribute to its satisfaction, and so on, as many levels as required and likewise for the local goals at the CS-level.

Moreover, the local goals are linked to their corresponding KPIs and their current and target values, and all goal levels are visually displayed as a tree graph illustrating achieved and unachieved goals of the selected goal and its sub-goals, as shown in Figure 5.6, where achieved goals are displayed in green and unachieved ones are displayed in red. Square shape goals represent global goals, hexagon shape indicates a sub-global goal, and circular shapes represent local goals.
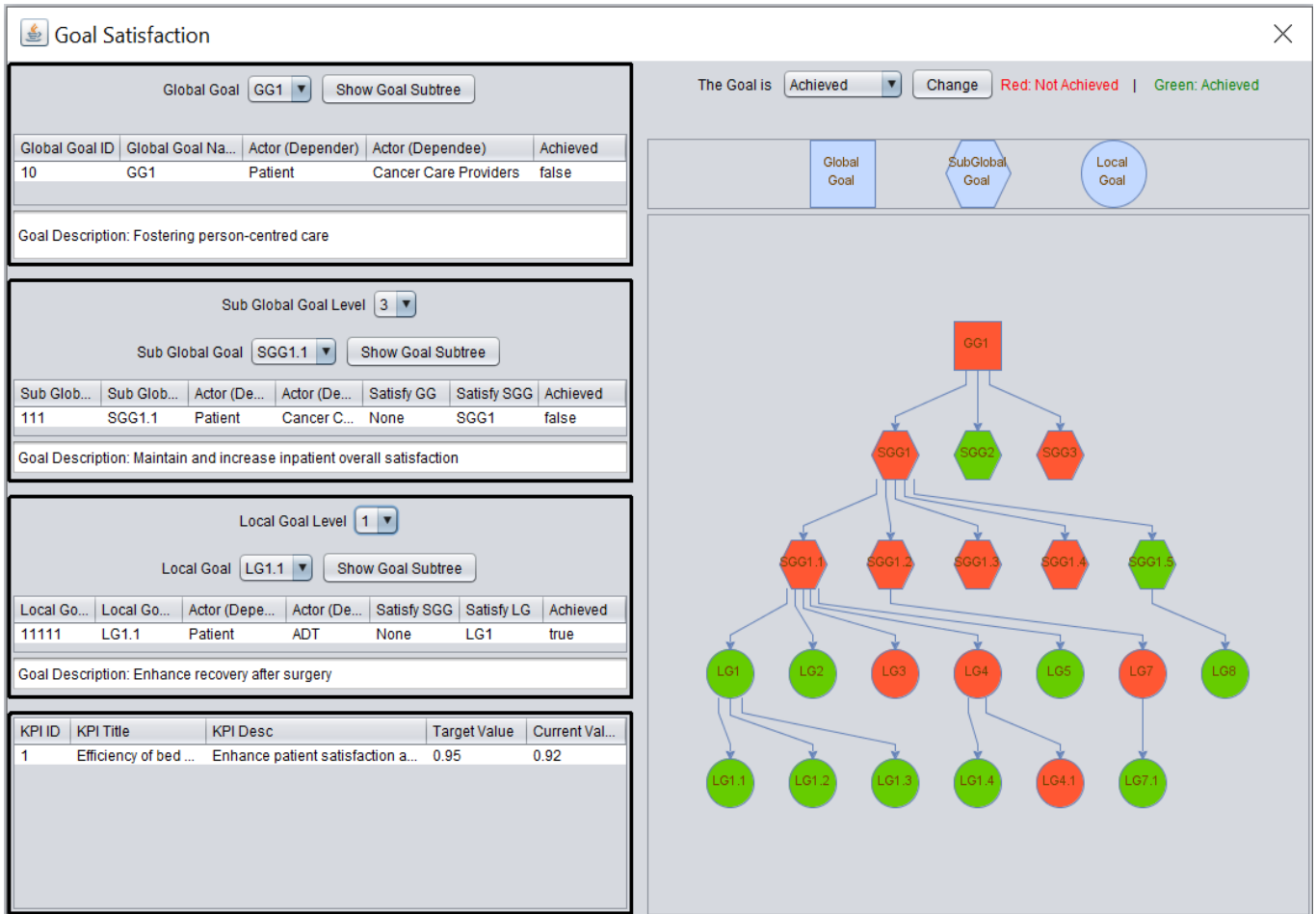
Figure 5.6: Implementation of Goal Satisfaction in SoS Context (Strategic Goal-Management Tool)

The above example illustrating goal satisfaction in SoS multiple levels and applied to the KHCC Cancer Care case study is presented and discussed in more detail as part of the demonstration phase, in Section 5.2. The automated process of inferring goals satisfaction helps senior management and stakeholders to track the achievement and progress of goals and their sub-goals easily and efficiently, and determine the needed actions in order to satisfy the remaining unaccomplished goals.

Implementing goals referential integrity in an SoS context will also pave the way for the conflict management process, i.e. conflict detection and resolution, to be applied to the multiple levels of the SoS arrangement and be operationalised by means of rules and analysing the priority, specificity and complexity of goals, as will be discussed in Chapter 6.

5.1.2 Semantic Ontology Model for i* Goal-Oriented Modelling in an SoS Context

The use of formal ontologies has increased in a wide range of areas as a way of specifying content-specific agreements for the sharing and reuse of knowledge among software entities, besides the use of reasoning and logic inference offered by ontologies (Noy and McGuinness, 2001; Horridge et al., 2009).

In general, developing an ontology consists of (1) defining the ontology classes; (2) classifying them in a taxonomic hierarchy (subclass-superclass); (3) defining properties and restrictions on them and identifying allowed values for these properties; (4) filling in the values for properties for individual instances. An ontology, together with a set of individual instances of classes constitute a knowledge base (Noy and McGuinness, 2001).

Following the development of the GRI model and the associated set of tables, e.g. as in Figures 5.3, 5.4 and 5.5, an ontology-based model presented in (AlHajHassan et al., 2018b, 2019), was developed using OWL (Patel-Schneider, 2004), to semantically represent the i* goal modelling in an SoS context and support the GRI model. Together the GRI model and its associated ontology model form the **semantic Goals Referential Integrity (sGRI)** applied in SoS context, where conflicts between goals at the SoS and the CS levels can be discovered in an attempt to maintain the semantic integrity of the SoS global goals and the constituent systems local goals.

The conceptual metamodel for SoS i* strategic goal-oriented modelling presented earlier in Section 4.1.3, Figure 4.4 is translated into a formal ontology representation named SoSGORE ontology, where each entity in the metamodel is semantically represented. The OWL classes represent the main elements of the SoS i* goal modelling as follows: **SoS Organisation**, **Constituent System**, **Global Goal**, **Sub-Global Goal**, **Local Goal**, **i* Model**, **Policy Document**, **Dependency Type**, **Depender Actor**, **Dependee Actor**, and **KPI**.

Table 5.1 shows the main OWL ontology classes with their associated data and object properties for i* strategic goal modelling in an SoS context. The set of objects created and the describable relationships between them define the links between the global, sub-global and local goals and provide traceability to these goals. Therefore, satisfying all the local goals at the CS-level ensures satisfying the global goals at the SoS-level.

Table 5.1: Description of OWL Classes and Mapping between Conceptual Model and OWL Classes for SoS i* Strategic Goal-Oriented Modelling

OWL Class	EER / DB Schema Entity	Data Properties	Object Properties	Relationships in DB
SoS_Organisation	SoSOrganisation	- SoS_ID - SoS_Name	- SoSOrg_Has_ ConstSystem - SoSOrg_Has_GG	- SoSOrganiatstion Consists of ConstituentSystem - SoSOrganiatstion Has GlobalGoal
Constituent_ System	ConstituentSystem	- ConstSystem_ID - ConstSystem_Name	- ConstSystem_ ParticipatesIn_SoSOrg - ConstSystem _Has_LG - ConstSystem_ IsLinkedTo_iStarModel	- ConstituentSystem Participates in SoSOrganiatstion - ConstituentSystem Has LocalGoal - ConstituentSystem Has iStarModel
Global_Goal	GlobalGoal	- GG_ID - GG_Description - is_Achieved (true/ false)	- GG_Has_SGG - GG_BelongsTo_ SoSOrg - GG_Has_Depender_ Actor - GG_Has_Dependee_ Actor - GG_Has_Dependency_ Type	- GlobalGoal Has SubGlobalGoal - GlobalGoal Belongs to SoSOrganiatstion - GlobalGoal Has DependerActor - GlobalGoal Has DependeeActor
SubGlobal_Goal	SubGlobalGoal	- SGG_ID - SGG_Description - is_Achieved (true/ false)	- SGG_BelongsTo_GG - SGG_Has_LG - SGG_Has_SGG - SGG_Detracts_SGG - SGG_Has_Depender_ Actor - SGG_Has_Dependee_ Actor - SGG_Has_Dependency _Type	- SubGlobalGoal Contributes to Satisfaction of GlobalGoal - SubGlobalGoal Has LocalGoal - SubGlobalGoal Contributes to Satisfaction of SubGlobalGoal - SubGlobalGoal Detracts from Satisfaction of SubGlobalGoal - SubGlobalGoal Has DependerActor - SubGlobalGoal Has DependeeActor

OWL Class	EER / DB Schema Entity	Data Properties	Object Properties	Relationships in DB
Local_Goal	LocalGoal	- LG_ID - LG_Description - is_Achieved (true/ false)	- LG_IsAssignedTo_ConstSystem - LG_Has_KPI - LG_BelongsTo_SGG - LG_BelongsTo_LG - LG_Detracts_SGG - LG_Detracts_LG - LG_IsLinkedTo_PolDocument - LG_Has_Depender_Actor - LG_Has_Dependee_Actor - LG_Has_Dependency_Type	- LocalGoal Assigned to ConstituentSystem - LocalGoal Has KPI - LocalGoal Contributes to Satisfaction of SubGlobalGoal - LocalGoal Contributes to Satisfaction of LocalGoal - LocalGoal Detracts from Satisfaction of SubGlobalGoal - LocalGoal Detracts from Satisfaction of LocalGoal - LocalGoal Linked to PolicyDoc - LocalGoal Has DependerActor - LocalGoal Has DependeeActor
iStar_Model - SD Model (Subclass) - SR Model (Subclass)	iStarModel	- Model_ID - Model_Title	- iStarModel_Represents RefModelFor_SoSOrg - iStarModel_Has_Actor - iStarModel_IsLinkedTo _ConstSystem - iStarModel_IsLinkedTo _PolDocument	- iStarModel Represents RefModel for SoSOrganisation - iStarModel Has Actor - iStarModel Linked to ConstituentSystem - iStarModel Linked to PolicyDoc
Dependency_Type - Hard Goal (Subclass) - Softgoal (Subclass) - Task (Subclass) - Resource (Subclass)	Dependency_Type Property in the following tables: GlobalGoal SubGlobalGoal LalGoal			
Depender_Actor	Actor	- Depender_Actor_ID - Depender_Actor_Name	- Depender_Actor_Has_GG - Depender_Actor_Has_SGG - Depender_Actor_Has_LG	- DependerActor Has GlobalGoal - DependerActor Has SubGlobalGoal - DependerActor Has LocalGoal
Dependee_Actor	Actor	- Dependee_Actor_ID	- Dependee_Actor_Has_GG	- DependeeActor Has GlobalGoal

OWL Class	EER / DB Schema Entity	Data Properties	Object Properties	Relationships in DB
		- Depender_Actor_ Name	- Dependee_Actor_Has_ SGG - Dependee_Actor_Has_ LG	- DependeeActor Has SubGlobalGoal - DependeeActor Has LocalGoal
Policy_Document	PolicyDoc	- Policy_No - Policy_Title	- PolDoc_IsLinkedTo_ KPI - PolDoc_IsLinkedTo_ LG - PolDoc_IsModelledIn_ iStarModel	- PolicyDoc Linked to KPI - PolicyDoc Linked to LocalGoal - PolicyDoc Linked to iStarModel
KPI	KPI	- KPI_Description - KPI_Target_Value - KPI_Current_ Value	- KPI_IsLinkedTo_LG - KPI_IsLinkedTo_ PolDocument	- KPI Linked to LG - KPI Linked to PolicyDoc

The significance of applying an ontology-based approach is the use of detecting and resolving semantic heterogeneities, and maintaining the consistency of goals. Also, by applying reasoning and SWRL rules, the achievement and progress of goals at both local and global levels can be informed. The achievement of SoS high-level goals including global and sub-global levels could be inferred by reasoning and by only identifying the achievement of the local goals at the CS-level and defining the linkages between all goal levels.

Ontology axioms and reasoning are applied using Protégé to identify the relationships between the different goal levels in an SoS organisation and to inform their level of satisfaction. This is accomplished using OWL reasoner and a Boolean data property named "is_Achieved" for goals at all levels, as follows:

1) Global Goals (GG):

To fully achieve a global goal, all sub-global goals at the lower level should be achieved:
Is_Achieved (GGx) ↔ Is_Achieved (SGG1) ∧ Is_Achieved (SGG2) ∧ … Is_Achieved (SGGi) ∧ … Is_Achieved (SGGn)

In OWL-DL, an object property for **Global_Goal** class is defined as follows:
GG_hasRelated_SGG only ({SGG1 , SGG2, …, SGGi, …, SGGn})

2) Sub-Global Goals (SGG):

Typically to fully achieve a sub-global goal, all local goals at the lower level (CS-level), which are identified as sub-goals of this parent sub-goal, should be achieved. However, in the case that another level of sub-global goals is required, all sub-global goals at the lower level, which are child goals of this parent sub-goal, should be achieved:

Is_Achieved (SGGx) ↔ Is_Achieved (LG1) ∧ Is_Achieved (LG2) ∧ … Is_Achieved (LGi) ∧ … Is_Achieved (LGn)

Is_Achieved (SGGy) ↔ Is_Achieved (SGG1) ∧ Is_Achieved (SGG2) ∧ … Is_Achieved (SGGi) ∧ … Is_Achieved (SGGn)

In OWL-DL, two related object properties for **SubGlobal_Goal** class are defined as follows:

SGG_hasRelated_LG only ({LG1 , LG2, …, LGi, …, LGn})

SGG_hasRelated_SGG only ({SGG1 , SGG2, …, SGGi, …, SGGn})

3) Local Goals (LG):

Local goals are considered leaf goals at the CS-level and they are mostly linked to KPIs. To fully achieve a local goal which is linked to a specific KPI, the KPI's current value should be equal to the KPI's target value. The achievement of other local goals which are not linked directly to KPIs should be determined by the concerning stakeholders.

However, if a particular local goal is not a leaf goal, and in that case another level of local goals is required, all sub-local goals at the lower level, which are child goals of this parent local goal, should be achieved, representing a recursive relationship between local goals:

Is_Achieved (LGx) ↔ Is_Achieved (LG1) ∧ Is_Achieved (LG2) ∧ … Is_Achieved (LGi) ∧ … Is_Achieved (LGn)

In OWL-DL, a related object property for **Local_Goal** class is defined as follows:

LG_hasRelated_LG only ({LG1 , LG2, …, LGi, …, LGn})

Eventually, identifying the achievement/satisfaction of local goals informs the satisfaction of upper-levels goals by the use of OWL reasoning. Nevertheless, as KPIs are critical factors in informing the satisfaction of associated local goals, this implies they also have a great impact in

informing the satisfaction of upper-levels goals (i.e. global and sub-global goals) indirectly. Further research is still needed to implement this aspect in OWL-DL.

Example:

The following OWL classes, individuals, data properties and object properties are defined using Protégé. Depending on the values of "is_Achieved" property for local goals, whether it is true or false, the achievement values are inferred for the upper-levels goals (i.e. Global and sub-global goals) as shown in Table 5.2.

Table 5.2: Inferring the Achievement of Upper-Levels' Goals Using OWL Reasoning by Identifying Local Goals Achievement Value

OWL Class	Individuals	Data Properties	Inferred Value for is_Achieved Data Property	Object Properties
Global_Goal	GG1	is_Achieved ?	is_Achieved **false**	GG_hasRelated_SGG only ({SGG1 , SGG2})
SubGlobal_Goal	SGG1	is_Achieved ?	is_Achieved **false**	SGG_hasRelated_LG only ({LG1 , LG2 , LG3})
	SGG2	is_Achieved ?	is_Achieved **true**	SGG_hasRelated_LG only ({LG4 , LG5})
Local_Goal	LG1	is_Achieved **false**		
	LG2	is_Achieved **true**		
	LG3	is_Achieved **true**		
	LG4	is_Achieved **true**		
	LG5	is_Achieved **true**		

The demonstration of the developed sGRI model in an SoS context including the two components; maintaining goals referential integrity and the ontology-based model with real examples from the Cancer Care case study is presented in the next section.

5.2 Demonstration of the sGRI Model: Cancer Care Case Study

In this section, the SoSGRI model, the developed strategic goal-management tool, and its associated ontology are applied to the KHCC Cancer Care case study with reference to their strategic plans and ADT policies, as part of the demonstration phase of the second DSRM process iteration. The following subsections introduce the instantiation and demonstration of these components of the research framework.

5.2.1 Demonstration of the SoSGRI Model

An instantiation of the developed database system and GRI model in SoS context is created by applying the KHCC Cancer Care case study. The Cancer Care global and local goals at multiple levels are linked to the corresponding constituent systems, actors, policy documents, i* models and KPIs. Figure 5.7 illustrates an example of maintaining goals referential integrity in a Cancer Care SoS arrangement by linking the constituent systems local goals with their corresponding sub-global and global goals while applying i* goal-oriented modelling.

Cancer Care SoS at KHCC comprises more than 40 constituent systems under different categories. See the model presented in Section 4.2.1.3, in Figure 4.7, which was validated with input from KHCC's stakeholders and domain experts. The local goals of these constituent systems were identified and linked back to their corresponding global goals at the SoS-level. Therefore, any addition, modification, or deletion of goals applied on any of the levels will be restricted by enforcing the goals referential integrity through the identified links between the tables shown in Figure 5.7.

ConstituentSystem 1..*

CS_ID	Name	Description	SoS_ID
CS1	Lab System		SoS1
CS2	Pharmacy System		SoS1
CS3	IT System		SoS1
...			
CSn			

Consists of

SoS 1

SoS_ID	Name	Description
SoS1	Cancer Care	
SoS2		
...		
SoSn		

Has

LocalGoal 1..*

LG_ID	Description	Actor1 (Depender)	Actor2 (Dependee)	Dependency Type	SGG_ID	CS_ID
$LG_1.CS_1$	Minimise lab waiting times	Patient	Lab	Soft goal (Quality)	SGG1	CS1
$LG_1.CS_2$	Minimise pharmacy waiting times	Patient	Pharmacy	Soft goal (Quality)	SGG1	CS2
$LG_1.CS_3$	Improve the process of following KPIs	QMO	IT Head	Task	SGG2	CS3
...						
$LG_n.CS_n$						

Contributes to satisfaction of

GlobalGoal 1 *

GG_ID	Description	Actor1 (Depender)	Actor2 (Dependee)	Dependency Type	SoS_ID
GG1	Foster person-centred care and safety	Patient	KHCC Care Providers	Hard goal	SoS1
GG2	Improve and sustain KHCC institutional core competencies	Patient	KHCC Care Providers	Hard goal	SoS1
GG3	Positioning KHCC as a leading regional centre	Patient	KHCC Care Providers	Hard goal	SoS1

Contributes to satisfaction of

SubGlobalGoal 1..*

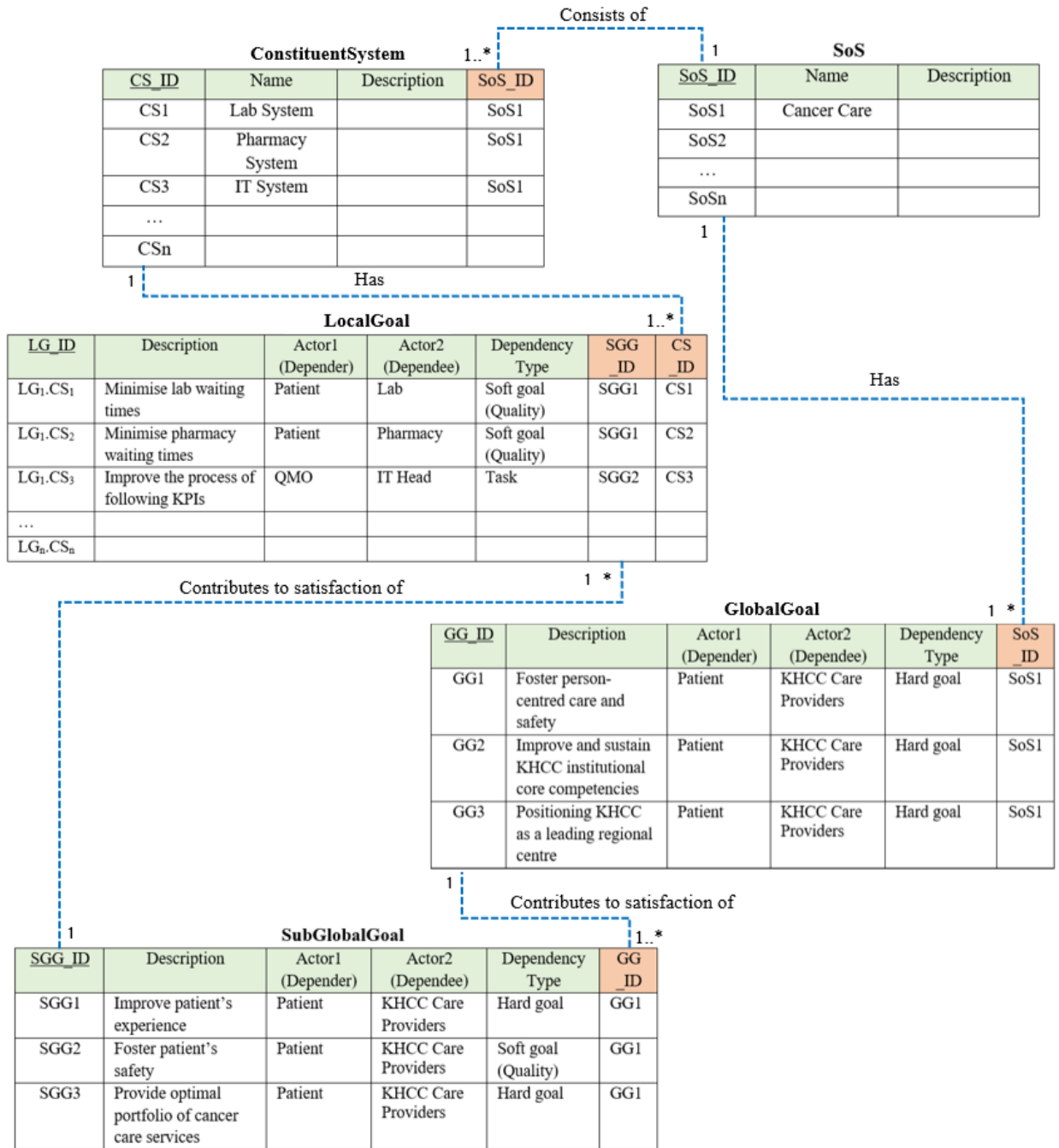| SGG_ID	Description	Actor1 (Depender)	Actor2 (Dependee)	Dependency Type	GG_ID
SGG1	Improve patient's experience	Patient	KHCC Care Providers	Hard goal	GG1
SGG2	Foster patient's safety	Patient	KHCC Care Providers	Soft goal (Quality)	GG1
SGG3	Provide optimal portfolio of cancer care services	Patient	KHCC Care Providers	Hard goal	GG1

Figure 5.7: Example of Maintaining Goals Referential Integrity in a Cancer Care SoS

With reference to the database schema presented in Figure 5.3 for i* strategic goal-oriented modelling in SoS context, and the example presented above in Figure 5.7 for Cancer Care GRI, and in particular, the two tables: **ConstituentSystem** and **LocalGoal**, examples of GRI constraints are presented in this subsection. The two tables are correlated to one another by means of a common column (i.e. CS_ID). For the purpose of simplifying the examples and

making them readable for the reader, only a subset of the tables' columns (properties) are used to demonstrate the GRI constraints. The applied schema of the two tables, the link between them, the primary key, and the foreign key constraints are highlighted in Figure 5.8, where the relationship cardinality between the parent and child tables is "one-to-many".
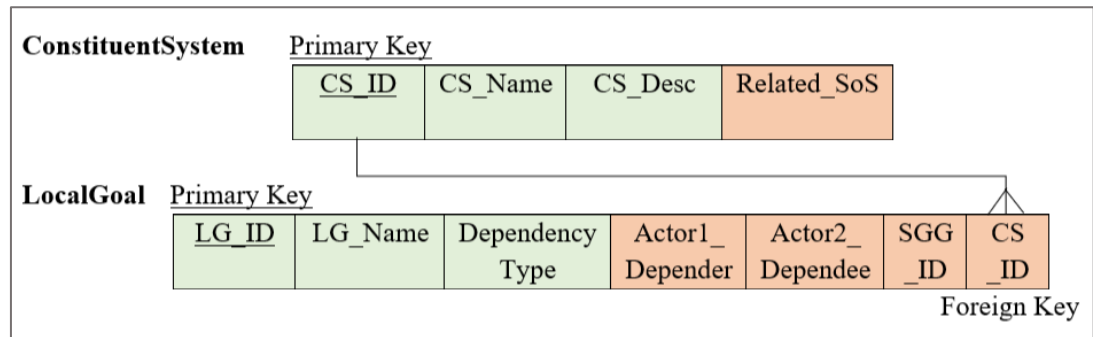

Figure 5.8: Database Schema for "ConstituentSystem" and "LocalGoal" Tables

A few records of the two database tables are described as follows:

ConstituentSystem (10, "Lab", "Laboratory System" , 1)

ConstituentSystem (20, "Pharmacy", "Pharmacy System" , 1)

ConstituentSystem (50, "Chemo", "Chemotherapy System" , 1)

LocalGoal (101, "Minimise lab waiting time", "Softgoal", "Patient", "Lab", "SGG1", 10)

LocalGoal (102, "Minimise pharmacy waiting time", "Softgoal", "Patient", "Pharmacy", "SGG1", 20)

Results of applying the Insert, Update, and Delete GRI constraints using test cases from the KHCC Cancer Care case study on the **ConstituentSystem** and **LocalGoal** tables, are shown as follows:

__Insert:__ The insert GRI constraint is checked through three cases: (a) the PK restriction in the parent table is breached when the PK already exists (i.e. not unique); (b) the FK restriction in the child table is breached when the related parent key does not exist; and (c) the record can be inserted into the table, if no constraints are violated.

(a) Insert into ConstituentSystem (20, "IT", "Information Technology System", 1)

➔ Primary key constraint violated – uniqueness of PK violated. Insert statement rejected.

(b) Insert into LocalGoal (103, "Minimise pharmacy waiting time", "Softgoal", "Patient", "IT Head", "SGG2", 40)

➔ Integrity constraint violated – parent key not found. Insert statement rejected.

(c) Insert into ConstituentSystem (30, "IT", "Information Technology System", 1)

➔ No constraints violated. Constituent system "IT" is added into table ConstituentSystem.

Update: The update GRI constraint is checked through three cases: (a) the PK restriction in the parent table is breached when the updated PK already exists; (b) the FK restriction in the child table is breached when the updated parent key does not exist; and (c) the record can be updated successfully, if no constraints are violated.

(a) Update table ConstituentSystem Set CS_ID = 20 Where CS_Name = "Lab"

➔ Primary key constraint violated – uniqueness of PK violated. Update statement rejected.

(b) Update table LocalGoal Set CS_ID = 60 Where LG_ID = 102

➔ Integrity constraint violated – parent key not found. Update statement rejected.

(c) Update table ConstituentSystem Set CS_ID = 40 Where CS_Name = "Lab"

➔ No constraints violated. CS_ID value is changed to 40 for constituent system "Lab".

Delete: The delete GRI constraint is checked through two cases: (a) the FK restriction is breached when there are corresponding records in the child table and the deletion cannot be performed; and (b) the record can be deleted from the table, if no constraints are violated.

(a) Delete from ConstituentSystem Where CS_Name = "Lab"

➔ Integrity constraint violated – child record found. Delete statement rejected.

(b) Delete from ConstituentSystem Where CS_Name = "Chemo"

➔ No constraints violated. Constituent system "Chemo" has been deleted.

5.2.2 Demonstration of the Developed Strategic Goal-Management Tool (Goal Satisfaction Panel)

The developed strategic goal-management tool, and in particular the "Goal satisfaction panel", that informs the satisfaction of goals at multiple levels, is demonstrated and tested using

the KHCC Cancer Care case study. Figure 5.9 shows the developed "Goal satisfaction panel" applied to real test cases of the Cancer Care case study at KHCC. KHCC's goals at multiple levels and KPIs are identified and linked together to inform the satisfaction of goals at all levels in an SoS context.

The example depicted in Figure 5.9 presents five levels of goals illustrating the global goal GG1 and its sub-goals which are all extracted from KHCC's strategic plans. GG1: "*Foster person-centred care and safety*" represents KHCC's first priority among three main priorities (i.e. Global Goals) at goal level 5. Two levels of sub-global goals (levels 4 and 3) and two levels of local goals (levels 2 and 1) are identified as shown in the associated tree graph. There could be as many levels as required of sub-global goals and local goals to achieve a global goal.
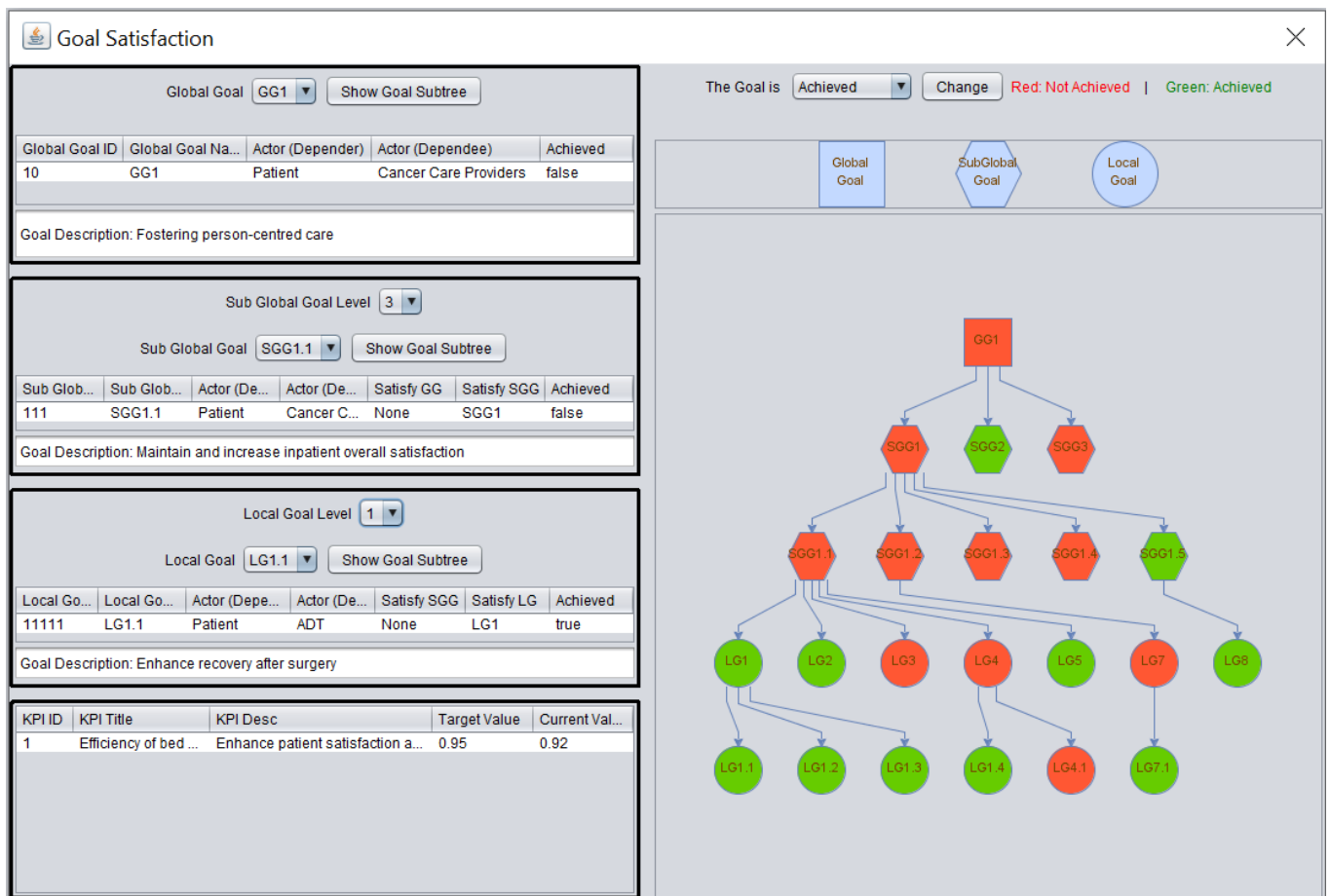
Figure 5.9: Goal Satisfaction for Cancer Care Goals in SoS Context (Strategic Goal-Management Tool)

As shown in Figure 5.9, information such as ID, name, description, achieved status, depender and dependee actors, are displayed for each goal. For sub-global and local goals, the

goal level is also displayed since multiple levels of these types of goals usually occur. Goals are also attached to other goals at upper levels that they contribute to the satisfaction of. Sub-global goals can satisfy global goals or other sub-global goals at an upper level, and local goals can satisfy sub-global goals or other local goals at upper levels but are not attached directly to global goals. Local goals are also attached to their corresponding KPIs, where KPI ID, title, description, target and current values are displayed.

As illustrated by Figure 5.10, stakeholders should determine the achievement value of the local goals (i.e. leaf goals) whether achieved or not. However, they are not allowed to change the achievement value for upper-levels goals, which will be inferred automatically. For simplification and enhancing readability, achieved goals appear in green in the graph, and unachieved ones appear in red. Also, different shapes are used to represent different goal levels; square for global goals, hexagon for sub-global goals, and circular for local goals.

Figure 5.10: Changing the "Achieved" Status for Goals (Strategic Goal-Management Tool)

5.2.3 Demonstration of the SoSGORE Ontology-Based Model

The developed SoSGORE ontology-based model is also instantiated and tested, as part of the demonstration phase of the second iteration of the DSRM process. Figure 5.11 demonstrates the instantiation of the ontology-based model to the KHCC Cancer Care case study. In the instantiation, individuals were identified for the ontology classes which were extracted from KHCC's strategic plans, policies and procedures and from the developed i* goal models. Figure 5.11 shows an example of inferring the satisfaction of global and sub-global goals using ontology axioms and reasoning with reference to the achievement value of local goals (i.e. is_Achieved property), and also inferring the linkages between goal levels by pointing out the parent goal of each sub-goal; hence, demonstrating the implementation of the goals referential integrity amongst goals using ontology. Figure 5.12 illustrates the goal-levels of the same example as a hierarchical goal network modelled using the i* framework.

The recursive relationship constructed among some ontology classes, in particular, between sub-global goals themselves and local goal themselves, is implemented using the developed ontology to represent multiple levels of the same goal type. As a result, the satisfaction of global and sub-global goals could be inferred for not only three levels of goals, but as many levels as needed adhering to the complexity and large-scale of SoS organisations.

In the example shown in Figures 5.11 and 5.12 stemming from KHCC's strategic plans, five levels of goals were identified as the following: Global goals, two levels of sub-global goals, and two levels of local goals. For instance, the global goal GG1: "***Foster person-centred care and safety***" consists of three sub-global goals: SGG1: "***Improve patient experience***", SGG2: "***Foster patient safety***", and SGG3: "***Provide the optimal portfolio of cancer care services***". SGG1 itself consists of five sub sub-global goals: SGG1.1: "***Maintain and increase overall inpatient satisfaction***" , SGG1.2: "***Maintain and increase inpatient satisfaction per each category***" , SGG1.3: "***Increase outpatient overall satisfaction***", SGG1.4: "***Maintain outpatient satisfaction per each category***" and SGG1.5: "***Minimise overall patient waiting times***". Each one of the sub sub-global goals consists of a set of local goals, and each local goal consists of other sub-local goals, as shown in Table 5.3, until all goals at all levels are able to be achieved.

By starting the ontology reasoner, the consistency of the ontology is checked first, and then the inferred properties are pointed out for the user. The inferred data property and object property

assertions for SGG1.1 are highlighted in yellow in Figure 5.11. First, it is inferred that SGG1.1: "*Maintain and increase overall inpatient satisfaction*" belongs to the parent sub-global goal SGG1: "*Improve patient experience*". Second, given that the local goals from LG1 to LG5, which are the sub-goals of SGG1.1, are all achieved, it's inferred that the sub-global goal SGG1.1 is achieved too. Similarly, the parent sub-global goal SGG1 is inferred to be achieved if child goals SGG1.2 and SGG1.3 are achieved too. A description of the instantiated ontology including main OWL classes and Cancer Care individuals is provided in Appendix C.
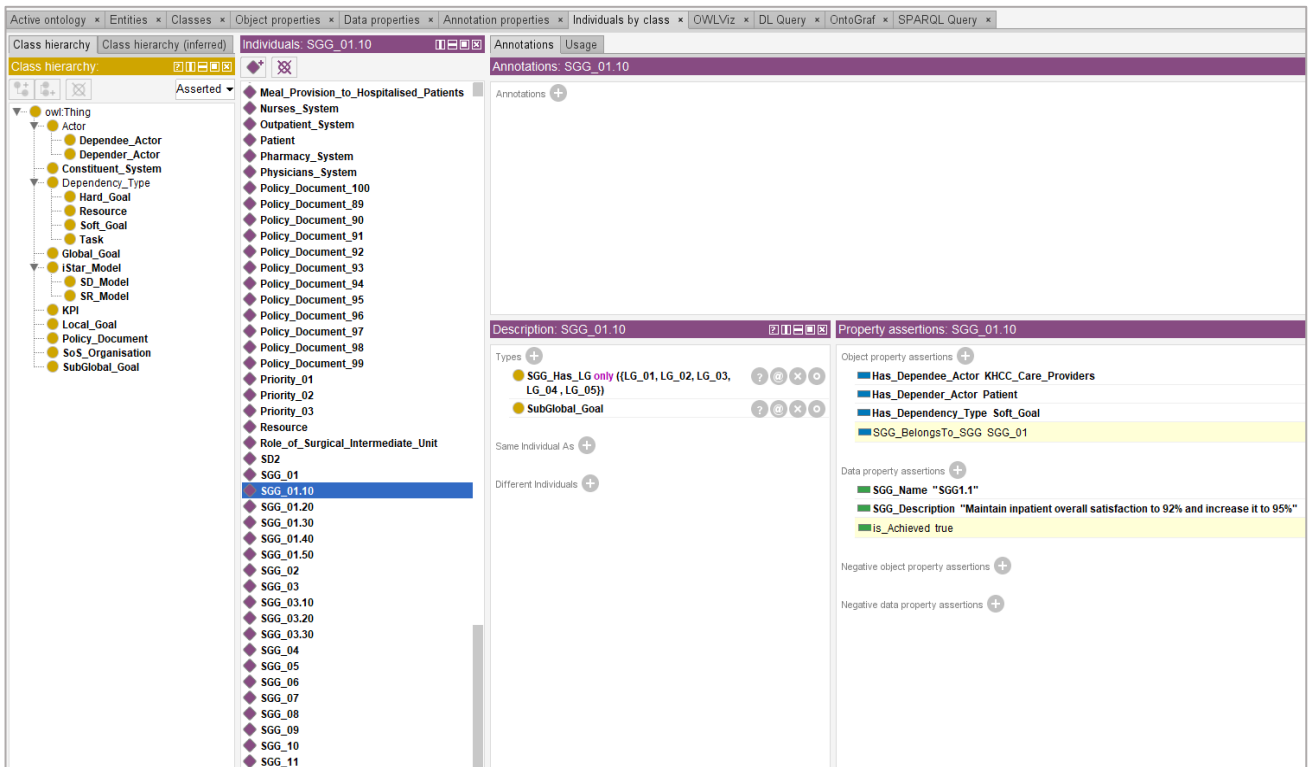

Figure 5.11: Inferring Goal Satisfaction in a Cancer Care SoS Using OWL Reasoning
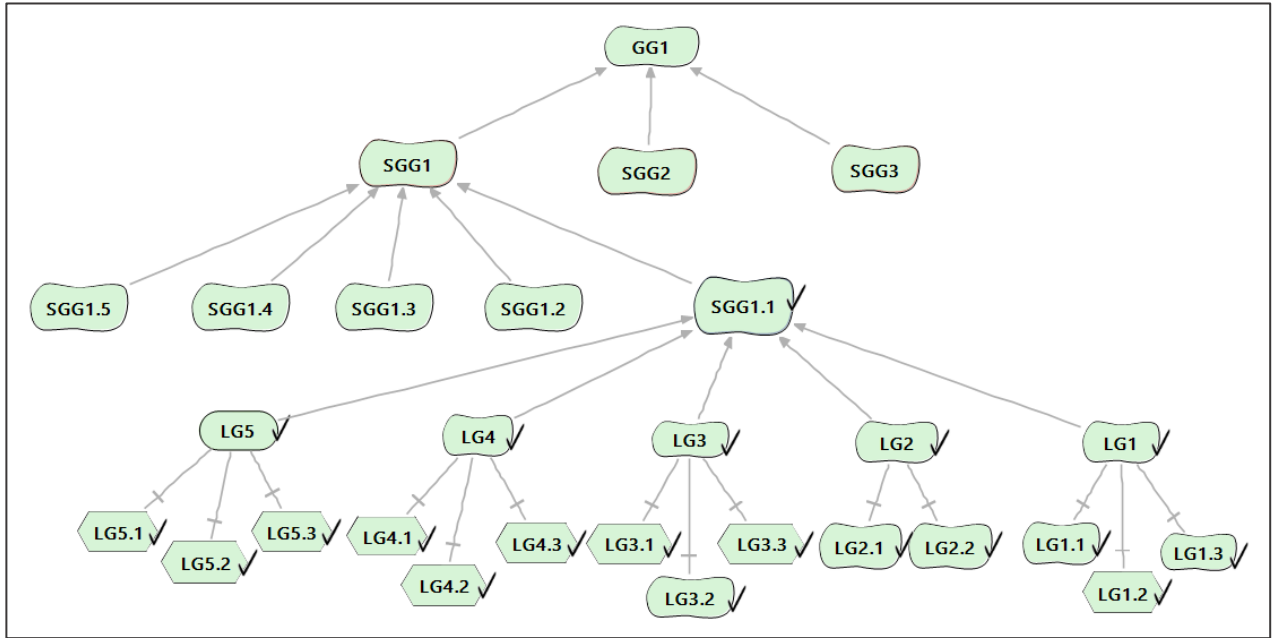(5-Goal Levels Cancer Care Example)

Figure 5.12: Hierarchical i* Goal Network Example of 5-Goal Levels in SoS Context

Table 5.3: OWL Classes and Individuals Representing Cancer Care Multiple Goal Levels
(5-Goal Levels Example)

OWL Class	Global_Goal	SubGlobal_Goal		Local_Goal	
Goal Level	Global Goals Level	Sub-Global Goals (Level 1)	Sub-Global Goals (Level 2)	Local Goals (Level 1)	Local Goals (Level 2)
Individuals	GG1: Fostering person-centric care and safety	SGG1: Improve patient experience	SGG1.1: Maintain inpatient overall satisfaction to 92% and increase it to 95%	LG1: Improve efficiency (Utilisation) of beds availability	LG1.1: Enhance early discharge of patients
					LG1.2: Action home care service
					LG1.3: Enhance recovery after surgery
				LG2: Improve food services	LG2.1: Improve food quality
					LG2.2: Enhance patient preferences

Individuals				LG3: Decrease environmental noise	LG3.1: Monitor and analyse noise levels
					LG3.2: Organise timing of cleaning to avoid patients' sleeping hours
					LG3.3: Educate staff on environmental noise
				LG4: Improve the satisfaction of the international patients	LG4.1: Provide fast track admission for international patients
					LG4.2: Provide escorting for international patients from admission to discharge
					LG4.3: Provide escorting for international patients from admission to discharge
				LG5: Launching person centred initiatives	LG5.1: Brainstorming person-centred initiatives
					LG5.2: Capture role models and highlight success stories
					LG5.3: Integrate the approved initiatives into inpatient services and processes
			SGG1.2: Maintain and increase inpatient satisfaction above 88%		

			SGG1.3: Increase outpatient overall satisfaction to 92%
			SGG1.4: Maintain outpatient satisfaction above 88%
			SGG1.5: Minimise overall patient waiting times
		SGG2: Foster patient safety	
		SGG3: Provide the optimal portfolio of cancer care services	

5.3 Evaluation of the sGRI Model with Input from the Cancer Care Case Study

In this section, the developed sGRI model in SoS context is evaluated with input from main KHCC's Cancer Care stakeholders and domain experts, by means of interviews, evaluation forms, and tool walk-throughs. The evaluation process of the sGRI model contains two main parts: (1) evaluating the *strategic goal-management tool* that informs the satisfaction and consistency of goals at multiple levels of an SoS arrangement, and (2) evaluating the *ontology-based model* for i* goal-oriented modelling in SoS context.

5.3.1 Evaluating the Developed Strategic Goal-Management Tool (Goal Satisfaction Panel)

The need behind developing the strategic goal-management tool arise while investigating the research case study and due to discovering that the approach applied currently at KHCC to follow on goals and KPIs progress does not follow a well-structured automated process. Data is kept in and retrieved from several resources and systems which are most stand-alone and not well interconnected, as well as paper-documents and spreadsheets. The current process

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consumes lots of effort and time and does not maintain the consistency of data if modifications occur due to the use of multiple unconnected resources.

Furthermore, linkages between KHCC strategic plans, including goals at different levels, are not well established with KPIs, policies and procedures, departments and constituent systems. Also, links between different stakeholders and their wished-for goals at all levels need to be clearly identified and established, in order to identify and resolve any conflicts or inconsistencies that may occur amongst these goals.

The developed proof-of-concept tool is demonstrated and tested by applying test cases stemming from KHCC's strategic plans, ADT policies, procedures, and KPIs. Interviews, walk-throughs and demonstration of the developed strategic goal-management tool were conducted with KHCC's domain experts to validate the tool. The following aspects and criteria were the main focus of the evaluation process: test and evaluate the tool's *usability* and *usefulness*; and evaluate the framework *effectiveness* in relation to the 3Cs (Zowghi and Gervasi, 2002): the *correctness, completeness* and *consistency* of the accomplished results.

According to (Iso, 1998), *usability* is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". *Usefulness* is "the extent to which a system's functions allow users to complete a set of tasks and achieve specific goals in a particular context of use" (MacDonald and Atwood, 2014).

Furthermore, regarding validating the tool with reference to the 3Cs, the results of applying the tool are considered *complete* if all the goal levels in SoS context are identified, all relationships between them and between other classes are modelled, and all goals related information is displayed. *Correctness* is validated by checking that linkages and relationships between goal levels and other entities in the SoS arrangement are built successfully and satisfaction of goals is inferred precisely. Finally, *consistency* is validated by ensuring that the SoSGRI model and its constraints are applied successfully through the tool, following the demonstration examples provided in Section 5.2.1

Interviews carried out to validate the tool with reference to the previous aspects are provided in Appendix D. The following results were concluded after the validation and evaluation process:

- The tool is designed to be reconfigurable. It allows reconfiguring new strategic goals at as many levels as required, and can expand to cover more policies and procedures other than ADT's and KHCC's strategic plans, as well as maintaining the changes of the current ones in a dynamic way.

- The tool establishes proper linkages and dependencies between the goals at different levels with their stakeholders, departments, and Cancer Care constituent systems by utilising the i* framework and its modelling concepts as an intermediate engine, which informs the *consistency* of goals identified by the model and their levels.

- The tool also links goals at multiple SoS levels properly with their corresponding KPIs, and keeps their *consistency* at all times.

- Inferring goal satisfaction for upper-level goals (i.e. global and sub-global goals) depending on information about lower-level goals (i.e. local goals) and identifying the linkages between goal levels was successfully accomplished for as many goal levels as needed for the SoS arrangement, as per the results revealed in the demonstration Section 5.2, in Figure 5.9 which inform their *correctness*.

- The tool can track the satisfaction and progress of all goals at multiple levels automatically, which inform achieving the *completeness* aspect.

- The tool allows stakeholders to modify the achievement value of lower-level leaf goals whenever it changes, but prohibits changing the achievement status of upper-level goals, which should be inferred, in a way that keeps the *consistency* of goals.

- Referential integrity and *consistency* of goals are maintained and kept at all times by applying the SoSGRI constraints and ensuring *correct* linkages between primary keys and foreign keys in the database, whether an addition, update or deletion occurs.

- The tool can also detect and resolve any conflicts or inconsistencies that may occur amongst goals at different levels which are owned by different stakeholders and departments, as will be discussed in Chapter 6.

- Using visual coloured tree graphs that represent the achieved and unachieved goals and their relationships enhances the *usability* and *usefulness* of the tool and readability to

users and stakeholders, and makes tracking the progress of goals much easier and effective compared to the previous approach.

- According to *usability* and *usefulness* aspects, the tool was found useful in GORE and SoS context in identifying goals at multiple levels, inferring and following their satisfaction and progress. However, as a proof-of-concept tool, users still need some adequate training to navigate and operate the tool features easily and effectively, and more enhancements should be applied as future work to deliver a full product to stakeholders.

5.3.2 Evaluating the SoSGORE Ontology-Based Model

The developed ontology-based model was also validated and evaluated by conducting interviews with KHCC's domain experts and demonstrating the ontology model and its results. Related interviews and evaluation forms are provided in Appendix E. The following results were concluded after the validation process:

- The standardisation of knowledge offered by the ontology-based model for SoS strategic goal modelling defines clearly the links between classes and in particular the global and local goals, with their depender and dependee actors, KPIs and constituent systems.

- The ontology-based model provides backward traceability of goals at multiple levels to their corresponding policy documents and i* goal models, which informs the *consistency* of goals and relationships identified by the model.

- The ontology-based model offers by means of reasoning the ability to check and maintain the *consistency* of the developed model, its OWL classes, individuals and its rules.

- The ontology-based model also provides the ability to infer linkages between multiple goal levels in the SoS arrangement.

- The ontology-based model facilitates monitoring and inferring by reasoning the satisfaction and progress of global and sub-global goals at the SoS-level of the organisation (upper-level goals) by following-up the satisfaction of their local goals at the CS-level.

5.4 Chapter Summary

This chapter presented the second layer of the research framework development: the sGRI model, its design and development, demonstration and evaluation. The sGRI model is a central artefact of the research framework, which combines the semantic representation of SoS strategic goal-oriented modelling using ontology with maintaining goals referential integrity and informing the satisfaction of goals in multiple SoS levels. This is an attempt to address the current challenges of managing goals in an SoS arrangement and to maintain the consistency and integrity of goals at both local and global levels.

The sGRI model has been demonstrated using the KHCC Cancer Care case study, which adheres to the complexity of the proposed framework and its internal artefacts and components. In a Cancer Care SoS arrangement, the sGRI model links the constituent systems local goals with their corresponding SoS global goals, maintains the integrity of goals at multiple levels, informs the satisfaction of goals and offers standardisation of knowledge provided by the ontology-based model for SoS strategic goal modelling.

Two main research questions: RQ2 and RQ3 were addressed and answered through this chapter. RQ2 is concerned about maintaining the referential integrity of the SoS goals and the constituent systems' goals at all levels of an SoS arrangement, and this was achieved by the developed GRI model and its outcomes with reference to the Cancer Care case study. And RQ3 is concerned about the ability to inform and verify the satisfaction of both the SoS-level goals and the constituent systems-level goals, and this was discussed and accomplished through this chapter by the proposed GRI model and the developed strategic goal-management tool, as well as the developed ontology-based model in an SoS context.

The research hypothesis, along with associated research questions and research objectives inform the evaluation of this research. As the research aim and objectives are incrementally evaluated through the iterations and phases of the DSRM process, the overall hypothesis of the research is evaluated and assessed through assessing the outcomes of answering the associated research questions. RQ1, RQ2, and RQ3 were answered so far, and the research hypothesis was partially proved through the thesis chapters following two iterations of the DSRM process phases and introducing the first and second layers of the research framework and their components.

In the next chapter, RQ4 is being answered, and its outcomes are being assessed by introducing the last layer of the research framework, the conflict management approach in SoS context, which contains two main components: goal conflict detection and goal conflict resolution. Thus, determining the extent to which the research hypothesis is fully correct, and the extent to which the research artefact is effective.

Chapter 6

The Research Framework OntoSoS.GORE – DSRM Third Iteration: Conflict Management Approach

Chapter 6 introduces and reflects on the third DSRM process iteration and the third and last layer of the OntoSoS.GORE research framework; with emphasis on the newly proposed conflict management approach in SoS context, including its two main processes: goal conflict detection and goal conflict resolution. Three DSRM process phases were applied to bring about this layer of the framework, including the design and development phase in Section 6.1, the demonstration phase in Section 6.2, and finally the evaluation phase in Section 6.3.

First, goal conflict detection is implemented by identifying positive and negative correlations amongst goals in order to identify conflicts at three levels of an SoS arrangement; amongst local goals at the constituent systems level, global goals at the SoS level, and between SoS global goals and CS local goals at different levels. Second, after a goal conflict is detected, conflict resolution is implemented by analysing the complexity of conflicting goals and comparing their goal level, priority and specificity values.

The development of a conflict management approach in SoS context aims at answering the fourth research question (RQ4) addressed in the thesis, which is formulated as follows:

RQ4: How to manage conflicts that may occur amongst goals at the following three levels:
  a) between individual local goals of constituent systems;
  b) between SoS global goals; and
  c) between SoS global goals and constituent systems local goals?

Following the development of the new conflict management approach, it has been instantiated and then evaluated with input from the Cancer Care case study at KHCC with reference to their strategic plans and ADT policies.

6.1   Design and Development of Conflict Management Approach in an SoS Context

Requirements engineers live in a world where conflicts are the rule, not the exception (Easterbrook, 1994; Van Lamsweerde, 2001). Goals have been recognised to provide the roots for detecting conflicts amongst requirements and resolving them eventually. In SoS arrangements, conflicts may occur amongst goals in the local level between several constituent systems, as they may occur amongst goals in the SoS-level, and also between goals in the SoS-level and those in the CS-level; and therefore, the need for adapting conflict management mechanisms. Conflict management consists of two main stages: conflict detection and conflict resolution (Van Lamsweerde, 2001).

Van Lamsweerde (2001) pointed out some conflict management strategies in the GORE field such as the prioritisation of conflicting goals, appealing to compromises, or reconciling a goal conflict through negotiation between concerned stakeholders to reach a mutually agreed set of goals, constraints, and alternatives. However, the conflict management approach developed through this research proposes an automated process for goal conflict detection and resolution in an SoS context.

This section describes the design and development phase of the third layer of the research framework, regarding applying the newly developed conflict management approach in SoS goal-oriented modelling, including the two main components: implementing goal conflict detection and goal conflict resolution in an SoS context.

6.1.1   Goal Conflict Detection in an SoS Context

Conflicts amongst goals at the different levels of an SoS arrangement may arise for several reasons, such as (Cavalcante et al., 2015): (i) the existence of a broader range of stakeholders including stakeholders at the SoS level and at the constituent system level, each having their own objectives and interests; (ii) conflicts in the relationships between constituent systems and the SoS arrangement; (iii) conflicts arisen from interactions among constituent systems; and (iv) knowing that a given constituent system might simultaneously belong to more than one SoS.

In an SoS arrangement, goal conflicts may occur at three levels: (i) conflicts occurring at the CS-level amongst individual local goals of constituent systems; (ii) conflicts occurring at the

SoS-level amongst high-level global goals of the entire SoS; and (iii) conflicts occurring between the local and global levels amongst constituent systems' local goals and SoS global goals.

Goal conflicts could be described in terms of conditions, or resources of operators that attempt to achieve a goal; a relationship of supports/detracts (i.e., +/-) amongst goals, that simply summarises the details on how goals interact, has been found to be a practical solution for conflict detection (Robinson et al., 2003). Table 6.1 summarises the types of goal correlations found in the requirements engineering related literature, where correlation types are divided into positive, negative, unspecified, and neutral.

Table 6.1: Types of Goal Correlations (Adapted from Robinson et al., 2003) © ACM 2003

Correlation Type	Description	Example
Positive correlation	Increasing the satisfaction of goal G_i increases the satisfaction of G_j	Make, Help, Some, +, ++
Negative correlation	Increasing the satisfaction of goal G_i decreases the satisfaction of G_j	Break, Hurt, Contradictory, -, --
Unspecified correlation	Changing the satisfaction of goal G_i has an unspecified effect on the satisfaction of G_j	Impacts on, Interdependent
No correlation	Increasing the satisfaction of goal G_i does not affect the satisfaction of G_j	Neutral

The supports/detracts relationship between goals is expressed by contribution links in the i* language. However, a limitation has been discovered through this research in the i* goal modelling regarding the semantics of contribution links. More specifically, contribution links are established to link tasks to softgoals indicating how performing specific tasks contribute to achieving softgoals (positively or negatively), but its interpretation does not currently cover other cases such as linking dependencies of the same type to each other. Thus, this research suggests extending the semantics and the use of i* contribution links to link all types of dependencies to each other (i.e. goals, softgoals, tasks, and resources); and hence facilitates identifying different types of correlation between goals.

This research focuses on the first two correlation types, i.e. positive and negative, for clarity in identifying relationships amongst goals; and hence identifying any conflicting goals,

depending on the relationship type whether it is "supports" or "detracts". The unspecified correlation type is not tackled in this research due to the lack of information it gives regarding detecting conflicts, and the same applies for no correlation type. Therefore, a goal which supports the satisfaction of another goal has a positive correlation with that goal, and in this case, no conflict occurs. On the other hand, if a goal detracts from the satisfaction of another goal, a negative correlation type is identified between them; and hence, a goal conflict is detected.

Conflict detection is implemented after modelling the organisation's goals using the i* framework and then discovering the positive or negative relationships between them. Here, the i* goal modelling is an intermediate engine which paves the way for the conflict detection process to be applied, starting with modelling and recognising the different types of correlations amongst goals.

As part of the developed strategic goal-management tool, a "Conflict Management Panel" with its two parts: conflict detection and conflict resolution, is proposed. Implementing the conflict detection process for multiple goal levels in an SoS context depends on the correlation type value amongst goals, where a negative correlation type implies the existence of a goal conflict. Three types of goal conflict are identified: (i) conflicts that occur amongst local goals at the CS-level; (ii) conflicts that occur amongst sub-global goals at the SoS-level; and (iii) conflicts that occur between local and sub-global goals (i.e. between the CS and SoS levels).

The output of the conflict detection process and the input to conflict resolution is a set called the *"Goal_Conflict_Set".* In order to implement the proposed goal conflict detection approach for the aforementioned three cases of goal conflict, pseudocode-based algorithms are developed. First, a parent (general) conflict detection algorithm *"Algorithm 1"* shown in Figure 6.1 is developed to (1) identify the type of conflict; (2) call the suitable conflict detection algorithm depending on the conflict type; and then (3) return the *"Goal_Conflict_Set"* which contains all Goal Conflicts *GCs*, where each Goal Conflict GC_j consists of two goals; G_x, G_y and their corresponding depender and dependee actors.

Then, child algorithms are developed depending on the conflicting goals' types as follows: *"Algorithm 1.1"* aims at detecting conflicts amongst local goals at the CS-level; *"Algorithm 1.2"* detects conflicts amongst sub-global goals at the SoS-level; and *"Algorithm 1.3"* is developed

to detect conflicts between local goals at the CS-level and sub-global goals at the SoS-level. The developed algorithms 1.1, 1.2, and 1.3 are demonstrated in Figures 6.2, 6.3, and 6.4, respectively.
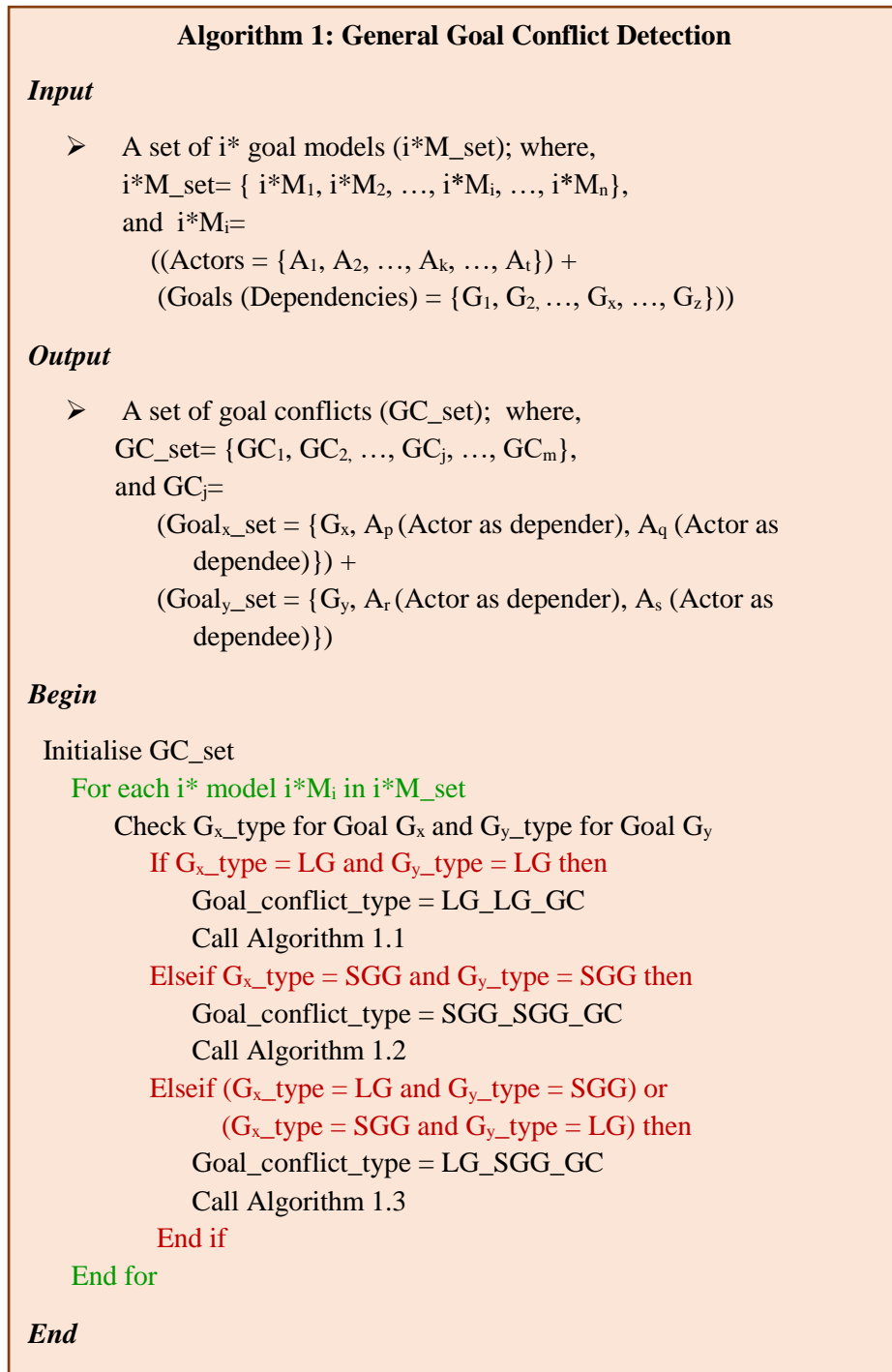
Algorithm 1: General Goal Conflict Detection

Input

➤ A set of i* goal models (i*M_set); where,
  i*M_set= { i*M$_1$, i*M$_2$, …, i*M$_i$, …, i*M$_n$},
  and i*M$_i$=
    ((Actors = {A$_1$, A$_2$, …, A$_k$, …, A$_t$}) +
    (Goals (Dependencies) = {G$_1$, G$_2$, …, G$_x$, …, G$_z$}))

Output

➤ A set of goal conflicts (GC_set); where,
  GC_set= {GC$_1$, GC$_2$, …, GC$_j$, …, GC$_m$},
  and GC$_j$=
    (Goal$_x$_set = {G$_x$, A$_p$ (Actor as depender), A$_q$ (Actor as
      dependee)}) +
    (Goal$_y$_set = {G$_y$, A$_r$ (Actor as depender), A$_s$ (Actor as
      dependee)})

Begin

Initialise GC_set
  For each i* model i*M$_i$ in i*M_set
    Check G$_x$_type for Goal G$_x$ and G$_y$_type for Goal G$_y$
      If G$_x$_type = LG and G$_y$_type = LG then
        Goal_conflict_type = LG_LG_GC
        Call Algorithm 1.1
      Elseif G$_x$_type = SGG and G$_y$_type = SGG then
        Goal_conflict_type = SGG_SGG_GC
        Call Algorithm 1.2
      Elseif (G$_x$_type = LG and G$_y$_type = SGG) or
          (G$_x$_type = SGG and G$_y$_type = LG) then
        Goal_conflict_type = LG_SGG_GC
        Call Algorithm 1.3
      End if
  End for

End

Figure 6.1: Algorithm 1 - General Goal Conflict Detection in SoS Context

Algorithm 1.1: LG_LG Conflict Detection

Input

> A set of local goals (LG_set) + a set of actors (Actor_set); where
> > LG_set= {LG_1, LG_2, …, LG_x, …, LG_z} and
> > Actor_set = {A_1, A_2, …, A_k, …, A_t}

Output

> A set of local goals conflicts (LG_LG_GC_set); where
> > LG_LG_GC_set = {LG_LG_GC_1, LG_LG_GC_2, …,
> > > LG_LG_GC_j, …, LG_LG_GC_m}
> > and LG_LG_GC_j=
> > > (LG_x_set = {LG_x, A_p (Actor as depender), A_q (Actor as
> > > > dependee)})
> > > + (LG_y_set = {LG_y, A_r (Actor as depender), A_s (Actor as
> > > > dependee)})

Begin

  Initialise LG_LG_GC_set
    For each LG_x and LG_y in LG_detracts_LG table where
    LG_x_LG_y_ Correlation_type= "-"
        If LG_x_set is not added to LG_LG_GCj then
            Add LG_x_set to LG_LG_GCj
        Endif
        If LG_y_set is not added to LG_LG_GCj then
            Add LG_y_set to LG_LG_GCj
        Endif
        If LG_LG_GCj is not added to LG_LG_GC_set then
            Add LG_LG_GCj to LG_LG_GC_set
        End if
      Save LG_LG_GC_set
    End for
  Return LG_LG_GC_set

End

Figure 6.2: Algorithm 1.1 - Conflict Detection Amongst Local Goals at the CS-Level

Algorithm 1.2: SGG_SGG Conflict Detection

Input

> A set of sub-global goals (SGG_set) + a set of actors (Actor_set); where
> SGG_set= {SGG_1, SGG_2, …, SGG_x, …, SGG_z}and
> Actor_set = {A_1, A_2, …, A_k, …, A_t}

Output

> A set of sub-global goals conflicts (SGG_SGG_GC_set); where
> SGG_SGG_GC_set = {SGG_SGG_GC_1, SGG_SGG_GC_2, …,
> SGG_SGG_GC_j, …, SGG_SGG_GC_m}
> and SGG_SGG_GC_j=
> (SGG_x_set = {SGG_x, A_p (Actor as depender), A_q (Actor as
> dependee)})
> + (SGG_y_set = {SGG_y, A_r (Actor as depender), A_s (Actor as
> dependee)})

Begin

  Initialise SGG_SGG_GC_set
    For each SGG_x and SGG_y in SGG_detracts_SGG table where
    SGG_x_SGG_y_Correlation_type= "-"
        If SGG_x_set is not added to SGG_SGG_GCj then
           Add SGG_x_set to SGG_SGG_GCj
        Endif
        If SGG_y_set is not added to SGG_SGG_GCj then
           Add SGG_y_set to SGG_SGG_GCj
        Endif
        If SGG_SGG_GCj is not added to SGG_SGG_GC_set then
           Add SGG_SGG_GCj to SGG_SGG_GC_set
        End if
      Save SGG_SGG_GC_set
    End for
  Return SGG_SGG_GC_set

End

Figure 6.3: Algorithm 1.2 - Conflict Detection Amongst Sub-Global Goals at the SoS-Level

<div style="border:1px solid">

Algorithm 1.3: LG_SGG Conflict Detection

Input

➢ A set of local goals (LG_set) + a set of sub-global goals (SGG_set) +
a set of actors (Actor_set); where
   LG_set= {LG_1, LG_2, …, LG_x, …, LG_z} and
   SGG_set= {SGG_1, SGG_2, …, SGG_y, …, SGG_v}and
   Actor_set = {A_1, A_2, …, A_k, …, A_t}

Output

➢ A set of local goals_sub-global goals conflicts (LG_SGG_GC_set); where
   LG_SGG_GC_set = {$LG\_SGG\_GC_1$, $LG\_SGG\_GC_2$, …,
      $LG\_SGG\_GC_j$, …, $LG\_SGG\_GC_m$}
   and $LG\_SGG\_GC_j$=
      (LG_x_set = {LG_x, A_p (Actor as depender), A_q (Actor as
         dependee)})
      + (SGG_y_set = {SGG_y, A_r (Actor as depender), A_s (Actor as
         dependee)})

Begin

Initialise LG_SGG_GC_set
   For each LG_x and SGG_y in LG_detracts_SGG table where
   LG_x_SGG_y_Correlation_type= "-"
      If LG_x_set is not added to LG_SGG_GCj then
         Add LG_x_set to LG_SGG_GCj
      Endif
      If SGG_y_set is not added to LG_SGG_GCj then
         Add SGG_y_set to LG_SGG_GCj
      Endif
      If LG_SGG_GCj is not added to LG_SGG_GC_set then
         Add LG_SGG_GCj to LG_SGG_GC_set
      End if
      Save LG_SGG_GC_set
   End for
Return LG_SGG_GC_set

End

</div>

Figure 6.4: Algorithm 1.3 - Conflict Detection Amongst Local Goals and Sub-Global Goals

As appears in Figure 6.3, Algorithm 1.2, conflicts are detected at the SoS-level amongst sub-global goals only, and not also amongst global goals. The rationale behind that refers to the organisation's global goals being at the most conceptual goal level representing the highest

priorities or missions at the organisation which are usually very few and precisely specified, and unlikely to be conflicting. This assumption was further substantiated after investigating the Cancer Care case study at KHCC, and finding out three general priorities that play the role of the organisation's global goals with reference to their strategic plans. These three global goals are well-articulated, and identified at the top of the pyramid of the highest conceptual level of the organisation's hierarchical goal structure, and never conflicting. Thus, conflicts may occur at lower goal levels of the SoS arrangement amongst sub-global goals and local goals.

The previous goal conflict detection approach and associated algorithms are demonstrated and applied to real examples of the KHCC Cancer Care case study through the demonstration phase in Section 6.2. The next step once a goal conflict is detected is applying a conflict resolution approach to resolve the conflict, which is discussed in the next subsection.

6.1.2 Goal Conflict Resolution in an SoS Context

Conflict resolution process is the second phase of applying conflict management and aims at providing mechanisms and strategies either to: (1) resolve conflicting goals that may occur at any level of the SoS arrangement, or (2) to mitigate conflicts. Conflict resolution could be achieved by returning to the stakeholders who own the conflicting goals to see whether they would be prepared to negotiate and accept a compromise.

Five approaches for resolving conflicts and their related general procedures, strategies, and outcomes were proposed in (Moore, 2014). These are: (1) *avoidance* with a nonresolution outcome; (2) *competition* with win-lose outcomes; (3) *compromise* with an outcome of shared benefits and losses; (4) *accommodation* with an outcome that involves one or more parties giving in and meeting another's interests; and (5) *collaboration* with a win-win outcome that provides mutual benefits or gains for all involved.

In (Robinson et al., 2003), another eight conflict resolution methods were presented, namely: relaxation, refinement, compromise, restructuring, re-enforcement, re-planning, postponement and abandonment. All of these approaches and mechanisms of conflict resolution are not automated and require the full involvement of stakeholders. Depending on the conflict situation, type and impact of conflict, stakeholders choose which approach to be applied in order to resolve the conflict.

In production systems, two conflict resolution strategies called LEX and MEA were provided by Official Production System, version 5 (OPS5) (Forgy, 1981). These strategies contain rules which are applied in order to find productions that dominate others, and with more specific Left-Hand Sides (LHSs); (i.e. the condition part of productions). More specific productions are therefore chosen when they are available. Specificity is an attribute that is being borrowed from production systems, reused in this research, and attached to goals in order to calculate the conflict resolution outcome as will be discussed in this section.

In this research, we propose a structured approach with a process that has been automated to implement goal conflict resolution in SoS arrangements in the context of the i* framework. Once a goal conflict is identified and detected amongst two goals by means of correlation type value and applying the proposed conflict detection approach, the conflict should be resolved.

The complexity of goals associated in conflict is analysed in order to determine the conflict resolution outcome and the goal that dominates others and should be applied amongst the conflicting goals. Following this approach, the goal conflict is resolved automatically, rather than only applying the traditional resolution methods and strategies, which need full involvement of stakeholders and do not give automated solutions. Three significant factors are identified in order to analyse the complexity level of goals, and determine the conflict resolution outcome:

1) **Goal Priority**:

Priority is an important attribute that can be attached to goals and often used for resolving conflicts amongst goals (Van Lamsweerde, 2001). Prioritisation of goals is a strategy that allows resolving the conflicts that might appear between two goals by selecting the goal with the highest priority. This could be achieved by assigning a specific weight to each goal priority value. Stakeholders are usually responsible for determining the priority value of goals in their organisations, whether it is high, medium, or low. In this research, values of '**3**', '**2**', and '**1**' are assigned to goals of high, medium, and low priority, respectively.

2) **Goal Level:**

Goal level, whether it is within the global, sub-global or local level also affects the conflict resolution outcome and should be determined. The highest the goal level is, the highest is its outcome and value. Each goal level is given a specific weight depending on the number of goal

levels involved. Assuming the number of goal levels is *m*, then a value of '*m*' is given to global goals which indicates the highest goal-level value. Then, a value of '*m-1*' is given to the subsequent lower level (i.e. first sub-global goals level), until reaching a value of '*1*' assigned to the lowest local level goals.

3) **Goal Specificity**:

Goal specificity refers to the level of precision and explicitness of the goal (Wofford, 1982; Leung and Liu, 2003). Specificity is a rank or weight given to goals according to certain rules, to determine which goal is more specific and ultimately applied in the case of conflict resolution (Data, 2008). The determination of goal specificity for the management of conflicts among stakeholders and their goals is fundamental in order to determine the best value, and then to resolve the conflict by consensus or compromise. A higher degree of goal specificity and greater conflict resolution outcomes can eventually improve stakeholders' satisfaction.

In this research, in order to calculate goal specificity, the number of relationships that each goal has with other classes (entities), which informs how specific the goal is, should be determined. The number of "supports" and "detracts" relationships with other goals, the number of related constituent systems, policy documents, and KPIs should be identified. For instance, if a goal affects more goals, is connected to more policy documents and linked to more KPIs in the organisation, then the goal has higher specificity value.

Calculating goal specificity value varies depending on the level of conflict that may occur within the SoS arrangement. For instance, local goals have direct relationships with constituent systems, KPIs, and policy documents, however, global and sub-global goals have not. Goal specificity value is calculated as follows:

(i) If a goal conflict occurs between two local goals (at the CS-level), then:

Goal Specificity =
    no. of relationships with constituent systems
+ *no. of related KPIs*
+ *no. of relationships with policy documents*
+ *no. of relationships with lower-level goals (no. of sub-goals)*
+ *no. of supports relationships with higher-level goals*   *(1)*

(ii)   If a goal conflict occurs between two sub-global goals (at the SoS-level), then:

Goal Specificity =
    no. of relationships with lower-level goals (no. of sub-goals)
  + no. of supports relationships with higher-level goals   *(2)*

(iii)   If a goal conflict occurs between a local goal and a sub-global goal (between the CS and SoS levels), then:

Goal Specificity =
    no. of relationships with lower-level goals (no. of sub-goals)
  + no. of supports relationships with higher-level goals   *(3)*

After determining the value of each of the previous factors for the conflicting goals, the complexity value of each goal is calculated depending on their priority, goal level, and specificity value, as well as the number of negative (i.e. detracts) relationships with other goals, as shown in (4) below:

Goal Complexity = Goal's priority weight
                + Goal's level weight
                + Goal's specificity value
                – no. of detracts relationships with other goals   *(4)*

Questions may arise regarding the qualitative side of KPIs and its effect on goal specificity, rather than only measuring their quantitative side (i.e. number of KPIs). Although the proposed conflict resolution approach is related currently to the number of KPIs, however, further research is still needed to investigate their qualitative side, how critical the KPI is, and what are its implications or priority compared to other KPIs.

Three cases might result after analysing the complexity of conflicting goals and applying the previous conflict resolution approach:

a- If the conflicting goals have different complexity values, then the conflicting goal with the highest complexity value has the highest conflict resolution outcome and will be selected.

b- If both conflicting goals have the same complexity value, then each factor is tested by itself in the following order: goal priority, goal level, then goal specificity. The goal that

has a higher value of any of these factors first has the highest conflict resolution outcome and dominates the other goal.

c- If conflicting goals have the same weight of priority, specificity and goal level, hence, they have the same conflict resolution outcome, in this case, the system advises the stakeholders owning the conflicting goals to negotiate in order to resolve the conflict. One of the previously mentioned manual conflict resolution approaches could be applied, and in particular, the *compromise* approach where participants cooperate and are willing to negotiate and reach an agreement in which gains, and losses are shared in a mutually acceptable manner. Each gets some of what they want, but also gives up some benefits in order to reach an agreement. Perhaps one new goal would satisfy both stakeholders, to a reasonable extent, a process known as satisficing (Van Lamsweerde, 2001).

Figures 6.5-6.8 present the developed algorithms for implementing the proposed conflict resolution approach in SoS context. Figure 6.5 presents the general parent conflict resolution algorithm named *"Algorithm 2"* which aims at identifying the type of conflict resolution approach needed depending on the type of conflict, and returning the conflict resolution outcome for conflicting goals as well as the resolution result.

Figures 6.6, 6.7, and 6.8 describe the child conflict resolution algorithms developed depending on the type of goal conflict as follows: *"Algorithm 2.1"* aims at resolving conflicts amongst local goals at the CS-level; *"Algorithm 2.2"* resolves conflicts amongst sub-global goals at the SoS-level; and *"Algorithm 2.3"* resolves conflicts between local goals at the CS-level and sub-global goals at the SoS-level, respectively.

The results of applying the newly proposed conflict detection and conflict resolution approaches to the KHCC Cancer Care case study are presented through the demonstration phase in the next section.

Algorithm 2: General Goal Conflict Resolution

Input

➢ A set of goal conflicts (GC_set); where,
GC_set= {GC_1, GC_2, …, GC_j, …, GC_m},
and GC_j=
(Goal$_x$_set = {G_x, A_p (Actor as depender), A_q (Actor as dependee)}) +
(Goal$_y$_set = {G_y, A_r (Actor as depender), A_s (Actor as dependee)})

Output

➢ A set of goal conflict resolutions (CR_set); where,
CR_set= {CR_1, CR_2, …, CR_j, …, CR_m},
and CR_j=
Goal$_x$ conflict resolution outcome +
Goal$_y$ conflict resolution outcome +
Resolution result

Begin

Initialise CR_set
For each Goal Conflict GC_i in GC_set
Check G_x_type for Goal G_x and G_y_type for Goal G_y
If G_x_type = LG and G_y_type = LG then
Goal_conflict_resolution_type = LG_LG_CR
Call Algorithm 2.1
Elseif G_x_type = SGG and G_y_type = SGG then
Goal_conflict_resolution_type = SGG_SGG_CR
Call Algorithm 2.2
Elseif (G_x_type = LG and G_y_type = SGG) or
(G_x_type = SGG and G_y_type = LG) then
Goal_conflict_resolution_type = LG_SGG_GC
Call Algorithm 2.3
End if
End for

End

Figure 6.5: Algorithm 2 - General Goal Conflict Resolution in SoS Context

Algorithm 2.1: LG_LG Conflict Resolution

Input

➢ A set of local goals conflicts (LG_LG_GC_set); where
LG_LG_GC_set = {LG_LG_GC$_1$, LG_LG_GC$_2$, …, LG_LG_GC$_j$, …, LG_LG_GC$_m$}
and LG_LG_GC$_j$=
(LG$_x$_set = {LG$_x$, A$_p$ (Actor as depender), A$_q$ (Actor as dependee)})
+ (LG$_y$_set = {LG$_y$, A$_r$ (Actor as depender), A$_s$ (Actor as dependee)})

Output

➢ A set of local goal conflict resolutions (LG_LG_CR_set); where,
LG_LG_CR_set= { LG_LG_CR$_1$, LG_LG_CR$_2$, …, LG_LG_CR$_j$, …, LG_LG_CR$_m$},
and LG$_x$_LG$_y$_CR$_j$= LG$_x$ conflict resolution outcome (LG$_x$_CRO) +
LG$_y$ conflict resolution outcome (LG$_y$_CRO) +
Conflict resolution result (CRR)

Begin

Initialise LG_LG_CR_set
  For each LG$_x$_LG$_y$_GC in LG_LG_GC_set
    If LG$_x$_LG$_y$_CR is not added to LG_LG_CR_set then
    LG$_x$_CRO = LG$_x$ level value + LG$_x$ priority value + LG$_x$ no. of related KPIs +
      LG$_x$ no. of related CSs + LG$_x$ no. of related policy documents + LG$_x$ no. of sub-goals +
      LG$_x$ no. of parent-goals – LG$_x$ no. of detracts relationships

    LG$_y$_CRO = LG$_y$ level value + LG$_y$ priority value + LG$_y$ no. of related KPIs +
      LG$_y$ no. of related CSs + LG$_y$ no. of related policy documents + LG$_y$ no. of sub-goals +
      LG$_y$ no. of parent-goals – LG$_y$ no. of detracts relationships

      If LG$_x$_CRO > LG$_y$_CRO then
        CRR = "LG$_x$ has higher conflict resolution outcome than LG$_y$"
      Endif
      ElseIf LG$_y$_CRO > LG$_x$_CRO then
        CRR = "LG$_y$ has higher conflict resolution outcome than LG$_x$"
      Endif
      ElseIf LG$_x$_CRO = LG$_y$_CRO then
        CRR = "LG$_x$ and LG$_y$ has the same conflict resolution outcome"
      End if
    LG$_x$_LG$_y$_CR = LG$_x$_CRO + LG$_y$_CRO + CRR
    Add LG$_x$_LG$_y$_CR to LG_LG_CR_set
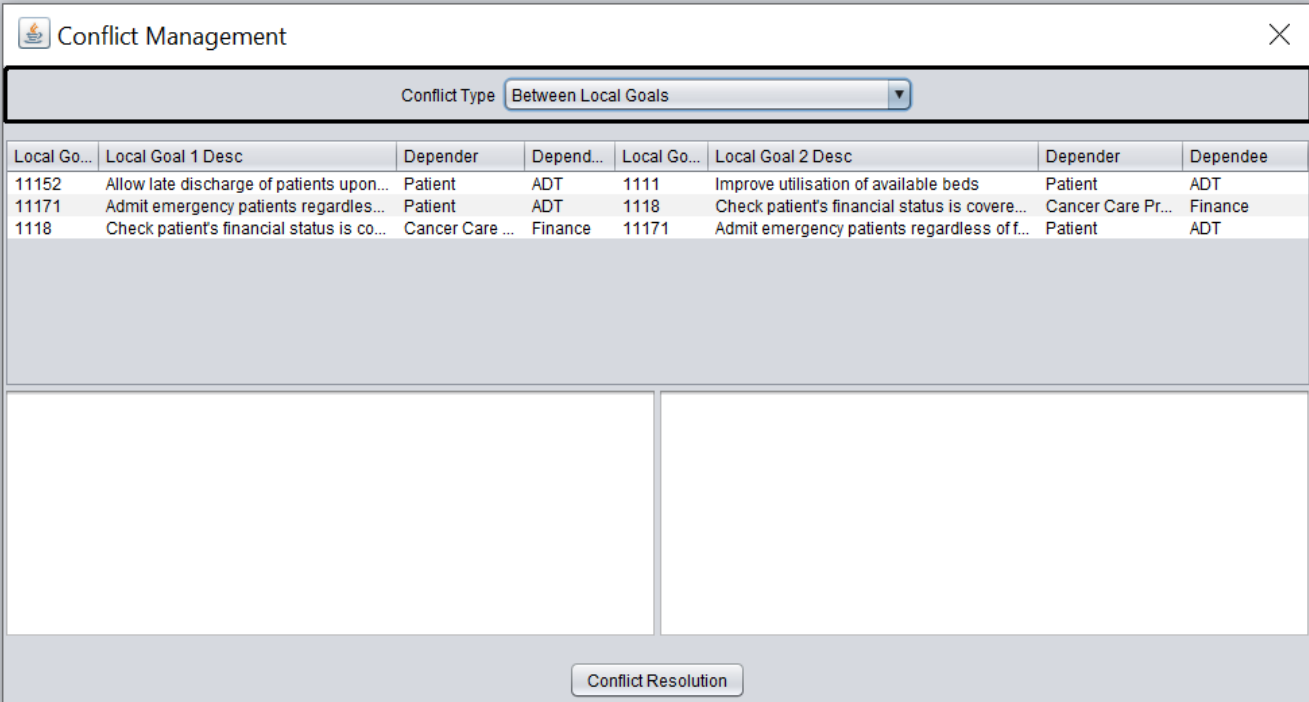   Save LG_LG_CR_set
    End if
  End for
Return LG_LG_CR_set
End

Figure 6.6: Algorithm 2.1 - Conflict Resolution Amongst Conflicting Local Goals at the CS-Level

Algorithm 2.2: SGG_SGG Conflict Resolution

Input

➤ A set of sub global goals conflicts (SGG_SGG_GC_set); where

SGG_SGG_GC_set = {SGG_SGG_GC$_1$, SGG_SGG_GC$_2$, ..., SGG_SGG_GC$_j$, ...,

SGG_SGG_GC$_m$}

and SGG_SGG_GC$_j$=

(SGG$_x$_set = {SGG$_x$, A$_p$ (Actor as depender), A$_q$ (Actor as dependee)})

+ (SGG$_y$_set = {SGG$_y$, A$_r$ (Actor as depender), A$_s$ (Actor as dependee)})

Output

➤ A set of sub global goals conflict resolutions (SGG_SGG_CR_set); where,

SGG_SGG_CR_set= { SGG_SGG_CR$_1$, SGG_SGG_CR$_2$, ..., SGG_SGG_CR$_j$, ...,

SGG_SGG_CR$_m$},

and SGG$_x$_SGG$_y$_CR$_j$= SGG$_x$ conflict resolution outcome (SGG$_x$_CRO) +

SGG$_y$ conflict resolution outcome (SGG$_y$_CRO) +

Conflict resolution result (CRR)

Begin

Initialise SGG_SGG_CR_set

For each SGG$_x$_SGG$_y$_GC in SGG_SGG_GC_set

If SGG$_x$_SGG$_y$_CR is not added to SGG_SGG_CR_set then

SGG$_x$_CRO = SGG$_x$ level value + SGG$_x$ priority value + SGG$_x$ no. of sub-goals +

SGG$_x$ no. of parent-goals – SGG$_x$ no. of detracts relationships

SGG$_y$_CRO = SGG$_y$ level value + SGG$_y$ priority value + SGG$_y$ no. of sub-goals +

SGG$_y$ no. of parent-goals – SGG$_y$ no. of detracts relationships

If SGG$_x$_CRO > SGG$_y$_CRO then

CRR = "SGG$_x$ has higher conflict resolution outcome than SGG$_y$"

Endif

ElseIf SGG$_y$_CRO > SGG$_x$_CRO then

CRR = "SGG$_y$ has higher conflict resolution outcome than SGG$_x$"

Endif

ElseIf SGG$_x$_CRO = SGG$_y$_CRO then

CRR = "SGG$_x$ and SGG$_y$ has the same conflict resolution outcome"

End if

SGG$_x$_SGG$_y$_CR = SGG$_x$_CRO + SGG$_y$_CRO + CRR

Add SGG$_x$_SGG$_y$_CR to SGG_SGG_CR_set

Save SGG_SGG_CR_set

End if

End for

Return SGG_SGG_CR_set

End

Figure 6.7: Algorithm 2.2 - Conflict Resolution Amongst Conflicting Sub-Global Goals at the SoS-Level

Algorithm 2.3: LG_SGG Conflict Resolution

Input

> ➢ A set of local goals_sub global goals conflicts (LG_SGG_GC_set); where
> LG_SGG_GC_set = {LG_SGG_GC$_1$, LG_SGG_GC$_2$, …, LG_SGG_GC$_j$, …,
> LG_SGG_GC$_m$}
> and LG_SGG_GC$_j$=
> (LG$_x$_set = {LG$_x$, A$_p$ (Actor as depender), A$_q$ (Actor as dependee)})
> + (SGG$_y$_set = {SGG$_y$, A$_r$ (Actor as depender), A$_s$ (Actor as dependee)})

Output

> ➢ A set of local goals_sub global goals conflict resolutions (LG_SGG_CR_set); where,
> LG_SGG_CR_set= { LG_SGG_CR$_1$, LG_SGG_CR$_2$, …, LG_SGG_CR$_j$, …, LG_SGG_CR$_m$},
> and LG$_x$_SGG$_y$_CR$_j$= LG$_x$ conflict resolution outcome (LG$_x$_CRO) +
> SGG$_y$ conflict resolution outcome (SGG$_y$_CRO) +
> Conflict resolution result (CRR)

Begin

Initialise LG_SGG_CR_set
   For each LG$_x$_SGG$_y$_GC in LG_SGG_GC_set
    If LG$_x$_SGG$_y$_CR is not added to LG_SGG_CR_set then
     LG$_x$_CRO = LG$_x$ level value + LG$_x$ priority value + LG$_x$ no. of sub-goals +
      LG$_x$ no. of parent-goals – LG$_x$ no. of detracts relationships

     SGG$_y$_CRO = SGG$_y$ level value + SGG$_y$ priority value + SGG$_y$ no. of sub-goals +
      SGG$_y$ no. of parent-goals – SGG$_y$ no. of detracts relationships

      If LG$_x$_CRO > SGG$_y$_CRO then
       CRR = "LG$_x$ has higher conflict resolution outcome than SGG$_y$"
      Endif
      ElseIf SGG$_y$_CRO > LG$_x$_CRO then
       CRR = "SGG$_y$ has higher conflict resolution outcome than LG$_x$"
      Endif
      ElseIf LG$_x$_CRO = SGG$_y$_CRO then
       CRR = "LG$_x$ and SGG$_y$ has the same conflict resolution outcome"
      End if
     LG$_x$_SGG$_y$_CR = LG$_x$_CRO + SGG$_y$_CRO + CRR
     Add LG$_x$_SGG$_y$_CR to LG_SGG_CR_set
     Save LG_SGG_CR_set
    End if
  End for
Return LG_SGG_CR_set
End

Figure 6.8: Algorithm 2.3 - Conflict Resolution Amongst Conflicting Local Goals and Sub-Global Goals

6.2 Demonstration of Conflict Management Approach in an SoS Context: Cancer Care Case Study

After the development of the conflict detection and resolution approaches, the strategic goal-management tool, and in particular, the conflict management panel is demonstrated and tested through applying real test cases of the Cancer Care case study with reference to KHCC's strategic plans and ADT policies.

Figure 6.9 presents the developed "Conflict Management Panel" and shows an example of detecting goal conflicts amongst local goals in a Cancer Care SoS, where the *"conflict set"* contains three cases of goal conflict as shown in the Figure. For example, in the first case: LG5.2 "Allow late discharge of patients upon their request" conflicts with LG1 "Improve utilisation of available beds", where conflict occurs here between goals of the same constituent system (i.e. ADT). In the second case of conflict: LG7.1 "Admit and treat emergency patients regardless of their financial coverage" conflicts with LG8 "Check patient's financial status is covered pre-admission", considering a negative correlation detected amongst the conflicting goals. In this case, the goal conflict occurs between ADT and Finance systems.

Local Go...	Local Goal 1 Desc	Depender	Depend...	Local Go...	Local Goal 2 Desc	Depender	Dependee
11152	Allow late discharge of patients upon...	Patient	ADT	1111	Improve utilisation of available beds	Patient	ADT
11171	Admit emergency patients regardles...	Patient	ADT	1118	Check patient's financial status is covere...	Cancer Care Pr...	Finance
1118	Check patient's financial status is co...	Cancer Care ...	Finance	11171	Admit emergency patients regardless of f...	Patient	ADT

Figure 6.9: Applying Goal Conflict Detection into a Cancer Care SoS

After detecting goal conflicts and provide the user with a *conflict set* that contains the conflicting goals with their concerned stakeholders, the next step is to provide solutions and resolve the goal conflict, following the conflict resolution approach introduced in the previous section. Figures 6.10 and 6.11 present two examples of resolving conflicts amongst goals which are owned by the same constituent system and by different constituent systems, respectively. The examples reveal the results of applying the proposed conflict resolution approach after goal conflicts were identified in SoS context.

In the first example, demonstrated in Figure 6.10, where conflicting goals are owned by the same constituent system (i.e. ADT), local goal LG1 "Improve utilisation of available beds" has a higher conflict resolution outcome over local goal LG5.2 "Allow late discharge of patients upon their request" since having a higher complexity value, as shown in detail in Table 6.2. Therefore, stakeholders are advised to apply LG1 over LG5.2.

And in the second example, illustrated in Figure 6.11, both local goals LG7.1 "Admit and treat emergency patients regardless of their financial coverage" which is owned by ADT constituent system and LG8 "Check patient's financial status is covered pre-admission" which is owned by Finance system, have the same complexity value. Therefore, the result of applying the conflict resolution approach, in this case, is that both conflicting goals have the same conflict resolution outcome and associated stakeholders are advised to negotiate and decide which goal receives the highest priority, as shown by the message displayed in Figure 6.11. Table 6.2 presents the calculated conflict resolution outcomes and the values of the analysed resolution factors for both goal conflict cases.

Figure 6.10: Applying Goal Conflict Resolution into a Cancer Care SoS – Example 1

Figure 6.11: Applying Goal Conflict Resolution into a Cancer Care SoS – Example 2

Table 6.2: Conflict Resolution Outcomes for Two Goal Conflict Cases in a Cancer Care SoS

Goal Conflict Set	Goal ID	Goal Description	Owner Stakeholder	Priority Value	Goal Level Value	Specificity Value	Complexity Value (Conflict Resolution Outcome)	Result
Goal Conflict Case 1	LG1	Improve utilisation of available beds	ADT System	High Priority = 3	Goal level = 2	Specificity = 7	Complexity = 12	LG1 has a higher conflict resolution outcome than LG5.2 (Actors are advised to give priority to LG1 over LG5.2)
	LG5.2	Allow late discharge of patients upon their request	ADT System	Low Priority = 1	Goal level = 1	Specificity = 5	Complexity = 5	
Goal Conflict Case 2	LG8	Check patient's financial status is covered pre-admission	Finance System	Medium Priority = 2	Goal level = 2	Specificity = 3	Complexity = 5	Both goals have the same conflict resolution outcome (Actors are advised to negotiate to decide which goal receives higher priority)
	LG7.1	Admit and treat emergency patients regardless of their financial coverage	ADT System	High Priority = 3	Goal level = 1	Specificity = 3	Complexity = 5	

6.3 Evaluation of Conflict Management Approach in an SoS Context with Input from the Cancer Care Case Study

In this section, the developed conflict management approach in SoS context is evaluated with input from main KHCC's Cancer Care stakeholders and domain experts, by means of interviews, tool walk-throughs, and evaluation forms. The evaluation process of the conflict management approach and developed tool contains two main parts: (1) evaluating the *goal conflict detection* component, and (2) evaluating the *goal conflict resolution* component in SoS context.

The approach applied currently at KHCC to manage their strategic plans and goal documents does not include automated or formal conflict management of any form. Therefore, detecting conflicts that may occur amongst goals at multiple levels of the SoS organisation, analysing the complexity and priority of conflicting goals, and providing solutions to resolve the conflict are considered of great benefit for stakeholders who own the conflicting goals and for the whole SoS organisation, and this is what the developed conflict management tool aimed at achieving.

The developed proof-of-concept conflict management tool is demonstrated and tested by applying test cases stemming from KHCC's strategic plans, ADT policies and procedures. Interviews, walk-throughs and demonstration were conducted with KHCC's domain experts to validate the *effectiveness* of the tool, evaluate its *usefulness* and *usability*, and check the *correctness*, *consistency* and *completeness* of the accomplished results. Interviews carried out to validate the conflict management part of the tool in relation to these criteria are provided in Appendix D, Section 2. The following results were accomplished after the validation process:

- The tool can detect conflicts that may occur amongst goals at multiple levels: (1) between local goals at the CS level; (2) between global goals at the SoS level; and (3) between global SoS goals and local CS goals.

- The tool can analyse the complexity and specificity of conflicting goals at different levels which are owned by different stakeholders and departments.

- The tool can resolve the occurring conflicts amongst goals and advise stakeholders to apply the goal with the highest conflict resolution outcome, as per the results revealed in the demonstration Section 6.2, and discussed through the examples provided in Figures 6.5 and 6.6.

- The tool allows reconfiguring new strategic goals at as many levels as needed, identifying positive and negative relationships between them, detecting and resolving conflicts among them, and can expand to cover more policies and procedures other than ADT's and KHCC's strategic plans, as well as maintaining the changes of the current ones.

- The tool provides useful and informative messages for stakeholders who own conflicting goals, and advise them on how to resolve the goal conflict.

It is apparent now that applying the OntoSoS.GORE framework is more effective than the current approach applied at KHCC in following the progress of the organisation's goals at multiple levels, as discussed in Section 5.3, and in detecting and resolving occurring goal conflicts in SoS context, as discussed in this section. This was achieved in terms of addressing higher 3Cs with regard to goal management and conflict management in SoS context.

6.4 Chapter Summary

By the end of this chapter, the research framework layers and components were completed and finalised by introducing the third and last layer: the conflict management approach in SoS context. The research framework OntoSoS.GORE was enhanced and matured incrementally through following multiple iterations of the DSRM process phases, including the design and development phase, the demonstration phase, and the evaluation phase for each layer of the framework.

The conflict management approach proposed in this chapter with its two components: goal conflict detection and goal conflict resolution, is a main research artefact that aims at managing conflicts that may occur amongst goals at multiple levels in SoS arrangements. Three types of goal conflict were detected and resolved by the proposed conflict management approach: (1) conflicts that may occur amongst local goals at the CS-level, (2) conflicts that may occur amongst sub-global goals at the SoS-level, and (3) conflicts that may occur amongst local goals at the CS-level and sub-global goals at the SoS-level.

Goal conflict detection was implemented by identifying positive and negative correlations amongst goals in order to recognise goal conflicts at multiple levels of an SoS arrangement. Goal conflict detection algorithms were developed and then the conflict detection component of the developed strategic goal-management tool was implemented. The output of applying the conflict detection process is a set called the *"Goal_Conflict_Set"*, which also plays the role as the input of the conflict resolution process.

After a goal conflict is detected and the *"Goal_Conflict_Set"* is determined, conflict resolution is implemented by analysing the complexity of conflicting goals and comparing their goal level, priority and specificity values. The proposed goal conflict resolution approach can determine the goal with the higher resolution outcome among the conflicting goals, and advise

the concerned stakeholders to apply this goal over others or to negotiate and reach a compromise if the conflicting goals have the same complexity value and conflict resolution outcome. Moreover, the goal conflict detection and conflict resolution approaches were fully implemented by developing a strategic goal-management tool in SoS context.

The conflict management approach has been demonstrated and evaluated using the KHCC Cancer Care case study with reference to their strategic plans and ADT policies. In a Cancer Care SoS arrangement, the proposed conflict management approach succeeded in managing goal conflicts by detecting conflicts that may occur amongst goals at multiple SoS levels, and then resolve the goal conflict by analysing and comparing the complexity of the conflicting goals. The accomplished results were supported by applying several sufficient test case study examples through utilising the new conflict management approach.

The fourth research question (RQ4), which is concerned about managing conflicts that may occur amongst goals at multiple levels in SoS arrangements, was addressed and answered through this chapter. By answering the last research question, the overall hypothesis of the research is fully assessed and can now be proved correct combining the outcomes of all the research questions that were answered incrementally following the iterations and phases of the DSRM process, as will be discussed in detail in the conclusion Chapter, Section 7.2.

Chapter 7

Discussion and Conclusions

In the last decades, monolithic systems are being composed into bigger systems as Systems of Systems that are capable of delivering unique functionalities that span more complex operating environments. This evolution of SoS and SoSE raises a number of software engineering key challenges such as the management of emerging inconsistent requirements, and involving more stakeholders than traditional systems engineering, where competing stakeholders' needs and goals establish a complex stakeholder environment. In an SoS, the various constituent systems may present conflicting goals and requirements among themselves, as well as emerging conflicting goals and requirements between the whole SoS and the participating constituent systems (Viana et al., 2017).

This research is aimed at investigating the implications of applying goal-oriented requirements engineering approaches in identifying, modelling, and managing emerging goals and their conflicts in an SoS context and in particular to the Cancer Care domain. The developed research framework and main artefact named OntoSoS.GORE was utilised in such investigation. The main functionalities and purposes of the developed framework are: (1) identifying and modelling the SoS global goals and constituent systems local goals at different levels of an SoS arrangement using the i* goal-oriented framework; (2) maintaining the consistency and integrity of these goals at all levels; and (3) managing any conflicts that may occur amongst goals at both the SoS-level and CS-level. This novel framework was validated by a Cancer Care case study and by domain experts at King Hussein Cancer Center (KHCC) in Jordan.

This chapter is the last chapter of the thesis and is structured as follows. Section 7.1 presents the research outcomes and main contributions to knowledge, which are further discussed in Section 7.2. Section 7.3 provides bottom-up traceability of answering the research questions and fulfilling the research hypothesis. Recommendations for further future research directions and the research limitations are discussed in Section 7.4. Then the chapter concludes in Section 7.5.

7.1 Main Contributions to Knowledge

Several contributions to knowledge and artefacts have been accomplished through conducting this research, which are discussed in the following section (Section 7.2) and listed below:

- **The Research Framework OntoSoS.GORE**
- **A Process to Extract i* Elements from Existing User Documentation**
- **An SoS Strategic Goal-Oriented Modelling Metamodel**
- **A Proposed Reference i* Goal-Oriented Model for Access to Cancer Care**
- **A Goals Referential Integrity (GRI) Model in SoS Context**
- **An Ontology-Based Model in SoS Context (SoSGORE Ontology)**
- **A Conflict Management Approach in SoS Context**
- **A Strategic Goal-Oriented Management Tool in SoS Context**

7.2 Discussion of Research Findings

- **The Research Framework OntoSoS.GORE**

The development of an Ontology-based Goal-Oriented Requirements Engineering framework for Systems of Systems (OntoSoS.GORE) is one of the main outcomes of this research. The OntoSoS.GORE framework is a three-layered framework, where the first layer is concerned with modelling and managing SoS and CS goals at different levels. The second layer aims at maintaining their consistency and integrity in SoS context and semantically enrich i* SoS goal-oriented modelling. And the third layer aims at managing any conflicts that may occur amongst goals at both the SoS-level and CS-level.

The OntoSoS.GORE framework is described as being goal-oriented, ontology-based, goal management-driven, conflict management-oriented, and developed following a hybrid design approach of top-down and bottom-up processes. The framework contributes to both GORE and SoS domains by applying new solutions mainly for goal-oriented modelling and goal conflict management in SoS context.

- **A Process to Extract i* Elements from Existing User Documentation**

In order to achieve the aim of the first layer of the framework of developing global and local i* goal-oriented modelling for the SoS of interest and its constituent systems, a new process was developed in order to extract i* elements and concepts from the organisation's existing user documentation. The extraction method was expressed as heuristics that describe which element of user documentation can be typically transformed into which i* element. As a result, the extracted i* elements were utilised afterwards in the i* goal modelling in SoS context.

The i* extraction process was applied to and validated through the KHCC Cancer Care case study, with regard to their strategic documents and ADT policies and procedures. Cancer Care i* goal-oriented modelling in SoS context resulted as an outcome of applying this extraction method to the Cancer Care documents, and then employing the extracted i* elements to perform the i* goal-oriented modelling.

- **An SoS Strategic Goal-Oriented Modelling Metamodel**

This model defines the multiple goal-levels in an SoS arrangement, as well as the relationships and linkages between these goal levels and corresponding components such as constituent systems, KPIs, actors, i* models, and the organisation's policy documents. This metamodel is also linked to the second layer of the research framework; the sGRI model that provides the enforcement of goals referential integrity in SoS context. It is considered the base that paved the way for developing the SoSGRI model and the SoSGORE ontology.

Three different levels of goals are adopted in this metamodel: (1) *SoS Global Goals*, which are the highest strategic priorities and missions of the SoS organisation; (2) *Sub-Global Goals*, which aim at achieving the global goals at the higher level and are also considered within the SoS-level; and (3) *Local Goals* which are the individual goals of each constituent system at the local level, that collaborate together in order to achieve the higher-level global and sub-global goals.

- **A Proposed Reference i* Goal-Oriented Model for Access to Cancer Care**

A generic or reference i* goal-oriented model was developed and proposed for access to Cancer Care with reference to the case of ADT at KHCC, KHCC's strategic plans and domain experts' input. The model stemming from the developed Cancer Care SD and SR i* models provides the most generic concepts in Cancer Care domain, from a GORE perspective including Cancer Care hard goals, softgoals, tasks and resources with their main depender and dependee actors and the dependencies between them.

The proposed reference i* model was validated by input from KHCC's domain experts and was incrementally enhanced following multiple iterations. By proposing the model to KHCC, stakeholders gained the benefits of recognising and understanding the linkages and relationships with other stakeholders and departments more efficiently, since it concisely highlighted what actors need and expect from each other. The model provides a wider system engineering perspective and offers an accessible level of abstraction for stakeholders and domain experts in validating choices among alternative designs.

Moreover, one of the major benefits sought from developing such a reference goal model is the use of knowledge and standardisation of common generic concepts about the domain, in which other Cancer Care organisations can considerably reuse and facilitate the process of capturing and specifying the goals and requirements for their practice, required systems or applications.

- **A Goals Referential Integrity (GRI) Model in SoS Context**

New terms were introduced by this research: the ***"Goals Referential Integrity (GRI)"*** which is defined as *"the capability to maintain the integrity of evolving goals for a particular system/organisation",* and ***"Systems of Systems Goals Referential Integrity (SoSGRI)"*** which is *"the capability to maintain the integrity of the SoS goals with the evolving local goals of the monolithic constituent systems in an SoS arrangement".*

SoSGRI intends to maintain the integrity and consistency of both the SoS-level goals and the constituent systems-level goals, if either any goal at any of the two levels has been updated, deleted, or a new goal has been identified, by establishing proper linkages among Primary Keys (PKs) and Foreign Keys (FKs) in SoS context. The integrity of

goals is being maintained both ways: top-down (from the SoS to the constituent systems); and bottom-up (from constituent systems to the SoS).

Three types of constraints on goals have been identified and specified to maintain and enforce GRI in an SoS arrangement: Insert, update, and delete constraints. The GRI model was applied to and evaluated by the KHCC Cancer Care case study. Furthermore, the GRI model was linked to the next artefact, the SoSGORE ontology which semantically enriched the GRI model and the i* strategic goal-oriented modelling in SoS context.

- **An Ontology-Based Model in SoS Context (SoSGORE Ontology)**

Following the development of the SoSGRI model, an ontology-based model was developed to semantically represent the i* goal-oriented modelling in SoS context, and inform the satisfaction and achievement of the SoS goals at multiple levels. Together the GRI model and its associated ontology model form the **semantic Goals Referential Integrity (sGRI)** applied in SoS context, where conflicts between goals at the SoS and the CS levels can be discovered in an attempt to maintain the semantic integrity of the SoS global goals and the constituent systems local goals.

The significance of developing an ontology-based model in SoS context is the standardisation of knowledge offered by the model, besides the use of detecting and resolving semantic heterogeneities, and maintaining the consistency of goals. Also, by applying reasoning and SWRL rules, the achievement and progress of goals at both local and global levels can be informed. The achievement of SoS high-level goals including global and sub-global levels could be inferred by reasoning and by only identifying the achievement of the local goals at the CS-level and defining the linkages between all goal levels.

- **A Conflict Management Approach in SoS Context**

The developed conflict management approach in SoS context consists of two main processes: goal conflict detection and goal conflict resolution. The proposed goal conflict detection process aims at detecting any conflicts that might occur amongst goals at different levels of SoS arrangements: (1) conflicts occurring at the CS-level amongst

individual local goals of constituent systems; (2) conflicts occurring at the SoS-level amongst high-level global goals of the entire SoS; and (3) conflicts occurring between the local and global levels amongst constituent systems' local goals and SoS global goals.

On the one hand, the conflict detection process depends on the supports/detracts relationships established between goals which are expressed by contribution links in the i* language. This research suggested extending the semantics and the use of i* contribution links to link all types of i* dependencies to each other (i.e. goals, softgoals, tasks, and resources), and utilised the negative correlation "detracts" in identifying conflicts amongst goals. Conflict detection is implemented after modelling the SoS organisation's goals using the i* framework and then discovering the positive or negative relationships between them, where a negative correlation type implies the existence of a goal conflict. The output of the conflict detection process is a set called the *"Goal_Conflict_Set"*, which contains all detected goal conflicts and plays the role as input to the conflict resolution process.

On the other hand, the conflict resolution process aims at resolving detected conflicts amongst goals at multiple SoS levels automatically. The resolution process is based on analysing the complexity of the conflicting goals in order to determine their conflict resolution outcome and highlight the goal that dominates others. The complexity of goals associated in conflict is analysed by determining their level, priority and specificity values, and the number of "detracts" relationships they have with other goals. Goal specificity is calculated by identifying the number of relationships that the goal has with other entities, which informs how specific the goal is. For instance, if a conflicting goal affects more goals, is connected to more policy documents and linked to more KPIs in the SoS organisation, then the goal has higher specificity value. Associated algorithms were developed to support the implementation of the conflict detection and conflict resolution approaches.

- **A Strategic Goal-Oriented Management Tool in SoS Context**

A strategic goal-management proof-of-concept tool was developed in SoS context, with access to the organisation's SoS high-level strategic goals and the CS-level local goals

linked to KPIs that adhere to satisfying these goals. The developed strategic goal-management tool consists of two main parts: (1) Goal satisfaction panel; and (2) Conflict management panel. On the one hand, the goal satisfaction panel enables stakeholders to track down the progress and satisfaction of Global Goals, Sub-Global Goals, and Local Goals at multiple levels of an SoS arrangement, where the achievement and satisfaction of upper-levels goals can be inferred automatically depending on the achievement status of lower-level local goals.

On the other hand, the conflict management panel enables stakeholders to detect and resolve conflicts that may occur amongst goals at multiple levels of the SoS. Conflicts are detected by means of identifying negative correlations amongst goals, then resolved by analysing the complexity and specificity of conflicting goals which are owned by different stakeholders and departments, and then advising the stakeholders to apply the goal with the highest conflict resolution outcome.

7.3 Fulfilment of the Research Hypothesis and Research Questions

This section provides a critical review of how the research outcomes fulfilled the research hypothesis by answering the research questions, along with a discussion for answering each research question. Figure 7.1 presents bottom-up traceability of answering the research questions through the findings and outcomes of Chapters 4, 5, and 6 of the thesis, directing to proving the validity of the research hypothesis. Figure 7.1 shows that *RQ1* is principally answered through Chapter 4, *RQ2* and *RQ3* are addressed in Chapter 5, and finally, *RQ4* is satisfied by the outcomes of Chapter 6. The outcomes of developing the research framework OntoSoS.GORE, followed by its instantiation and evaluation using the KHCC Cancer Care case study need to be discussed in order to answer the research questions as follows:
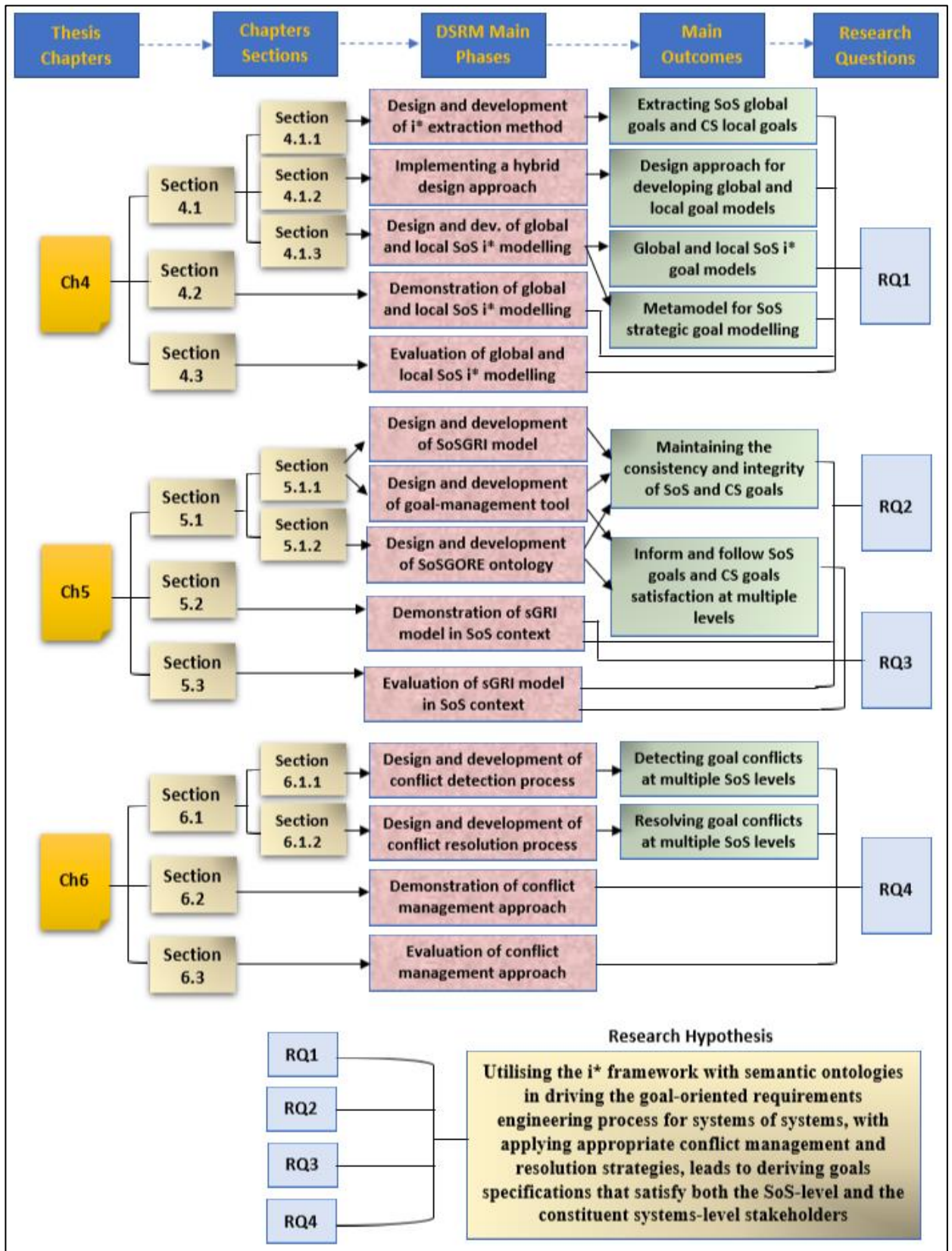
Figure 7.1: Bottom-Up Answering of the Research Questions and Research Hypothesis

RQ1: How should the SoS-level goals and the constituent systems-level goals be identified at several levels of the SoS arrangement using the i* framework?

RQ1 was mainly addressed and answered through the outcomes of Chapter 4. First, following a hybrid design approach of developing the OntoSoS.GORE framework contributed to identifying and modelling the multiple levels of goals at SoS arrangements (i.e. the SoS-level and the CS-level). A hybrid of top-down and bottom-up approaches has been adopted in identifying SoS global goals and CS local goals, and in the development of the global and local goal-oriented models for the SoS and its associated constituent systems using the i* framework. This mix of approaches ensured capturing and considering all aspects related to the SoS as a whole and to the constituent monolithic systems, rather than missing some aspects if only one of the approaches is applied in isolation, hence, informing the *completeness* of goal modelling concepts identified at both global and local levels.

Moreover, in order to identify the different types of the SoS-level global goals and the CS-level local goals, the SoS organisation's documents and policies are analysed in order to extract global and local goals and their associated actors to act as input for performing the i* goal-oriented modelling for the SoS organisation. An i* extraction process from existing user documentation was developed and presented in Section 4.1.1, expressed by heuristics that describe which element of user documentation can be typically transformed into which i* modelling element. Applying this new process, different types of goals were extracted and identified: hard goals, softgoals, tasks, and resources at multiple global and local levels of the SoS arrangement. The i* extraction process was instantiated and evaluated with input from the KHCC Cancer Care case study using sufficient and representative documents that were analysed, in which several i* goal modelling elements were extracted. Results revealed the *correctness*, *consistency* and *completeness* of the heuristics that comprise the i* extraction process in general, and of the Cancer Care i* goal modelling elements extracted when applying the extraction process and its heuristics.

Furthermore, a conceptual metamodel for i* strategic goal-oriented modelling in SoS context were developed to support the i* goal modelling and identify the different levels of goals in SoS arrangements, their related entities and relationships between them. Three different levels of goals were identified: (1) *SoS Global Goals*, which are the highest strategic priorities and

missions of the SoS organisation; (2) **Sub-Global Goals**, which aim at achieving the global goals at the higher level and are also considered within the global SoS-level; and (3) **Local Goals** which are the individual goals of constituent systems at the local level, that collaborate together in order to achieve the higher-level global and sub-global goals. This developed metamodel with its goal levels was instantiated and validated using the KHCC Cancer Care case study. It was confirmed that Cancer Care goals at different levels are *consistent* with the developed metamodel, and that as many goal levels as required could be identified using the model which employs recursive relationships among the different goal levels. *Correct*, *consistent* and *complete* relationships between goals at multiple SoS levels, and their associated actors, constituent systems, policy documents and KPIs were identified by applying the model.

RQ2: Can the referential integrity of the SoS goals and the constituent systems' goals be maintained at all levels in an operational context?

RQ2 was answered and attended to through the outcomes of Chapter 5. Three main components collaborated in satisfying *RQ2*. First, an SoSGRI model was developed in order to maintain the consistency and integrity of both the SoS-level goals and the constituent systems-level goals, by applying three types of constraints: Insert, update, and delete. The SoSGRI model was applied to and validated through the KHCC Cancer Care case study, with regard to their strategic documents and ADT policies and procedures, which resulted in maintaining the *consistency* of Cancer Care global and local goals at multiple levels. Sufficient and representative examples of the case study were provided in Section 5.2.1 to confirm this result.

Second, a strategic goal-management tool was developed in SoS context, with access to the organisation's SoS high-level strategic goals and the CS-level local goals. One of the main features of the tool is maintaining the *consistency* and integrity of SoS global and sub-global goals and the CS local goals, by establishing proper linkages among the different goal levels by means of enforcing PKs and FKs constraints in SoS context. The developed proof-of-concept tool was demonstrated and validated by applying representative test cases stemming from KHCC's strategic plans, ADT policies and KPIs, where results revealed that the *consistency* of the Cancer Care global and local goals was kept at all levels and at all times, by applying the SoSGRI model and its constraints successfully through the tool, as discussed in Section 5.3.1.

Third, an ontology-based model was developed to semantically represent the SoS i* strategic goal modelling, namely the SoSGORE ontology. One of the main characteristics of the developed ontology is maintaining the semantic integrity and *consistency* of the SoS global goals and the constituent systems local goals and maintain the *consistency* of the model and its entities by applying OWL reasoning and SWRL rules. The SoSGORE ontology was also instantiated and evaluated with input from the KHCC Cancer Care case study. The evaluation outcomes showed that the SoSGORE ontology provides backward traceability of Cancer Care goals at multiple levels to their corresponding policy documents and i* goal models, which informs the *consistency* of goals and relationships identified by the model. Furthermore, it was revealed that the ontology model offers by means of reasoning the ability to check and maintain the *consistency* of the developed model, its OWL classes, and individuals including Cancer Care goals at multiple levels.

RQ3: To what extent can the satisfaction of both the SoS-level goals and the constituent systems-level goals be checked and verified by applying the OntoSoS.GORE framework?

RQ3 was also answered in Chapter 5, by the collaboration of two components: the developed strategic goal-management tool, and the SoSGORE ontology. On the one hand, the first component of the developed strategic goal-management tool; the goal satisfaction panel enables stakeholders to track down the progress and satisfaction of global goals, sub-global goals, and local goals at multiple levels of an SoS arrangement, where the achievement and satisfaction of upper-levels goals can be inferred automatically depending on the achievement value of lower-level local goals. By evaluating the goal satisfaction panel, several representative Cancer Care examples were applied through the KHCC case study instantiation and validation processes, which confirmed the stakeholders' ability to check the satisfaction of Cancer Care global goals, sub-global goals, and local goals at multiple levels.

However, stakeholders may change the achievement value of local leaf goals if needed, but they cannot manipulate the satisfaction of upper-levels goals, as it depends on local goals' satisfaction and inferred automatically via the tool. One limitation of the research work was discovered though, regarding ensuring the satisfaction of local goals. The stakeholders' input is required at the current stage of developing the tool to determine the satisfaction (i.e. achievement value) of the local goals. However, in future work, this can be accomplished and implemented

automatically with reference to KPIs current and target values. Consequently, if a KPI's current value is equal to its target value, this enlightens the full satisfaction of the related local goal.

On the other hand, the developed SoSGORE ontology model that semantically represent the i* goal-oriented modelling in an SoS context, informs the satisfaction and achievement of the SoS goals at multiple levels. By applying OWL reasoning and SWRL rules, the achievement of SoS high-level goals including global and sub-global levels could be inferred by identifying the achievement of the local goals at the CS-level and establishing linkages between global and local goal levels in SoS context. By instantiating the SoSGORE ontology using the Cancer Care case study and validating the model with input from KHCC's domain experts, it was discovered that the ontology-based model for KHCC Cancer care facilitates monitoring and inferring the satisfaction and progress of Cancer Care global and sub-global goals at the SoS-level by following-up the satisfaction of their local goals at the CS-level.

RQ4: How to manage conflicts that may occur amongst goals at the following three levels:

 a) ***between individual local goals of constituent systems;***

 b) ***between SoS global goals; and***

 c) ***between SoS global goals and constituent systems local goals?***

In order to manage goal conflicts at multiple SoS levels, two phases of goal management are required: goal conflict detection and goal conflict resolution. The last research question ***RQ4*** is addressed and answered in Chapter 6 through developing a conflict management approach in SoS context. Firstly, a goal conflict detection process was developed to detect conflicts that might occur amongst goals at different levels of SoS arrangements: (1) at the CS-level amongst individual local goals of constituent systems; (2) at the SoS-level amongst high-level global goals of the entire SoS; and (3) between the local and global levels amongst constituent systems' local goals and SoS global goals. The conflict detection process depends on discovering the negative detracts relationships between goals which implies the existence of a goal conflict.

In addition, the conflict resolution process resolves detected conflicts amongst goals at multiple SoS levels automatically. The resolution process is based on analysing the complexity of the conflicting goals by determining their level, priority and specificity values, in order to

determine the goal with the highest conflict resolution outcome. This was achieved for the aforementioned three levels that goal conflicts may occur at, in SoS context.

The developed conflict management approach in SoS context was demonstrated and evaluated by applying sufficient test cases stemming from KHCC's strategic plans, ADT policies and procedures, and with input from main KHCC's Cancer Care stakeholders and domain experts. Results revealed that the approach provided effective automation of the goal conflict detection and resolution processes, compared to the manual approach applied currently at KHCC to manage their strategic plans and goal documents. It was concluded that the tool can successfully detect conflicts that might occur amongst goals at multiple Cancer Care SoS levels, and can resolve the occurring goal conflicts by analysing the complexity of the conflicting goals and advise stakeholders to apply the goal with the highest conflict resolution outcome, as per the results revealed in Section 6.2. Moreover, Cancer Care main domain experts confirmed that the tool provides useful and informative messages for stakeholders who own conflicting goals, on how to assess the two conflicting goals and how to resolve the goal conflict.

After answering the four research questions, it is now required revisiting the research hypothesis presented in Section 1.4, in order to validate and accept the hypothesis with respect to the answered four research questions. The four answered research questions support the overall research hypothesis and it is concluded now that, ***"Utilising the i* framework with semantic ontologies in driving the goal-oriented requirements engineering process for systems of systems, with applying appropriate conflict management and resolution strategies, leads to deriving goals specifications that satisfy both the SoS-level and the constituent systems-level stakeholders".***

7.4 Future Research Directions

This section suggests further future work that is anticipated to contribute to this research, and to address some of the limitations and shortcomings of the work.

- **Automating the i* Extraction Process**

   The newly developed process to extract i* elements from organisations' existing user documentation, was applied manually to the KHCC ADT Cancer Care case study, to extract Cancer Care goals and actors to be used in developing i* goal-oriented models

for Cancer Care in SoS context. One limitation of the work is that this process was applied manually to the case study and not yet automated. This process can be automated or semi-automated by applying Natural Language Processing (NLP) and text classification and analysis tools to the SoS organisation's documents to translate textual specifications into suitable i* modelling elements. And this is anticipated to be done in further future work.

- **Enhancing the Proposed Reference i* Goal-Oriented Model for Access to Cancer Care and Submitting the Model to the World Health Organisation (WHO)**

The proposed "Reference i* Goal-Oriented Model for Access to Cancer Care" was developed with regard to the KHCC Cancer Care case study, and in particular their strategic plans and ADT's policies and procedures. It is intended to extend this reference goal model to include other categories of policy documents that were not covered within the scope of this research, such as the rest of ADT policies, IT and HR policies.

Applying and validating this reference model in only one Cancer Care organisation - although JCI accredited among other national and international accreditations- is still considered as a shortcoming of the research work. Therefore, it is also intended to test and apply this proposed reference model to other Cancer Care organisations and case studies to extend its validity. Furthermore, after enhancing and improving the model, it will be of a great benefit to the Cancer Care domain to submit such a model to the World Health Organisation (WHO) to be generalised, standardised and reused within the Cancer Care community in GORE and SoS contexts.

- **Applying KPIs Qualitative Side to the Conflict Resolution Process**

The number of related KPIs was considered in determining how specific a goal is in order to implement the conflict resolution process and identify the goal with the highest conflict resolution outcome. However, one discovered limitation of this research is that the proposed conflict resolution approach tackled only the quantitative side of KPIs and did not study the qualitative side of KPIs and its effect on goal specificity. Therefore, further research is still needed to investigate the KPIs qualitative side, how critical the KPI is, what are its implications or priority compared to other KPIs, and how does this analysis affect the conflict resolution process.

- **Applying the OntoSoS.GORE Framework to Other Case Studies**

The OntoSoS.GORE framework was instantiated and applied effectively through this research work to the KHCC Cancer Care case study. However, it is anticipated in future to apply the research framework to other SoS organisations and case studies, test and validate its effectiveness and usability beyond the Cancer Care domain.

- **Enhancing the Strategic Goal-Management Tool and Delivering a Full End-User Product to KHCC**

The developed strategic goal-management tool is a proof-of-concept tool that brings several functionalities to the SoS GORE context and supports this research in many ways. However, further development is still needed to produce a full-working end-user product which fully satisfies KHCC's needs and goals, and could be implemented in other organisations as well. Some of the key points that need enhancing are:

❖ *Implementing KPIs Utilisation to Inform the Satisfaction of Local Goals Automatically*

The developed strategic goal-management tool enables following and inferring the achievement and satisfaction of upper-levels goals at multiple levels of the SoS organisation automatically depending on the achievement value of lower-level local goals. However, a limitation of the research work is revealed regarding the ability to track the satisfaction and progress of local goals automatically with reference to KPIs. Currently, the stakeholders' involvement is required to determine the satisfaction (i.e. achievement value) of local goals. Nevertheless, it is intended to improve and mature the tool in future and implement the satisfaction of local goals to be inferred and tracked automatically by utilising KPIs current and target values; i.e. if KPI's current value is equal to its target value, this enlightens the full satisfaction of the related local goal and this could be inferred automatically.

❖ *Enhancing the Process of Tracking Goals' Satisfaction*

In future work, it is anticipated to calculate the goals' percentage of satisfaction depending on how many of its sub-goals are achieved and analysing the weight of these

sub-goals, rather than stating that a goal is even achieved or not. It is also useful to implement a new status attached to goals as part of the "Achieved" property, indicating that the goal satisfaction and achievement is "in progress". This will produce more accurate and meaningful information to stakeholders while tracking the progress of goals at all levels.

❖ *Extending the Conflict Management Approach to Detect Other Types of Goal Conflicts*

One of KHCC's stakeholders' concerns discovered during the evaluation process of the strategic goal-management tool is the tool's ability to detect different type of goal conflicts other than having a direct negative correlation among goals. One example of such conflict is detecting actors who have been assigned several tasks with very limited resources including time, equipment, and HR. Detecting this category of goal conflicts requires extending the research scope and analysing further organisation's documents and requirements related to these aspects.

7.5 Conclusions

This research has proposed a novel Semantically-Enriched Goal-Oriented Requirements Engineering Framework for Systems of Systems using the i* framework, named OntoSoS.GORE, that aimed at applying a goal-oriented requirements engineering approach in identifying, modelling and managing emerging goals and their conflicts in SoS context. The research framework were developed, demonstrated and then evaluated through following multiple iterations of the DSRM process phases, where the iterative nature of the DSRM process fits with the notion and direction of the OntoSoS.GORE framework development as an artefact.

A conceptual metamodel for SoS strategic goal-oriented modelling was developed within the research framework, which defines the different types of goals and multiple goal-levels in an SoS arrangement, as well as the relationships and linkages between these goal levels and other components such as constituent systems, KPIs, actors, and the organisation's policy documents. This metamodel could be used in the SoS domain as a reference model that covers and models general goal-oriented aspects and relationships in SoS arrangements from i* modelling perspective.

Furthermore, a semantic Goals Referential Integrity (sGRI) model in SoS context was developed to maintain the consistency of the SoS global goals and the CS local goals at multiple levels, as well as providing semantic enrichment of i* goal-oriented modelling from SoS perspective. The SoSGRI is a new concept the could be applied in the SoS domain to manage the emerging inconsistent goals in SoS arrangements and their constituent systems. Also, the SoSGORE ontology offers standardisation of knowledge to SoS organisations from a GORE perspective, especially to the Cancer Care domain, besides the use of detecting and resolving semantic heterogeneities, and maintaining the consistency of SoS goals.

The research framework has been instantiated and validated by applying a real Cancer Care case study at KHCC in Jordan. Evaluation results revealed the effectiveness of applying the framework compared to the current approach applied at KHCC, in terms of addressing higher consistency, completeness and correctness with regard to goal management and conflict management in SoS context. Besides, instead of the manual approach applied currently at KHCC, a strategic goal-oriented management tool was developed within the framework which plays the role of a strategic dashboard that provides automation of two main crucial processes at the organisation: (1) following the progress and satisfaction of SoS goals at multiple levels with linkages to KPIs and constituent systems, and (2) detecting and resolving any goal conflicts that may occur amongst goals at multiple SoS levels, through applying new goal management mechanisms and approaches. This tool is anticipated to be applied and utilised at other SoS organisations as a proposed solution for goal and conflict management.

Another contribution to the Cancer Care and SoS domains is developing a reference i* goal-oriented model for access to Cancer Care with reference to the case of ADT policies at KHCC and their strategic documents and plans. The reference model provides the most generic concepts in Cancer Care domain, from a GORE perspective including Cancer Care hard goals, softgoals, tasks and resources with their main actors and the dependencies between them. It provides a wider system engineering perspective and offers an accessible level of abstraction for stakeholders and domain experts in recognising and understanding the relationships with other stakeholders and departments, and in validating choices among alternative designs. The standardisation of knowledge and common concepts provided by the reference model can be reused by other Cancer Care organisations to facilitate the process of capturing and specifying goals and requirements for their practice or required systems.

It is intended to extend this reference goal model to include other categories of policy documents, and to test and apply this proposed reference model to other Cancer Care organisations and case studies in order to extend its validity and usefulness. After enhancing and improving the model, it will be of a great benefit to the Cancer Care domain to submit such a model to the WHO to be generalised, standardised and reused within the Cancer Care community in GORE and SoS contexts.

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Appendices

Appendix A

Cancer Care Case Study Interviews

This appendix presents the interviews conducted while running the Cancer Care case study at KHCC in Jordan, for both elicitation and validation purposes for the first layer of the OntoSoS.GORE framework.

Interviews

Faculty of Environment and Technology
Software Engineering Research Group

The following structured interviews are part of a PhD research project named "A Goal-Oriented Requirements Engineering Framework for the Software Engineering of Systems of Systems Using the i* Framework Applied to Cancer Care".

The interviews are conducted with KHCC's domain experts for the purpose of validating the outcomes of this research and consist of the following sections:

- ➤ **Section A-1** presents a brief introduction about i* goal modelling which is applied in this research to Cancer care SoS.
- ➤ **Section A-2** is a form of a survey targeted at identifying:
  (1) the constituent systems that comprise the Cancer Care Systems of Systems and
  (2) the set of strategies and ADT policies that are only cancer care-related at KHCC.
- ➤ **Section A-3** is targeted at determining the depender and dependee actors for all goals at multiple levels of KHCC strategic plans and collecting any missing requirements.
- ➤ **Section A-4** is targeted at validating the i* extraction process proposed by the researcher to extract i* elements and concepts from user documentation.
- ➤ **Section A-5** is targeted at validating the i* elements and dependencies in the proposed "Reference i* Cancer Care Goal-Oriented Model".
- ➤ **Section A-6** is targeted at validating the i* elements and dependencies in the developed i* Cancer Care models for KHCC strategic plans.
- ➤ **Section A-7** is targeted at validating the i* elements and dependencies in the developed i* Cancer Care models for KHCC ADT policies and procedures.
- ➤ **Section A-8** is concerned with linking Cancer Care goals with their corresponding KPIs to help in measuring their satisfaction/achievement, as well as linking them to the corresponding constituent system and ADT policy document.

Section A-1: Actors, Goals and Dependencies in i* Modelling

i* is a goal-oriented approach that adopts **social modelling** in requirements engineering, where the central conceptual modelling abstraction is the **actor**

i* goal modelling focuses on:
- ➢ **What** does each actor want?
- ➢ **How** do actors achieve what they want?
- ➢ **Who** do actors **depend on** to achieve what they want?

A dependency link between two actors indicates that:
- ➢ The **depender** actor depends on…
- ➢ the **dependee** actor for…
- ➢ something: the dependum…
- ➢ in order that the depender may achieve a goal

Actors depend on one another for 1) **Hard Goals** or 2) **Soft Goals (Qualities)** to be achieved 3) **Tasks** to be performed and 4) **Resources** to be furnished.

- ➢ E.g. I depend upon my doctor for an accurate diagnosis of Cancer symptoms.

    (Here the **patient** is the **depender** actor and the **doctor** is the **dependee** actor)
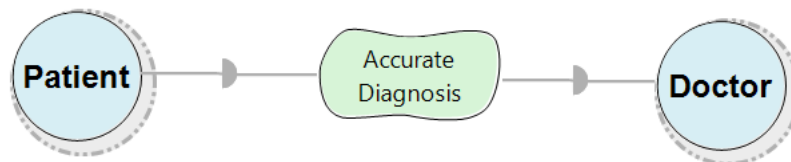
- ➢ E.g. **Objective 1.2.h**: CQO depends upon QMO for continuous follow up for all accreditation and certification indicators.

    (Here **CQO** is the **depender** actor and **QMO** is the **dependee** actor)
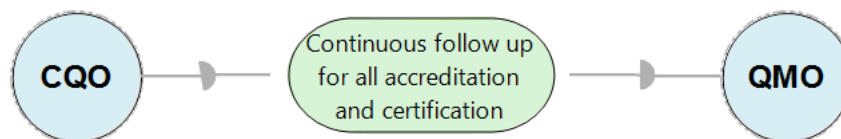
Section A-2: Cancer Care-Related Constituent Systems, Strategies and Policies

1) Which of the following Constituent Systems can be identified as part of the Sociotechnical Cancer Care SoS?

#	Name of System	Is it a Cancer Care CS?	
		Agree	Disagree
1	Patient Management System (PMS)	☐	☐
2	ER System	☐	☐
3	Laboratory System	☐	☐
4	Pharmacy System	☐	☐
5	Financial System	☐	☐
6	Surgical System	☐	☐
7	Chemotherapy System	☐	☐
8	Radiotherapy System	☐	☐
9	Radiology System	☐	☐
10	Social Services System	☐	☐
11	IT System	☐	☐
12	Medical Records	☐	☐
13	Admission and Discharge Office	☐	☐
14	Physical Therapy	☐	☐
15	Nutrition Unit	☐	☐
16	Intermediate Care Unit (IMU)	☐	☐
17	Intensive Care Unit (ICU)	☐	☐
18	New Patient Clinic	☐	☐
19	Multi-Disciplinary Clinic (MDC)	☐	☐
20	Nuclear Medicine Department	☐	☐
21	Outside Treatment Facilities	☐	☐
22	Jordan Cancer Registry (JCR)	☐	☐
23	Ministry of Health	☐	☐
24	Patients	☐	☐
25	Physicians	☐	☐
26	Nurses	☐	☐

2) Identify any other Constituent Systems that are considered part of the Cancer Care SoS?

In identifying cancer care strategies and policies, we relate them to the following definitions of (1) Cancer Care and (2) Cancer Care Informatics:

Cancer Care:
"Comprehensive care for the cancer patient as a whole including all his/her needs - not just the medical and physical ones - using the services of many professionals working together"
Mohammed Odeh, 2015, Cancer Care Modelling Workshop at King Hussein Cancer Centre.

Cancer Care Informatics
"The employment of Informatics to empower the process of cancer care, where the cancer patient is holistically the focus in the cancer care journey involving all the concerned stakeholders."
Mohammed Odeh, 2015, Cancer Care Modelling Workshop at King Hussein Cancer Centre.

3) Which of the following KHCC's Strategies and Policies can be identified as Cancer Care-Related?

#	Name of Strategy	Is it Cancer Care-Related?
	KHCC Strategic Plan	
	Strategic Priority 1: "To foster person-centred care and safety"	
1.1	Improve patient experience	☐
1.2	Foster Patient Safety	☐
1.3	Provide the optimal portfolio of cancer care services	☐
	Strategic Priority 2: "To improve and sustain KHCC institutional core competencies"	
2.1	Investing in KHCC Human Capital Engagements, Capacity Building and Retention	☐
2.2	Creation of Empowering Management Structure	☐
2.3	Assure smooth expansion	☐
2.4	Improve operational effectiveness	☐
	Strategic Priority 3: "Positioning KHCC as a leading regional oncology research, education and awareness centre"	
3.1	Position KHCC as a regional oncology academic centre	☐
3.2	Position KHCC as a regional oncology research centre	☐
3.3	Diversifying sources of income	☐
3.4	Optimise cancer control operations	☐

#	Name of Policy	Is it Cancer Care-Related?
	ADT Committee Policies	
1	Admission of Patients	☐
2	Discharge of Patients	☐
3	Discharge Planning Process	☐
4	Medical Referrals-Transfer	☐
5	Role of Surgical Intermediate Unit	☐
6	Flow of Patient and Waiting List Management	☐
7	Physicians Handover	☐
8	Referring Patients from Paediatric Department to Adult Services	☐
9	Patient - Family Rights and Responsibilities	☐
10	Meal Provision to Hospitalized Patients	☐
11	Critical Care Unit(s) Closure	☐
12	Patient's Pass	☐
13	Patient Companion	☐
14	Patient Delay	☐
15	Patients' No Show	☐
16	Storage of Patient's Belongings	☐
17	Release of minor to other than parent/ legal guardian	☐
18	Patient and Family Complaints	☐
19	Handling Disgruntled Patients/Families	☐

Section A-3: Interviews Regarding KHCC's Strategic Plan

- Determine the depender and dependee actors for KHCC's strategic goals and sub-goals listed below:

STRATEGIC PROIORITY 1 – Fostering person-centric care and safety

Strategic Goals	Depender Actor	Dependee Actor
1.1 Improve patient experience	Patient	KHCC Team & Depts
1.2 Foster patient safety	Patient	KHCC Team & Depts
1.3 Provide the optimal portfolio of cancer care services	Patient	KHCC Team & Depts

STRATEGIC PROIORITY 2 – Improving and sustaining KHCC institutional core competencies

Strategic Goals	Depender Actor	Dependee Actor
2.1 Investing in KHCC Human Capital Engagements, Capacity Building and Retention	KHCC Employees	Senior Management
2.2 Creation of Empowering Management Structure	KHCC Employees	Senior Management
2.3 Assure smooth expansion	Middle Management (Departments Managers)	HR
2.4 Improve operational effectiveness	Middle Management (Departments Managers)	Senior Management

STRATEGIC PROIORITY 3 – Positioning KHCC as a leading regional oncology research, education and awareness center

Strategic Goals	Depender Actor	Dependee Actor
3.1 Position KHCC as a regional oncology academic center	KHCC Employees	Academic Affairs
3.2 Position KHCC as a regional oncology research center	KHCC Employees	OSAR (Office of Scientific Affairs & Research)
3.3 Diversifying sources of income	KHCC Employees	Senior Management
3.4 Optimize cancer control operations	Cancer Control Participants	Cancer Control Committee

STRATEGIC GOAL 1.1 – IMPROVE PATIENT'S EXPERIENCE

SMART Objectives	Strategies	Depender Actor	Dependee Actor
1.1.a Maintain and increase overall inpatient satisfaction	Strategy 1. Improve Efficiency (Utilization) of the available beds	Patient	ADT

1.1.b Maintain and increase inpatient satisfaction per each category	Strategy 2. Improve food services	Patient	Food & Beverage Unit
	Strategy 3. Decrease environmental Noise	Patient	Nursing
	Strategy 4. Improve the satisfaction of the international patients	Patient	Head of Patient Journey Department
	Strategy 5. Launching person centred initiatives	Patient	Head of person-centred initiatives
1.1.c Increase outpatient overall satisfaction	Strategy 1. Provide mechanisms to improve patient appointment at outpatient	Patient	Outpatient Clinic Manager
	Strategy 2. Improve outpatient general environment	Patient	Outpatient Clinic Manager
1.1.d Maintain outpatient satisfaction per each category	Strategy 1. Improve outpatient pharmacy and laboratory waiting times	Patient	Outpatient Clinic Manager
	Strategy 2. Down time policy for VISTA and ATS	Patient	IT Director
	Strategy 3. Follow up of patient complaints and introduce proactive measures	Patient	QMO and IT
1.1.e Minimize overall patient waiting times	Strategy 1. Shadowing patients from first contact of KHCC throughout the process	Patient	QMO
	Strategy 2. Improve overall pharmacy waiting times	Patient	Pharmacy
	Strategy 3. Improve overall laboratory waiting times	Patient	Lab

STRATEGIC GOAL 1.2 – FOSTER PATIENTS SAFETY

SMART Objectives	Strategies	Depender Actor	Dependee Actor
1.2.a All KPIs on clinical and non-clinical levels to have attainable targets and measures	Strategy 1. Review all KPIs forms to utilize IT capabilities to support system and KPIs	QMO Head	IT Head
	Strategy 2. Improving all event reporting system	QMO Head	IT Head
1.2.b Utilizing the IT capabilities and business intelligence to support the quality systems at KHCC including the KPI

1.2.c All KPIs to be reported on-time by KHCC departments | Strategy 3. Improve the process of following KPIs | QMO Head | IT Head |

1.2.g Ensure that an electronic event reporting system is in place			
1.2.d. A clear coordinated structure for Departmental Performance Improvement Committees is in place 1.2.e. All Departmental Performance Improvements Committees' meetings to be held per the frequency set in the bylaws	Strategy 1. All departments should have a quality improvement committee	QMO Head	Middle Management
	Strategy 2. Recognizing involved staff	KHCC Employees	QMO & Senior Management
1.2.f Improvement on the scores of KHCC patient safety culture survey to meet the international benchmark in all domains	Strategy 1. Improving patients' safety culture	Senior Management	QMO Head
	Strategy 2. Raise awareness and training on non-punitive culture, to encourage reporting	Senior Management	QMO Head
1.2.h Maintain KHCC current accreditations and expanding it to include new accreditations	Strategy 1. Continuous follow up for all accreditation and certification indicators and assure full compliance with standards and find opportunities to improve	Senior Management	QMO Head
1.2.i Obtain ANCC (American Nursing Credential Centre) MAGNET Recognition by January 2018	Strategy 1: Attain ANCC MAGNET Recognition	Senior Management	Head of Nursing

STRATEGIC GOAL 1.3 – PROVIDE THE OPTIMAL PORTFOLIO OF CANCER CARE SERVICES

SMART Objectives	Strategies	Depender Actor	Dependee Actor
1.3.a The introduction of new techniques and technologies of cancer care services in annual basis	Strategy 1: Each clinical department to identify new techniques, technologies or medicine of cancer treatment annually	CMO	Departments Managers
1.3.b Maintain and Development of approved guidelines for	Strategy 1: Identification of non-existent clinical practice guidelines	CMO	Departments Managers

all clinical programs and services	Strategy 2: Utilise available data to measure the efficiency of the services /department	CMO	Departments Managers
1.3.d Screen and evaluate services for performance, effectiveness, efficiency and monitoring outcomes	Strategy 1: Development of the plan	Senior Management	CMO
	Strategy 2: Implementation of the plan	Senior Management	CMO

STRATEGIC GOAL 2.1 – INVESTING IN KHCC HUMAN CAPITAL ENGAGEMENTS, CAPACITY BUILDING AND RETENTION

SMART Objectives	Strategies	Depender Actor	Dependee Actor
2.1.a	Strategy 1	Physicians	CMO
	Strategy 2	Physicians	CMO
	Strategy 3	Physicians	CMO
2.1.b	Strategy 1	KHCC Employees	Head of HR
	Strategy 2	KHCC Employees	Head of HR
2.1.c	Strategy 1	Senior Management	HR
	Strategy 2	Senior Management	HR
	Strategy 3	Senior Management	HR/Nursing
2.1.d	Strategy 1	Senior Management	HR
2.1.e	Strategy 1	Senior Management	AAO (Academic Affairs Office)
	Strategy 2	Senior Management	Departments Managers

STRATEGIC GOAL 2.2 – CREATION OF EMPOWERING MANAGEMENT STRUCTURE

SMART Objectives	Strategies	Depender Actor	Dependee Actor
2.2.a	Strategy 1	Senior Management	HR
2.2.b	Strategy 1	Senior Management	HR
2.2.c	Strategy 1	Senior Management	HR
	Strategy 2	Senior Management	HR

STRATEGIC GOAL 2.3 – ASSURE SMOOTH EXPANSION

SMART Objectives	Strategies	Depender Actor	Dependee Actor
2.3.a	Strategy 1	Senior Management	HR Department
	Strategy 2	Senior Management	HR Department
2.3.b	Strategy 1	Senior Management	HR Department
	Strategy 2	Senior Management	HR Department

STRATEGIC GOAL 2.4 – IMPROVE OPERATIONAL EFFECTIVENESS

SMART Objectives	Strategies	Depender Actor	Dependee Actor
2.4.a	Strategy 1	Senior Management	Departments Managers
	Strategy 2	Senior Management	Departments Managers
	Strategy 3	Senior Management	Departments Managers

2.4.c	Strategy 1	Senior Management	Head of IT
	Strategy 2	Senior Management	Departments Managers
	Strategy 3	Senior Management	Departments Managers
2.4.d	Strategy 1	Senior Management	Maintenance Department
	Strategy 2	Senior Management	Maintenance Department
2.4.g	Strategy 1	Senior Management	Head of IT
2.4.h	Strategy 1	Senior Management	Head of Patient Journey & Health Informatics Dept
	Strategy 2	Senior Management	Head of Patient Journey & Health Informatics Dept
	Strategy 3	Senior Management	Head of Patient Journey & Health Informatics Dept
2.4.i	Strategy 1	Senior Management	Head of IT
2.4.j	Strategy 2	Senior Management	Head of IT
	Strategy 3	Senior Management	Head of IT
2.4.k	Strategy 1	Senior Management	Head of IT
	Strategy 2	Senior Management	Head of IT
	Strategy 3	Senior Management	Head of IT
	Strategy 4	Senior Management	Head of IT
2.4.l	Strategy 1	Senior Management	Head of IT

STRATEGIC GOAL 3.1 – POSITION KHCC AS A REGIONAL ONCOLOGY ACADEMIC CENTER

SMART Objectives	Strategies	Depender Actor	Dependee Actor
3.1.a	Strategy 1	Senior Management	CAO
	Strategy 2	Senior Management	CAO
	Strategy 3	Senior Management	CAO
3.1.b	Strategy 1	Senior Management	CAO
	Strategy 2	Senior Management	CAO
	Strategy 3	Senior Management	CAO
	Strategy 4	Senior Management	CAO
3.1.c	Strategy 1	Senior Management	Physician education center
	Strategy 2	Senior Management	Physician education center
	Strategy 3	Senior Management	Physician education center
3.1.d	Strategy 1		Regional & international scientific activities committee
	Strategy 2		Regional & international scientific activities committee
	Strategy 3		Regional & international scientific activities committee
3.1.e	Strategy 1	KHCC Employees	Training Center
	Strategy 2	KHCC Employees /Senior Management	Training Center
	Strategy 3	Senior Management	Training Center

STRATEGIC GOAL 3.2 – POSITION KHCC AS A REGIONAL ONCOLOGY RESEARCH CENTER

SMART Objectives	Strategies	Depender Actor	Dependee Actor
3.2.a 3.2.b	Strategy 1	KHCC Researchers	OSAR (Office of Scientific Affairs & Research)
	Strategy 2	CEO	RC (Research Council)
	Strategy 3	KHCC Researchers	RC (Research Council)
3.2.c	Strategy 1	Senior Management	CMO (Chief Medical Officer)
	Strategy 2	KHCC Researchers	Head of OSAR
3.1.d	Strategy 1	Senior Management	RC
	Strategy 2	RC	CMO
	Strategy 3	RC	CMO
3.1.e	Strategy 1	Senior Management	Head of OSAR
	Strategy 2	Senior Management	Head of OSAR
	Strategy 3	RC	CMO
	Strategy 4	Senior Management	RC

STRATEGIC GOAL 3.3 – DIVERSIFYING SOURCES OF INCOME

SMART Objectives	Strategies	Depender Actor	Dependee Actor
3.3.a	Strategy 1	Senior Management	Pharmacy
	Strategy 2	Senior Management	Radiation Department
	Strategy 3	Senior Management	Laboratory
	Strategy 4	Senior Management	Finance
3.3.b	Strategy 1	Senior Management	COO
	Strategy 2	Senior Management	Business Department
	Strategy 3	Senior Management	Business Department
3.3.c	Strategy 1	Senior Management	CFO (Chief Financial Officer)
	Strategy 2	Senior Management	CFO

STRATEGIC GOAL 3.4 - OPTIMIZE CANCER CONTROL OPERATIONS

SMART Objectives	Depender Actor	Dependee Actor
Revise the cancer control strategies at KHCC	Cancer Control Participants	Cancer Control Committee

- *Answer the following questions regarding KHCC's strategic plan.*
- *Discuss how it is possible to achieve each goal. What are the strategies and actions applied?*

STRATEGIC GOAL 1.1 – IMPROVE PATIENT'S EXPERIENCE

SMART Objectives	Strategies	Question	Answer
SMART Objectives 1.1.a and 1.1.b	Strategy 1	What is **ADT** (champ of strategy)?	
	Strategy 3	Is the champ of strategy both the **Quality force** and the **Nursing** department?	

	Strategy 4	What is the role of **Dr. Yaser Yamen**?	
	Strategy 5	What is the role of **Dr. Majeda Afeef?** Is it Nursing for this strategy? As she is also a member at Patient Care Task Force & Training and Education Task Force.	
SMART Objective 1.1.d	Strategy 3	Does **QMO** stand for Quality Management Office? What is the correct naming to be used **(Quality Taskforce/ Quality Dept/ QMO)?**	

STRATEGIC GOAL 1.2 – FOSTER PATIENTS SAFETY

SMART Objectives	**Strategies**	**Question**	**Answer**
SMART Objective 1.2.f	Strategy 2	Champ of strategy is not determined, is it also QMO?	
SMART Objective 1.2.h		- What is the role of **Ms. Dana Nashawati**? Quality Management?	
1.2.i Obtain ANCC MAGNET Recognition by January 2018	Strategy 1 - Attain ANCC MAGNET Recognition	What does **ANCC** stand for?	

STRATEGIC GOAL 1.3 – PROVIDE THE OPTIMAL PORTFOLIO OF CANCER CARE SERVICES

SMART Objectives	**Strategies**	**Question**	**Answer**
SMART Objectives 1.3.a and 1.3.b		What is the role of **Dr. Hikmat Abdel Razeq**?	
SMART Objectives 1.3.c and 1.3.d		What is the role of **Dr. Fawzi Abdelrahman**? Member of Strategic Planning Committee	

STRATEGIC GOAL 2.1 – INVESTING IN KHCC HUMAN CAPITAL ENGAGEMENTS, CAPACITY BUILDING AND RETENTION

SMART Objectives	**Strategies**	**Question**	**Answer**
SMART Objective 2.1.d	Strategy 3	What does **EES** stand for?	
SMART Objective 2.1.e		What does **AAO** stand for?	
SMART Objectives 2.1.a and 2.1.e		Is there any difference between **Dept. Chairmen** and **Dept. Heads**??	

STRATEGIC GOAL 2.2 – CREATION OF EMPOWERING MANAGEMENT STRUCTURE

SMART Objectives	Strategies	Question	Answer
SMART Objective 2.2.a & 2.2.c		Is there more information about the HR specialised consulting firm?	

STRATEGIC GOAL 2.3 – ASSURE SMOOTH EXPANSION

SMART Objectives	Strategies	Question	Answer
SMART Objective 2.3.a & 2.3.b		Can you provide more details about phase 1 and phase 2 of the expansion?	

STRATEGIC GOAL 2.4 – IMPROVE OPERATIONAL EFFECTIVENESS

SMART Objectives	Strategies	Question	Answer
SMART Objective 2.4.a	Strategy 2	Can you determine the starting date & deadline for this strategy?	
SMART Objective 2.4.b	Strategy 2	Can you determine the starting date & deadline for this strategy?	
SMART Objectives 2.4.d, 2.4.e & 2.4.f		Can you determine the strategies applied to achieve these objectives?	
SMART Objective 2.4.i & 2.4.j SMART Objective 2.4.k	Strategy 3	De Can you determine the starting date & deadline for this strategy?	
SMART Objective 2.4.g		What is the role of **Mr. Hussain Hassona**?	
SMART Objective 2.4.h	Strategy 1	What does **MP** stand for??	
SMART Objective 2.4.h	Strategy 1,2 & 3	What is the role of **Mr. Al-Sayyad**?	
SMART Objective 2.4.h	Strategy 3	Can you determine the external vendors?	
SMART Objective 2.4.k		- What does **HMIS** stand for? - Is the IT director responsible for all strategies? - Can you determine the champ of strategy for Strategies 2 & 3?	

STRATEGIC GOAL 3.1 – POSITION KHCC AS A REGIONAL ONCOLOGY ACADEMIC CENTER

SMART Objectives	Strategies	Question	Answer
SMART Objectives 3.1.a	Strategy 1,2	Has the full academic affiliation with JU been accomplished?	
SMART Objectives 3.1.a	Strategy 3	Has the affiliation with an international regional academic cancer institution been accomplished? Can you determine the institution?	
SMART Objective 3.1.b	Strategy 2	Is the Academy task force the same as the Research task force?	

		Can you explain the difference?	

STRATEGIC GOAL 3.2 – POSITION KHCC AS A REGIONAL ONCOLOGY RESEARCH CENTER

SMART Objectives	Strategies	Question	Answer
SMART Objectives 3.2.a	Strategy 1	What does **OSAR** stand for?	
SMART Objectives 3.2.a	Strategy 3	What does **RC** stand for?	
SMART Objective 3.2.c		What does **IRB** stand for?	
SMART Objective 3.2.c	Strategy 2	What is the role of **Dr. Amal**?	

STRATEGIC GOAL 3.3 – DIVERSIFYING SOURCES OF INCOME

SMART Objectives	Strategies	Question	Answer
SMART Objective 3.3.a	Strategy 4 & 5	What does **DG** stand for?	
SMART Objective 3.3.b	Strategy 3	The objective states that it should be accomplished by **Dec 2015** and the dead line of the strategy is **Dec 2017**. Which is correct?	

Section A-4: Validating the i* Extraction Process from User Documentation

1) Do you agree with the following rules for mapping between text in user documentation and i* goal-oriented modelling language elements?

#	Text type	i* Element	Examples	Correct Mapping?
1	Nouns that represent roles	Actor	Care Provider Patient	☐ Yes ☐ No
2	Nouns that represent job titles	Actor	Physician Nurse	☐ Yes ☐ No
3	Nouns that represent departments	Actor	Pharmacy	☐ Yes ☐ No
4	A role with a specialised adjective	Generalisation/ Specialisation Relationship ISA Relationship	Attending physician ISA physician	☐ Yes ☐ No
5	Noun phrases that represent services	Hard Goal	Diagnosis of patient Admission of patient	☐ Yes ☐ No
6	Verbs and verb phrases that represent activities	Task	Order a test Write a prescription	☐ Yes ☐ No
7	Entities that need to be delivered from one actor to another	Resource	Medical report Prescription	☐ Yes ☐ No
8	Adverbs and adjectives that represent qualities	Softgoal	Quick diagnosis Timely reporting	☐ Yes ☐ No
9	Numbers	Softgoal	Deadlines such as: plan discharge with up to 7 days' notice	☐ Yes ☐ No
10	Nouns that refer to qualities	Softgoal	Empathy Safety	☐ Yes ☐ No
11	Description of multiple possibilities or alternative ways	OR Decompositions	The patient shall sign the "Release from Liability Form" If the patient refuses to sign, two witnesses should sign the form	☐ Yes ☐ No
12	Numbered lists, bulleted lists, or description of several needed steps	AND Decompositions	Attending physician should:	☐ Yes ☐ No

#	Text type	i* Element	Examples	Correct Mapping?
			1. Counsel with the patient and explain the risks 2. Ensure that the Release from liability form is completed 3. Provide the patient with a medical summary 4. Provide prescriptions	

2) Do you suggest any other elements in existing user documentation that need to be mapped using the developed i* extraction process?

Section A-5: Validating the dependencies and relationships in the proposed "Reference i* Cancer Care Goal-Oriented Model"

1) Do you agree with the following dependency types and directions between the actors in the following "Reference i* Cancer Care Goal-Oriented Model"?
2) Do you consider each one of these dependencies generic/common in the cancer care domain?
3) Identify the corresponding constituent system for each dependency.

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
1	Create person-centred initiatives (Hard Goal)	Patient	Cancer Care team	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
2	Minimise pharmacy waiting times (Soft Goal)	Patient	Pharmacy	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
3	Prepare prescriptions (Task)	Patient	Pharmacy	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
4	Educate patient to use medication (Task)	Patient	Pharmacy	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
5	Minimise lab waiting times (Soft Goal)	Patient	Laboratory	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
6	Decrease environmental noise (Soft Goal)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
7	Empathy (Soft Goal)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
8	Follow up treatment (Task)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
9	Follow up appointments (Task)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
10	Medically educate the patient (Task)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
11	Coordinate with other medical services (Task)	Patient	Nursing	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
12	Initial diagnosis of cancer (Hard Goal)	Patient	Medical External Party	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
13	Empathy (Soft Goal)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
14	Cancer staging (Hard Goal)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
15	Cancer treatment (Hard Goal)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
16	Write prescription (Task)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
17	Medical reports and sick leaves (Resource)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
18	Get admission to IMU when required (Hard Goal)	Patient	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
19	Follow treatment plan (Task)	Physician	Patient	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
20	Empathy (Soft Goal)	Patient	ER Staff	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
21	Get Evaluated and stabilised (Hard Goal)	Patient	ER Staff	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
22	Handle Admission (Hard Goal)	ER Staff	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
23	Get Approval to Centre (Hard Goal)	Patient	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
24	Schedule clinic's appointments (Task)	Patient	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
25	Patient's medical record (Resource)	Patient	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
26	Send patients' cases (Task)	JCR	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
27	Study and approve patients' cases (Task)	Physician	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
28	Pre-Admission Form (Resource)	Medical Records	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
29	Confidentiality (Soft Goal)	A&D Office	Medical Records	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
30	Confidentiality (Soft Goal)	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
31	Get admission to centre (Hard Goal)	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
32	Get discharged or transferred (Hard Goal)	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
33	Admitted and treated regardless of	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
	financial coverage (Soft Goal)						
34	Safe and effective discharge (Soft Goal)	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
35	Efficiency of beds availability (Soft Goal)	Patient	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
36	Perform admission procedures (Task)	A&D Office	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
37	Perform discharge procedures (Task)	A&D Office	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
38	Order tests (Task)	A&D Office	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
39	Arrange beds for admission (Task)	A&D Office	Bed Manager	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
40	Notification of admission (Hard Goal)	Bed Manager	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
41	Admission list (Resource)	Bed Manager	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
42	Coordination about transferring patient to IMU (Hard Goal)	Bed Manager	OR Manger	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
43	Coordination about cases (Hard Goal)	Bed Manager	Surgeon	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
44	Coordination about cases (Hard Goal)	OR Manger	Surgeon	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
45	Surgery request form to reserve IMU bed (Resource)	OR Manger	Surgeon	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
46	Book & prioritise IMU beds (Task)	Surgeon	OR Manger	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
47	Coordination about transferring patient to ICU (Hard Goal)	ICU Nursing	OR Manger	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
48	Arrange patient transfer to ICU when required (Hard Goal)	ICU	Surgeon	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
49	Coordinate patient transfer to IMU	IMU	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
	when required (Hard Goal)						
50	Refer Patients (Task)	Surgeon	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
51	Perform surgical operations (Task)	Patient	Surgeon	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
52	Perform lab tests (Task)	Physician	Lab	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
53	Perform X-ray tests (Task)	Physician	Radiology Department	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
54	Consultation (Hard Goal)	Physician	Consultant Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
55	Quick diagnosis of patients (Soft Goal)	Physician	New Patient Clinic	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
56	Guidelines for cancer treatment (Resource)	New Patient Clinic	Multi-Disciplinary Clinic (MDC)	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
57	Guidelines for cancer treatment (Resource)	Physician	Multi-Disciplinary Clinic (MDC)	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
58	Approval to initiate treatment (Hard Goal)	Physician	Multi-Disciplinary Clinic (MDC)	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
59	Safe and effective patient transfer (Soft Goal)	Outside treatment facilities	A&D Office	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
60	Refer patients to Nuclear medicine (Task)	Nuclear Medicine	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
61	Cancer diagnosis (Hard Goal)	Patient	Nuclear Medicine	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
62	Cancer treatment (Hard Goal)	Patient	Nuclear Medicine	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
63	Refer patients to physical therapy (Task)	Physical Therapy	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
64	Assess physical status (Task)	Patient	Physical Therapy	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
65	Recommend needed exercise (Task)	Patient	Physical Therapy	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
66	Communication about patient case (Hard Goal)	Social Services	Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
67	Assistance & counselling (Hard Goal)	Patient	Social Services	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
68	Assess nutritional status (Task)	Patient	Nutrition Unit	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
69	Recommend diet (Task)	Patient	Nutrition Unit	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
70	Timely and accurate delivery of meals (Soft Goal)	Patient	Food Unit	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
71	Improvement of food services (Hard Goal)	Patient	Food Unit	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

4) Do you suggest other generic/common dependencies in the cancer care domain to be covered and modelled in the "Reference i* Cancer Care Goal-Oriented Model"?
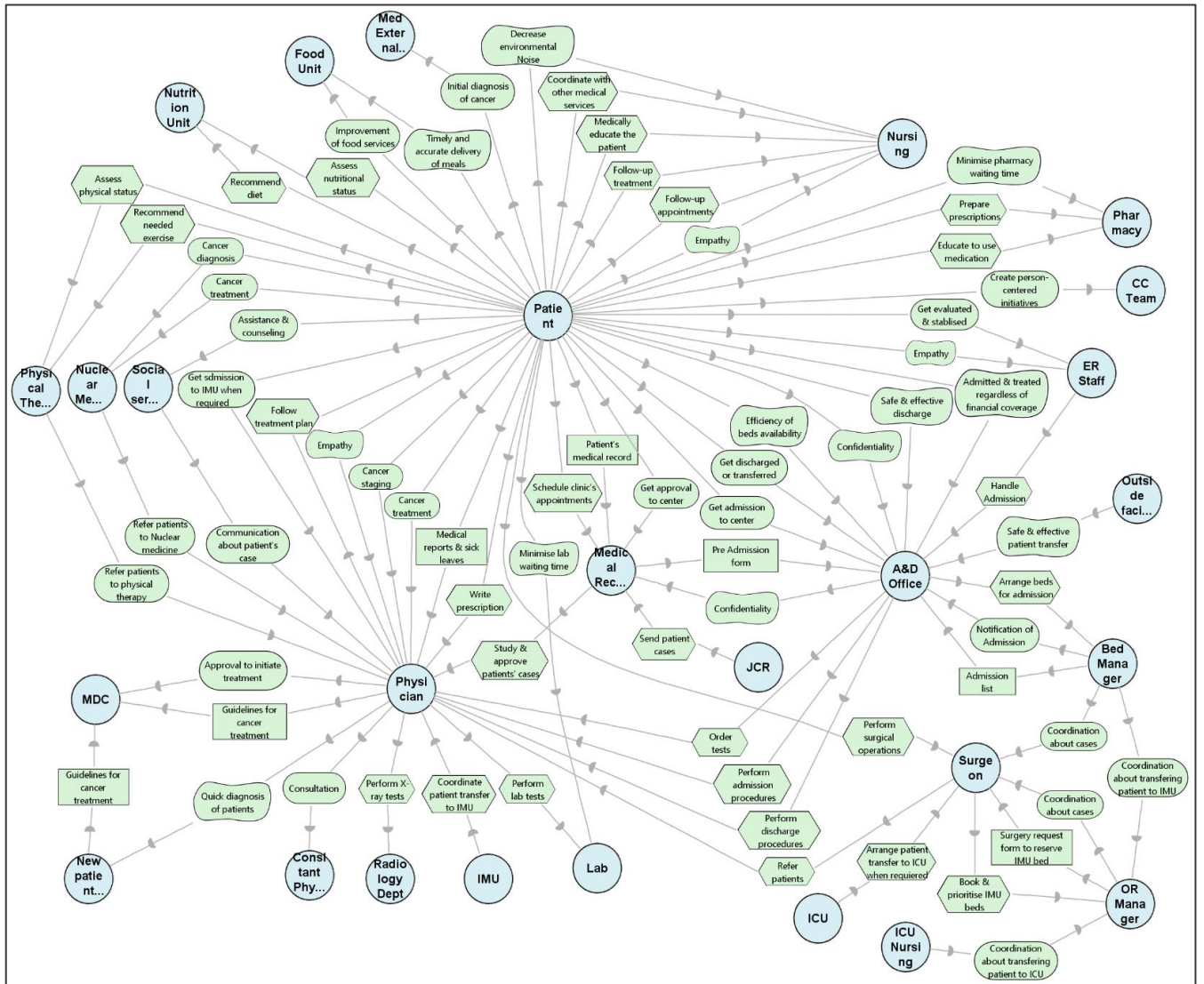
Figure A.1: Reference i* Cancer Care Goal-Oriented Model_V3 (After 2nd Iteration of Validation)
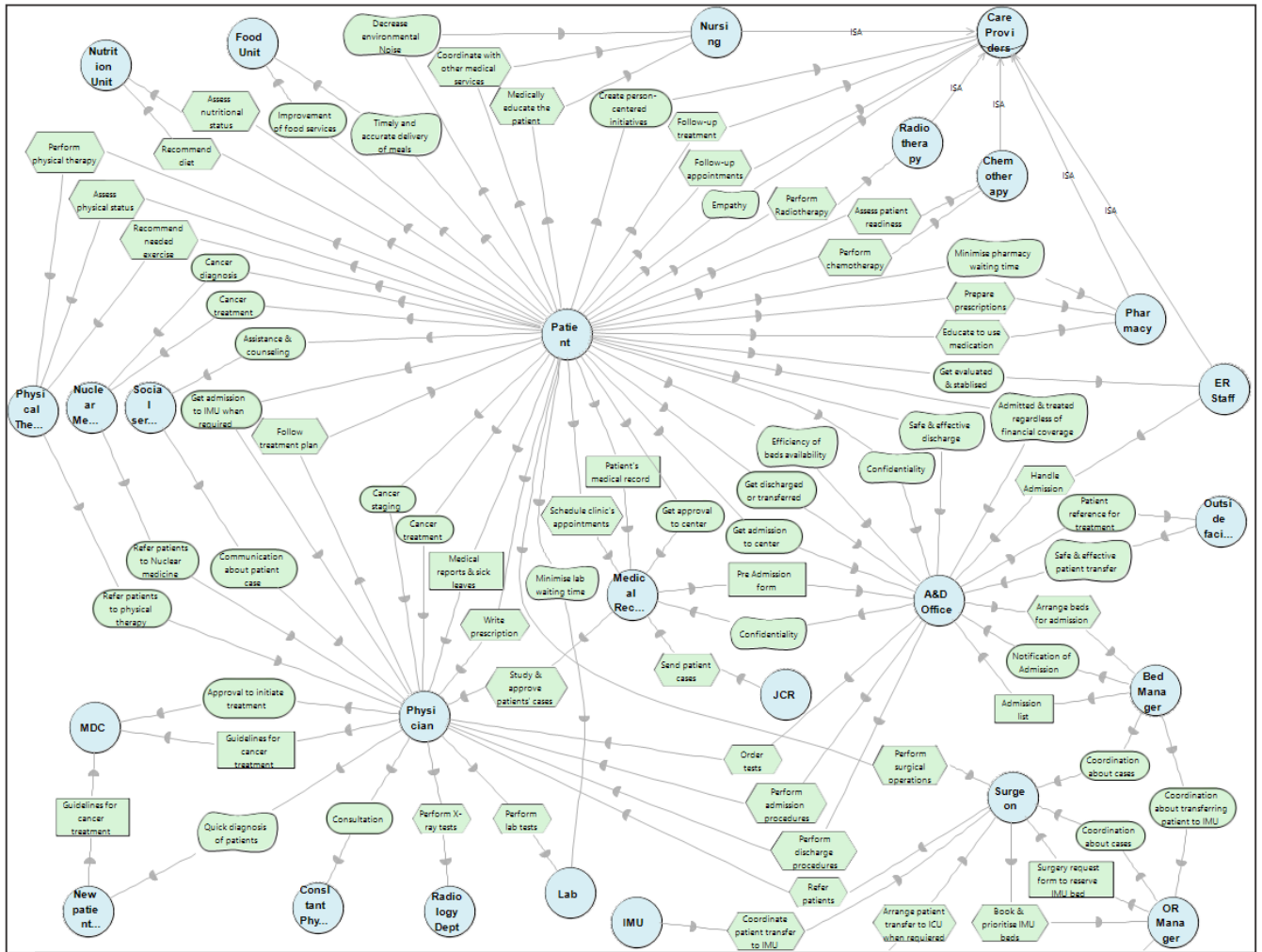
Figure A.2: Reference i* Cancer Care Goal-Oriented Model_Last Version (After 3rd Iteration of Validation)

Section A-6: Validating the i* elements, dependencies and relationships in the developed i* models for "KHCC Strategic Plan"

1) Do you agree with the following dependency types and directions between the actors in the following i* models?
2) Do you consider each one of these dependencies generic/common in the cancer care domain?
3) Identify the corresponding constituent system for each dependency.
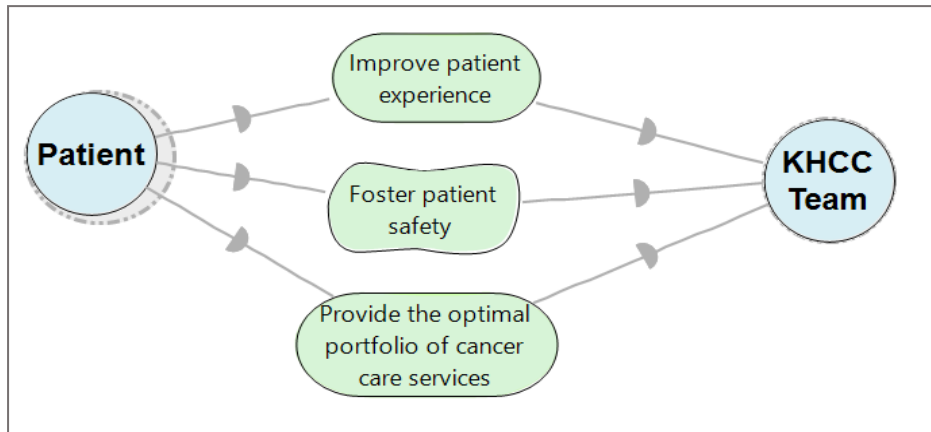
Figure A.3: HSD for Strategic Priority 1 "Foster person-centred care and safety"

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
1	Improve patient experience (Hard Goal)	Patient	KHCC Team	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	SoS Global Goal
2	Foster patient safety (Soft Goal)	Patient	KHCC Team	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	SoS Global Goal
3	Provide the optimal portfolio of cancer care services (Hard Goal)	Patient	KHCC Team	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	SoS Global Goal

Figure A.4: HSD Model for Strategic Goal 1.1 "Improve patient experience"
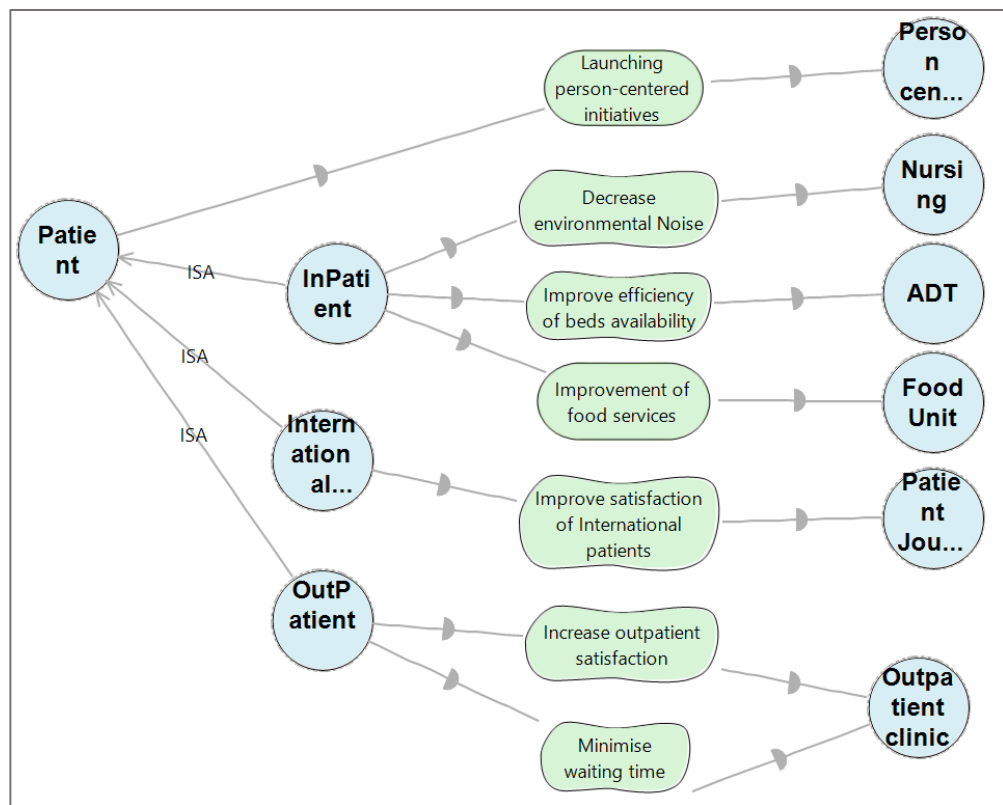
Figure A.5: SD Model for Strategic Goal 1.1 "Improve patient experience"

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
1	Launching person-centred initiatives (Hard Goal)	Patient	Person-Centred Initiatives	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

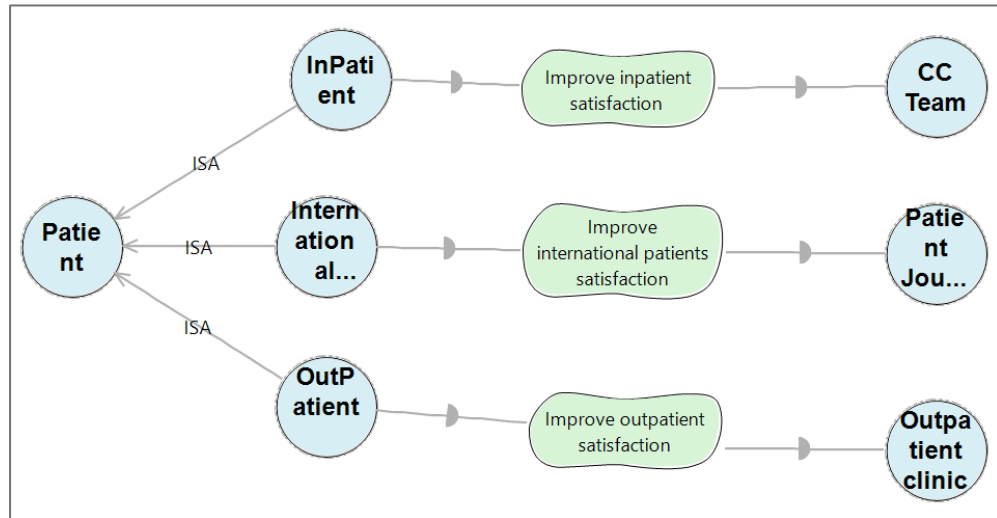| #	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
2	Decrease Environmental Noise (Soft Goal)	Inpatient	Nurses	☐ Yes ☐ No	☐ Yes ☒ No	☐ Yes ☐ No	
3	Improve efficiency of beds availability (Soft Goal)	Inpatient	ADT	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
4	Improvement of food services (Hard Goal)	Inpatient	Food and Beverages Unit	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
5	Increase outpatient satisfaction (Soft Goal)	Outpatient	Outpatient Clinic	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
6	Minimise waiting time (Soft Goal)	Outpatient	Outpatient Clinic	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
7	Improve satisfaction of international patients (Hard Goal)	International Patient	Patient Journey Department	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
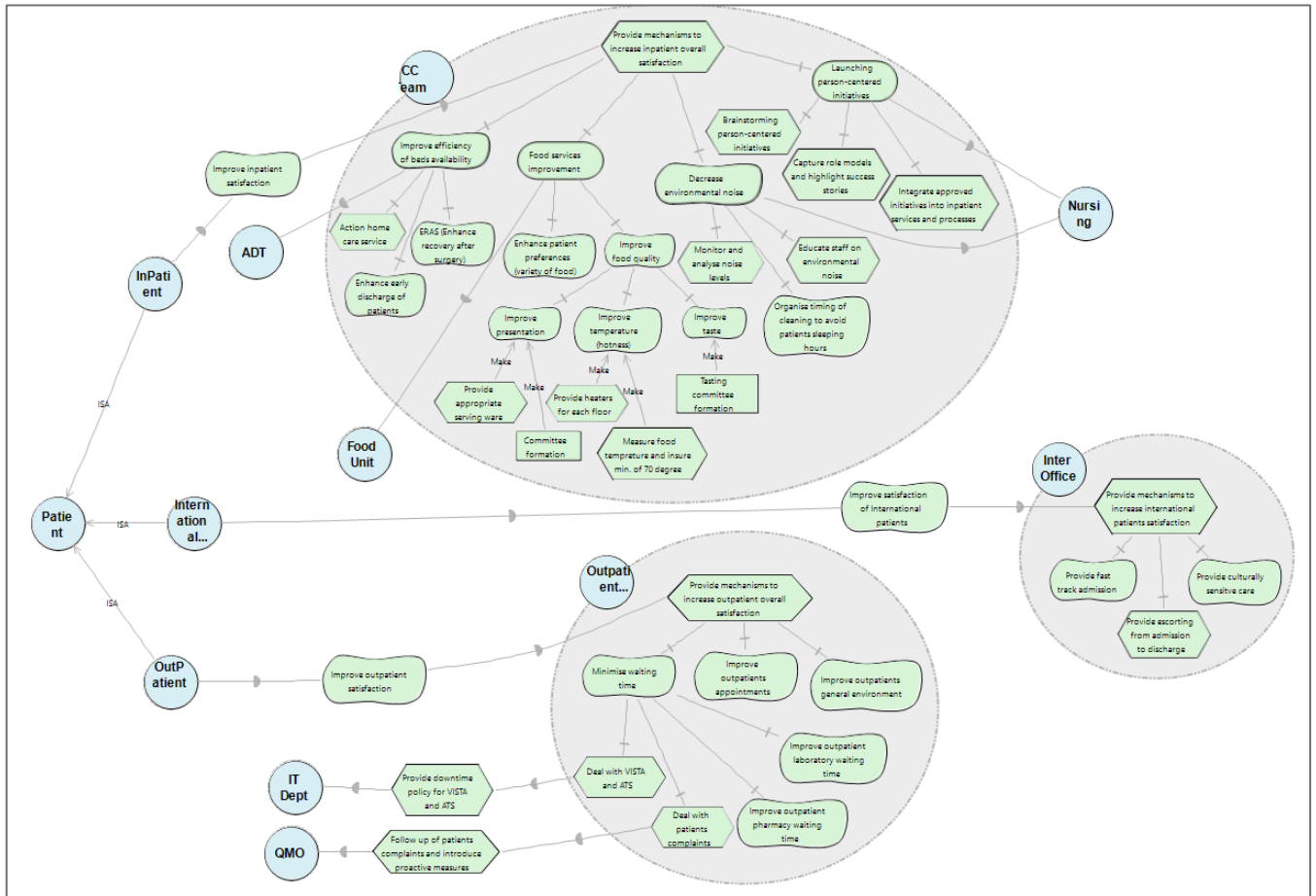
Figure A.6: SR Model for Strategic Goal 1.1 "Improve patient experience"
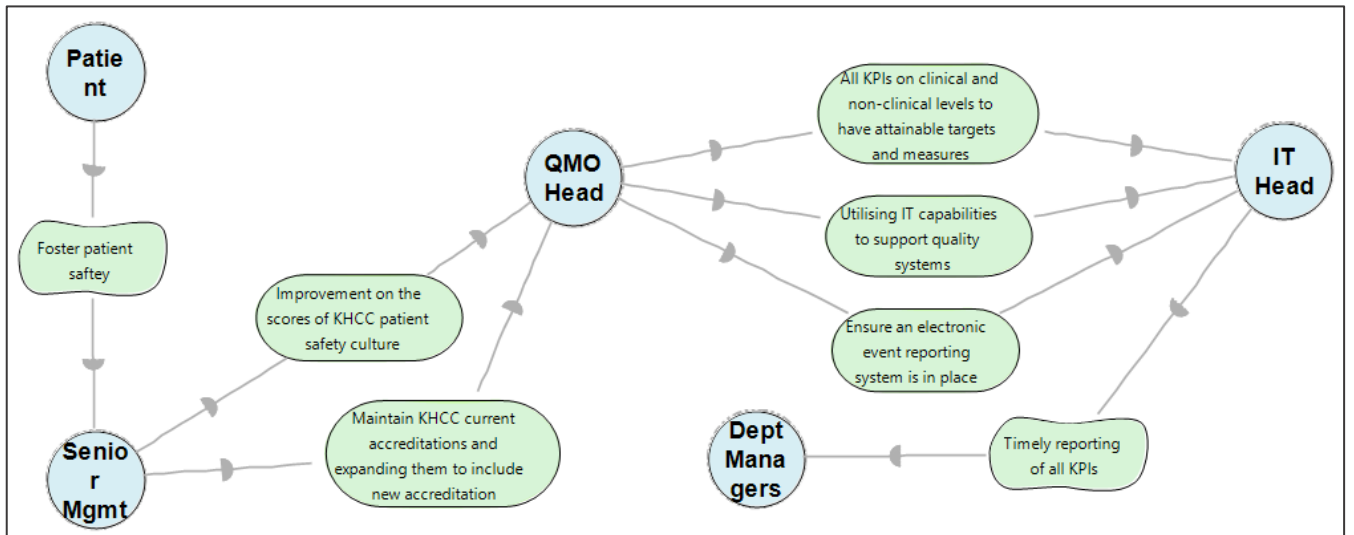
Figure A.7: SD Model for Strategic Goal 1.2 "Foster Patient Safety"
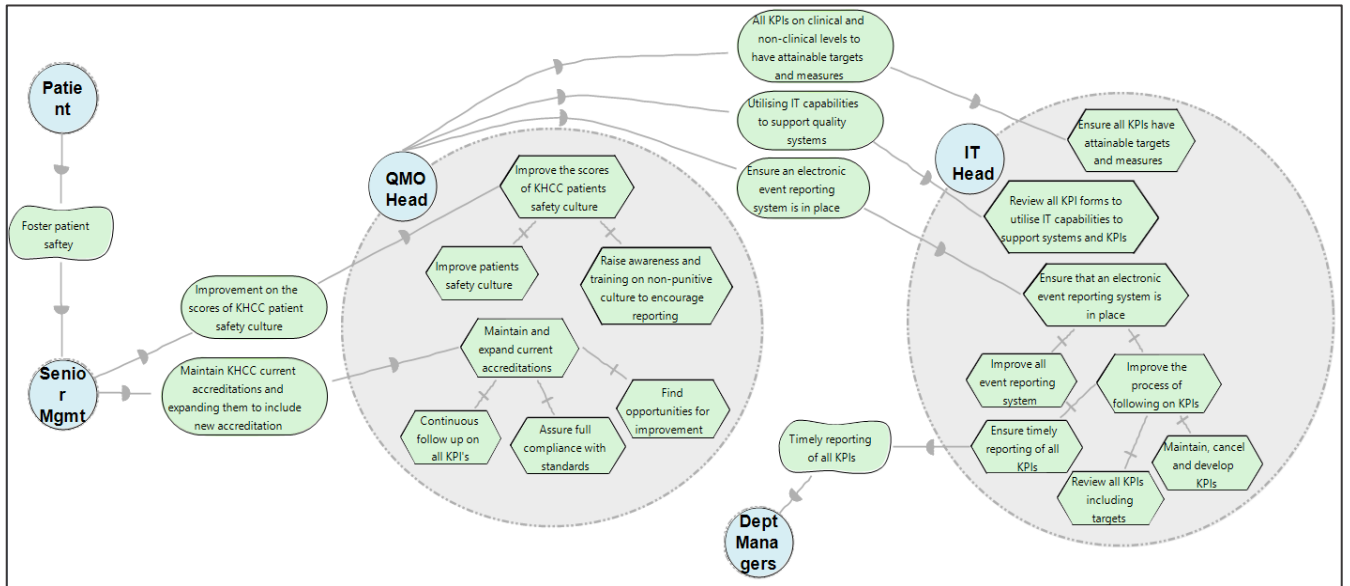
Figure A.8: SR Model for Strategic Goal 1.2 "Foster Patient Safety"
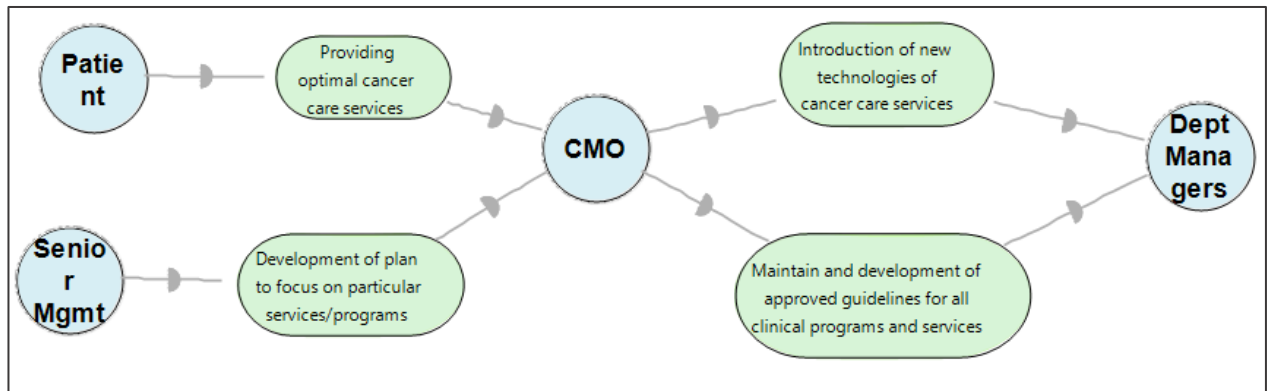
Figure A.9: SD Model for Strategic Goal 1.3 "Provide the Optimal Portfolio of Cancer Care Services"
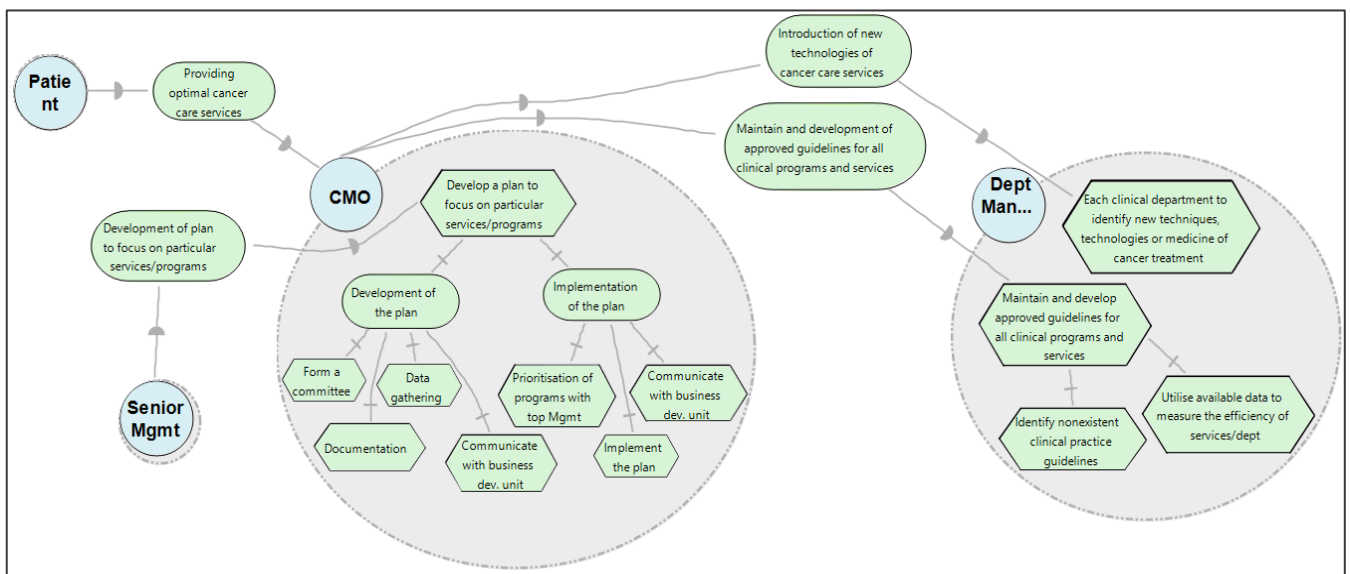
Figure A.10: SR Model for Strategic Goal 1.3 "Provide the Optimal Portfolio of Cancer Care Services"

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Section A-7: Validating the dependencies and relationships in the developed i* models for "ADT policies and procedures"

1) Do you agree with the following dependency types and directions between the actors in the following ADT i* models?
2) Do you consider each one of these dependencies generic/common in the cancer care domain?
3) Identify the corresponding constituent system for each dependency.
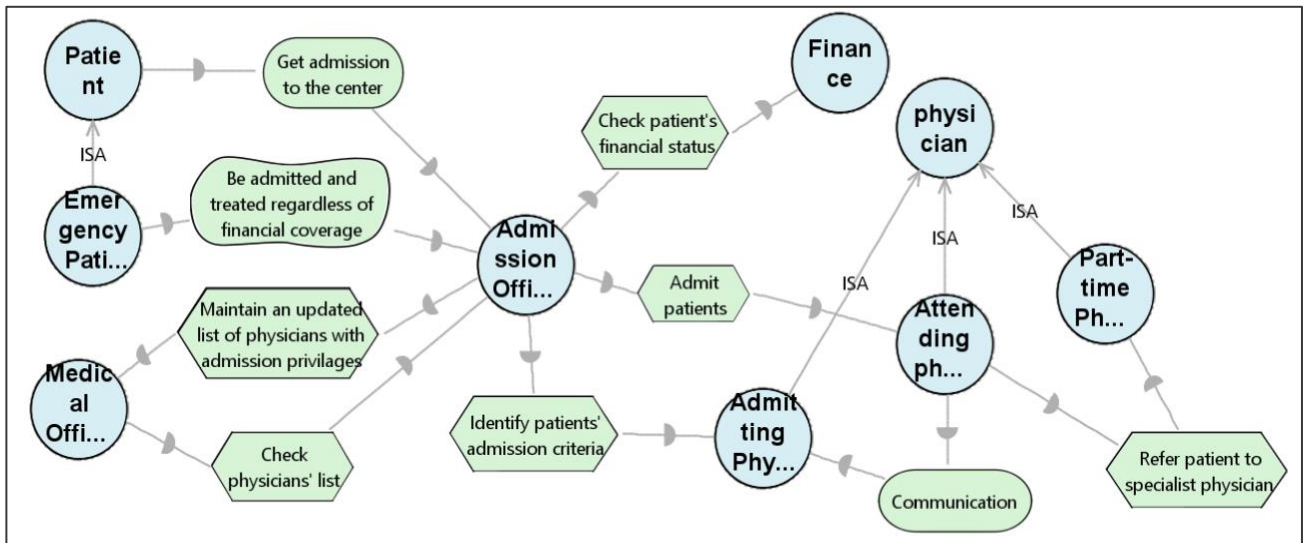
Figure A.11: SD Model for "Admission of Patients Policy"

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
1	Get admission to the center (Hard Goal)	Patient	Admission Officer	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
2	Be admitted and treated regardless of financial coverage (Soft Goal)	Emergency Patient	Admission Officer	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
3	Maintain an updated list of physicians with admission privileges (Task)	Admission Officer	Medical Staff Office Manager	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
4	Check physicians' list before admission (Task)	Medical Staff Office Manager	Admission Officer	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
5	Admit patients (Task)	Admission Officer	Attending Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

#	Dependency	Actor 1 (Depender)	Actor2 (Dependee)	Correct Dependency type?	Correct direction?	Is it generic?	Constituent System
6	Identify patients' admission criteria (Task)	Admission Officer	Admitting Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
7	Communication (Hard Goal)	Attending Physician	Admitting Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
8	Refer patient to specialist physician (Task)	Attending Physician	Part-time Physician	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
9	Check patient's financial status (Task)	Admission Officer	Finance	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
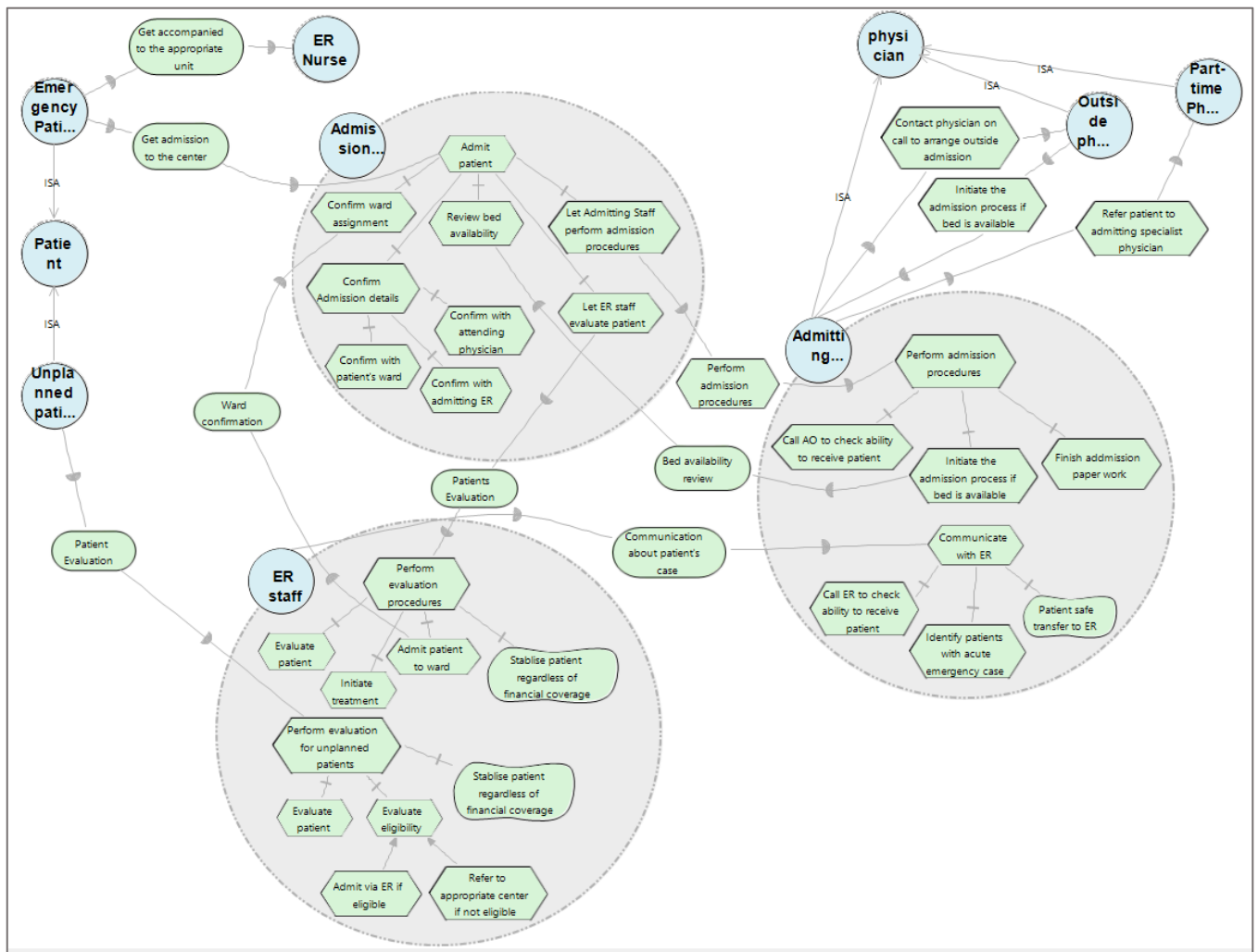
Figure A.12: SR Model for "Emergency Admission Procedures"
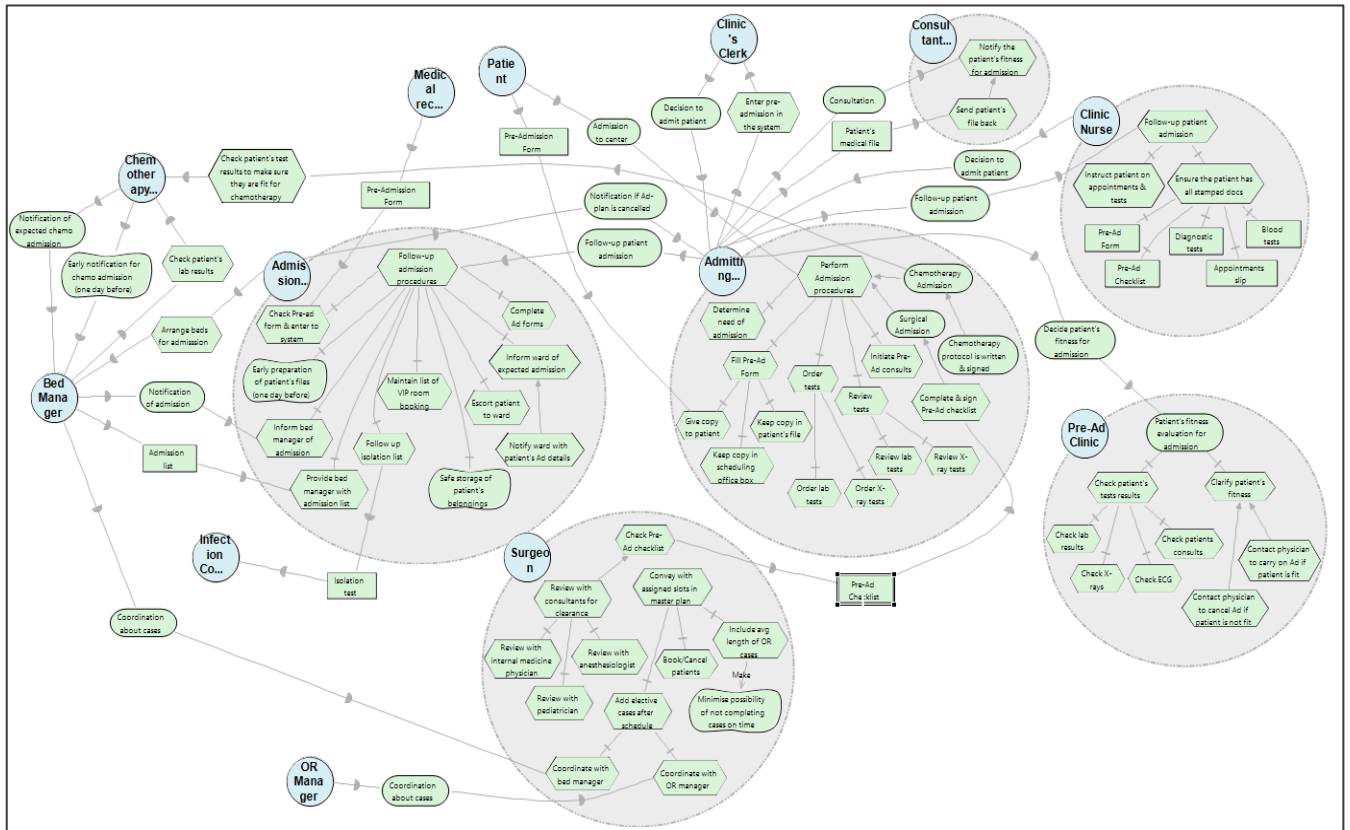
Figure A.13: SR Model for "Elective and Urgent Admission Procedures"
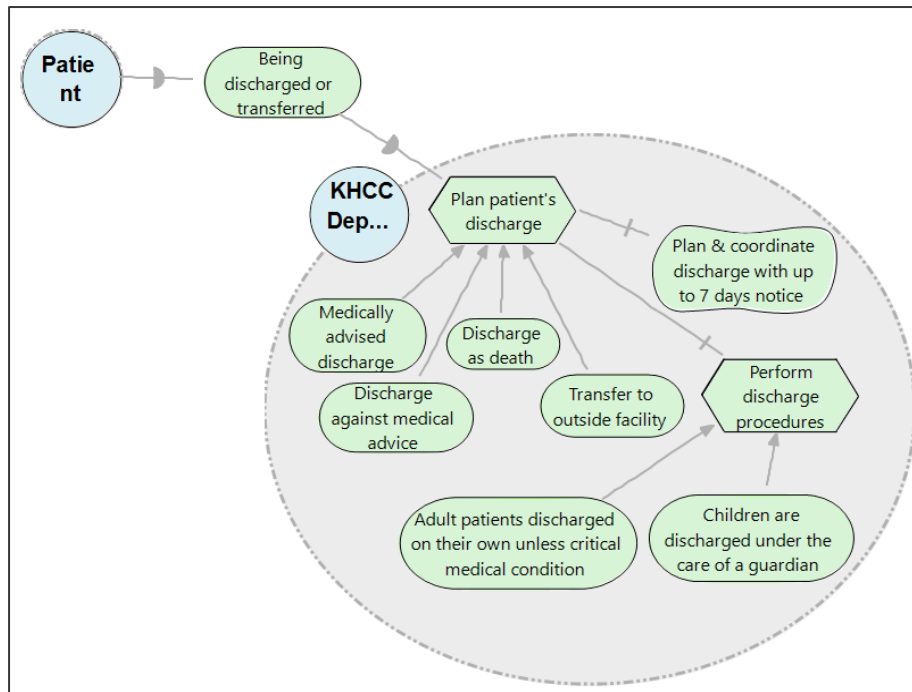
Figure A.14: SR Model for "Discharge of Patients Policy"

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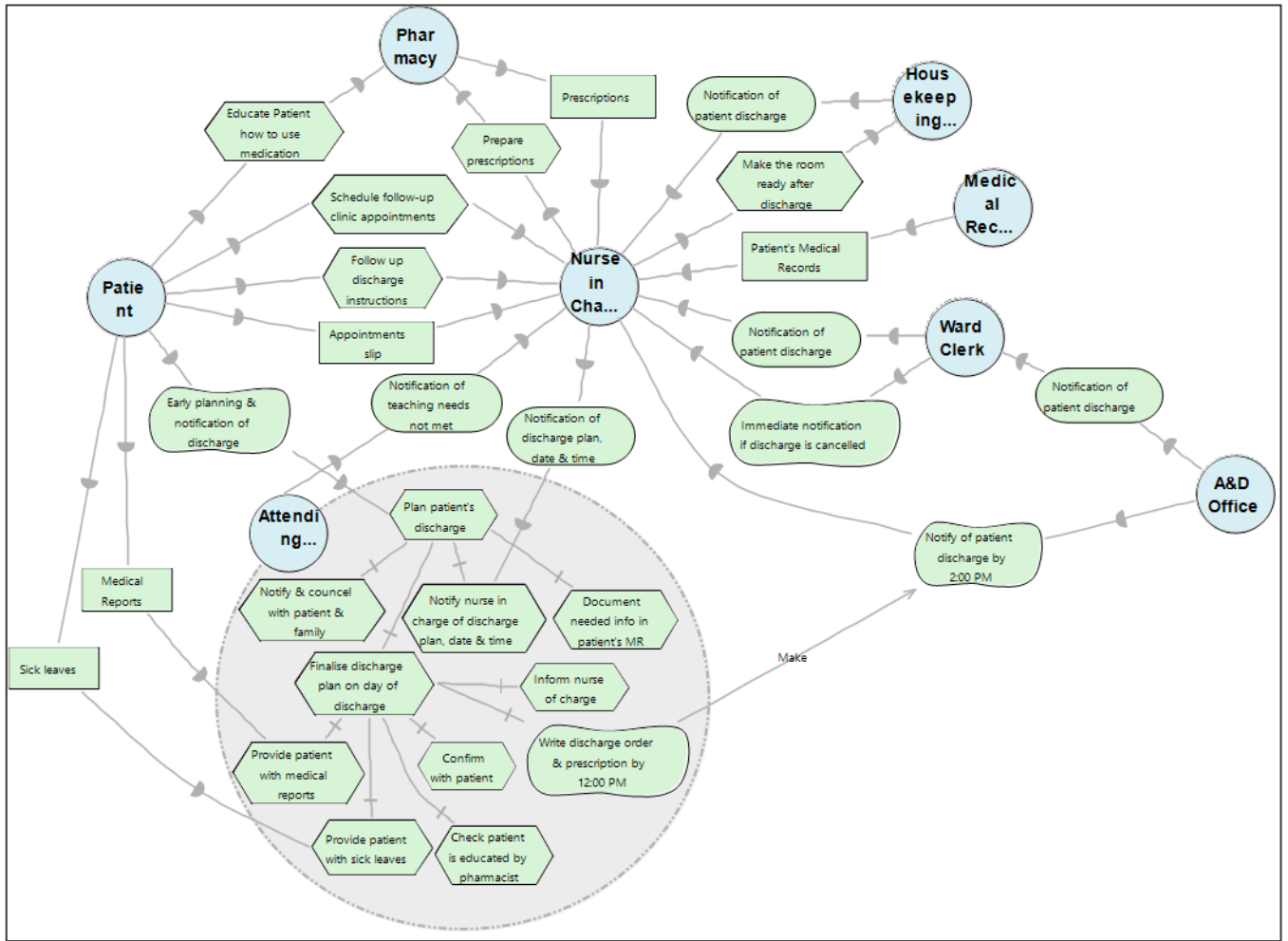
Figure A.15: SR Model for "Patient Medically Advised Discharge Procedures"
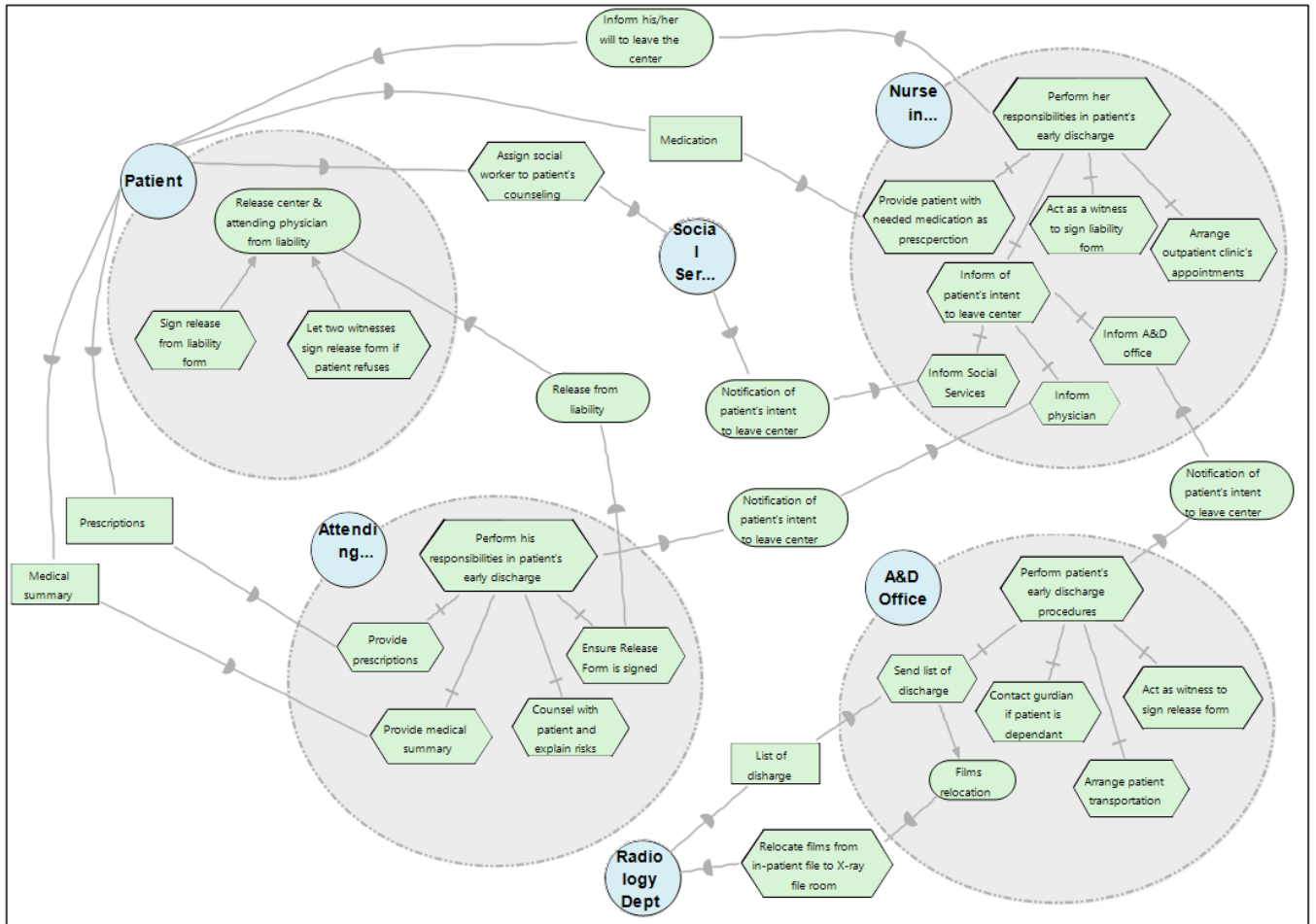
Figure A.16: SR Model for "Patient Discharge Against Medical Advice"
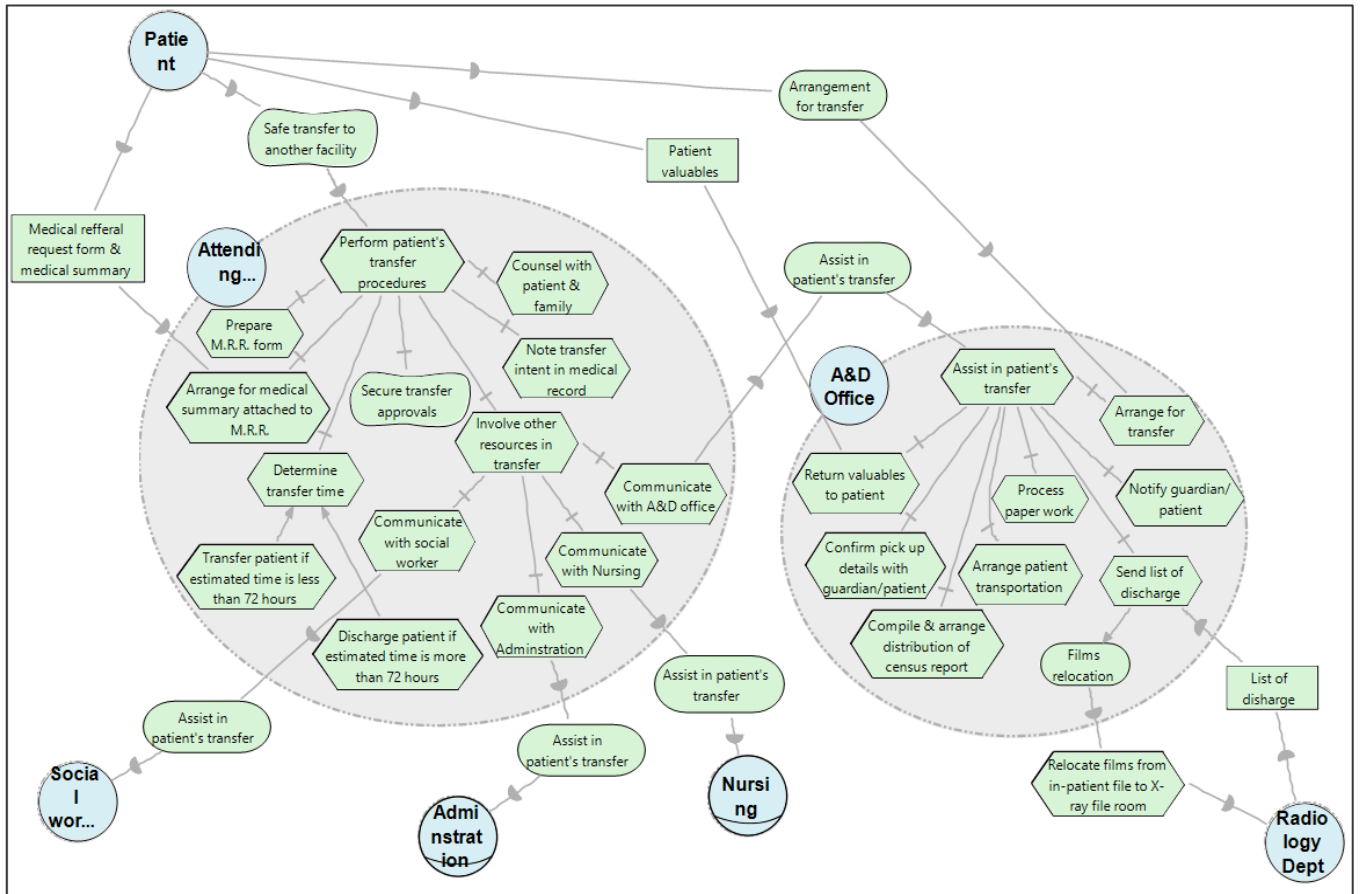
Figure A.17: SR Model for "Patient Transfer to Outside Facility"

Section A-8: Linking KHCC's Strategic Priorities, Global Goals & Local Goals with KPIs, Constituent Systems and ADT Policies

Strategic Priorities	Strategic Goals	SMART Objectives	Strategies/ Actions	i* Dependency Type	How to measure it? (KPIs)	Corresponding Constituent System	Corresponding ADT Policy
STRATEGIC PROIORITY 1 – Fostering person-centric care and safety	**1.1 Improve patient experience**	1.1.a Maintain inpatient overall satisfaction to 92% and increase it to 95% by Dec. 2017	Strategy 1. Improve Efficiency (Utilisation) of beds availability	**Soft Goal**			Admission of Patients
			Strategy 2. Improve food services	**Hard Goal**			Meal Provision to Hospitalised Patients
		1.1.b Maintain and increase inpatient satisfaction per each category above 88%	Strategy 3. Decrease environmental Noise	**Soft Goal**			
			Strategy 4. Improve the satisfaction of the international patients	**Soft Goal**			
			Strategy 5. Launching person centred initiatives	**Hard Goal**			
		1.1.c Increase outpatient overall satisfaction to 92% by Dec. 2017	Strategy 1. Provide mechanisms to improve patient appointment at outpatient	**Hard Goal**			
			Strategy 2. Improve outpatient general environment	**Hard Goal**			
		1.1.d Maintain outpatient satisfaction per	Strategy 1. Improve outpatient pharmacy and	**Soft Goal**			

		each category above 88%	laboratory waiting times				
			Strategy 2. Down time policy for VISTA and ATS	**Soft Goal**			
			Strategy 3. Follow up of patient complaints and introduce proactive measures	**Hard Goal**			
		1.1.e Minimise overall patient waiting times **(Soft Goal)**	Strategy 1. Shadowing patients from first contact of KHCC throughout the process	**Hard Goal**			
			Strategy 2. Improve overall pharmacy waiting times	**Soft Goal**			
			Strategy 3. Improve overall laboratory waiting times	**Soft Goal**			
	1.2 Foster patient safety	1.2.a 100% of KPI's on clinical and non-clinical levels to have attainable targets and measures	Strategy1. Review all KPI forms to utilise IT capabilities to support systems and KPIs	**Hard Goal**			
		1.2.b. Utilising the IT capabilities and business intelligence to support the quality systems at KHCC including the KPI	Strategy 2. Improving all event reporting system	**Hard Goal**			
			Strategy 3. Improve the process of following on KPIs	**Hard Goal**			

		1.2.c. All KPI's to be reported on-time by KHCC departments 1.2.g. Ensure that an electronic event reporting system is in place					
		1.2.d A clear coordinated structure for Departmental Performance Improvement Committees in place 1.2.e All Departmental Performance Improvements Committees' meetings to be held per the frequency set in the bylaws	Strategy 1. All departments should have a quality improvement committee	**Hard Goal**			
			Strategy 2. Recognising involved staff	**Hard Goal**			
		1.2.f Improvement on the scores of KHCC patient safety culture survey to meet the international benchmark in all domains	Strategy 1. Improving patients' safety culture	**Soft Goal**			
			Strategy 2. Raise awareness and training on non-	**Hard Goal**			

			punitive culture to encourage reporting			
		1.2.h. Maintain KHCC current accreditations and expanding them to include new accreditation	Strategy 1. Continuous follow up for all accreditation and certification indicators and assure full compliance with standards and find opportunities for improvement	**Hard Goal**		
		1.2.i Obtain ANCC MAGNET Recognition	Strategy 1. Attain ANCC MAGNET Recognition	**Hard Goal**		
	1.3 Provide the optimal portfolio of cancer care services	1.3.a The introduction of new techniques and technologies of cancer care services on an annual basis	Strategy 1. Each clinical department to identify new techniques, technologies or medicine of cancer treatment in 2016	**Hard Goal**		
			Strategy 2. Each clinical department to identify new techniques, technologies or medicine of cancer treatment in 2017	**Hard Goal**		
		1.3.b Maintain and development of approved	Strategy 1. Identification of non-existent	**Hard Goal**		

		guidelines for all clinical programs and services	clinical practice guidelines				
			Strategy 2. Utilise available data to measure the efficiency of the services/department	**Soft Goal**			
		1.3.c Develop plan to focus on particular services/programs (1-2 services or programs on an annual basis)	Strategy 1. Development of the plan	**Hard Goal**			
			Strategy 2. Implementation of the plan	**Hard Goal**			

Appendix B

SoSGORE Meta-Model, EER Model, and Database Schema Description

Table B.1: Description of the SoSGORE Conceptual Model Entities

#	EER / DB Schema Entity	Data Properties	Datatype	Constraints	Relationships with other Entities	Relationship Cardinality
1	SoSOrganisation	SoS_ID	Integer	Obligatory PK	SoSOrganiatstion Consists of ConstituentSystem	One-to-many
		SoS_Name	String	Obligatory		
		SoS_Desc	String	Optional	SoSOrganiatstion Has GlobalGoal	One-to-many
		Ref_Model_ID	Integer	Obligatory FK		
2	ConstituentSystem	CS_ID	Integer	Obligatory PK	ConstituentSystem Participates in SoSOrganiatstion	One-to-many
		CS_Name	String	Obligatory		
		CS_Desc	String	Optional	ConstituentSystem Has LocalGoal	One-to-many
		Related_SoS	Integer	Obligatory FK	ConstituentSystem Has iStarModel	Many-to-many
3	GlobalGoal	GG_ID	Integer	Obligatory PK	GlobalGoal Has SubGlobalGoal	One-to-many
		GG_Name	String	Obligatory		
		GG_Desc	String	Optional	GlobalGoal Belongs to SoSOrganisation	One-to-many
		Dependency_Type	Enumerated: (HG, SG, T, R)	Obligatory		
		Priority	Enumerated: (High, Medium, Low)	Obligatory/ Derived		
		Specificity	Double	Optional	GlobalGoal Has DependerActor	One-to-many
		Achieved	Integer (0,1)	Obligatory		
		Actor1_Depender	Integer	Obligatory	GlobalGoal Has DependeeActor	One-to-many

#	EER / DB Schema Entity	Data Properties	Datatype	Constraints	Relationships with other Entities	Relationship Cardinality
				FK		
		Actor2_Dependee	Integer	Obligatory FK		
		SoS_ID	Integer	Obligatory FK		
4	SubGlobalGoal	SGG_ID	Integer	Obligatory PK	SubGlobalGoal Contributes to Satisfaction of GlobalGoal	One-to-many
		SGG_Name	String	Obligatory		
		SGG_Desc	String	Optional	SubGlobalGoal Has LocalGoal	One-to-many
		Dependency_Type	Enumerated: (HG, SG, T, R)	Obligatory		
		Priority	Enumerated: (High, Medium, Low)	Obligatory	SubGlobalGoal Contributes to Satisfaction of SubGlobalGoal	One-to-many
		Specificity	Double	Optional/ Derived	SubGlobalGoal Detracts from Satisfaction of SubGlobalGoal	Many-to-many
		Achieved	Integer (0,1)	Obligatory		
		Actor1_Depender	Integer	Obligatory FK		
		Actor2_Dependee	Integer	Obligatory FK	SubGlobalGoal Has DependerActor	One-to-many
		Satisfy_GG	Integer	Obligatory FK		
		Satisfy_SGG	Integer	Obligatory FK	SubGlobalGoal Has DependeeActor	One-to-many
5	LocalGoal	LG_ID	Integer	Obligatory PK	LocalGoal Assigned to ConstituentSystem	One-to-many
		LG_Name	String	Obligatory	LocalGoal Has KPI	One-to-many
		LG_Desc	String	Optional	LocalGoal Contributes to Satisfaction of SubGlobalGoal	One-to-many

#	EER / DB Schema Entity	Data Properties	Datatype	Constraints	Relationships with other Entities	Relationship Cardinality
		Dependency_Type	Enumerated: (HG, SG, T, R)	Obligatory	LocalGoal Contributes to Satisfaction of LocalGoal	One-to-many
		Priority	Enumerated: (High, Medium, Low)	Obligatory	LocalGoal Detracts from Satisfaction of SubGlobalGoal	Many-to-many
		Specificity	Double	Optional/ Derived		
		Achieved	Integer (0,1)	Obligatory	LocalGoal Detracts from Satisfaction of LocalGoal	Many-to-many
		Actor1_Depender	Integer	Obligatory FK		
		Actor2_Dependee	Integer	Obligatory FK	LocalGoal Linked to PolicyDoc	Many-to-many
		Satisfy_SGG	Integer	Optional FK	LocalGoal Has Depender Actor	One-to-many
		Satisfy_LG	Integer	Optional FK	LocalGoal Has Dependee Actor	One-to-many
6	**iStarModel**	Model_ID	Integer	Obligatory PK	iStarModel Represents RefModel for SoSOrganisation	One-to-one
		Model_Type	String	Obligatory	iStarModel Has Actor	One-to-many
		Model_Title	String	Obligatory	iStarModel Linked to ConstituentSystem	Many-to-many
		Model_Desc	String	Optional	iStarModel Linked to PolicyDoc	Many-to-many
7	**Actor**	Actor_ ID	Integer	Obligatory PK	DependerActor or GlobalGoal	One-to-many
					DependerActor For SubGlobalGoal	One-to-many
					DependerActor For LocalGoal	One-to-many
		Actor_ Name	String	Obligatory	DependeeActor For GlobalGoal	One-to-many
					DependeeActor For SubGlobalGoal	One-to-many
					DependeeActor For LocalGoal	One-to-many

#	EER / DB Schema Entity	Data Properties	Datatype	Constraints	Relationships with other Entities	Relationship Cardinality
8	**PolicyDoc**	P_No	Integer	Obligatory PK	PolicyDoc Linked to KPI	One-to-many
		P_Title	String	Obligatory	PolicyDoc Linked to LocalGoal	Many-to-many
		P_Desc	String	Optional	PolicyDoc Linked to iStarModel	Many-to-many
		Orig_Entity	String	Optional		
9	**KPI**	KPI_ID	Integer	Obligatory PK	KPI Linked to LG	One-to-many
		KPI_Title	String	Obligatory		
		KPI_Description	String	Optional		
		KPI_Target_Value	Character	Optional		
		KPI_Current_Value	Character	Optional	KPI Linked to PolicyDoc	One-to-many
		KPI_Domain	String	Optional		
		P_No	Integer	Obligatory FK		
		LG_ID	Integer	Obligatory FK		
10	**CS_Has_iStarModel**	CS_ID	Integer	Obligatory PK/FK	CS Has iStarModel	Many-to-many
		Model_ID	Integer	Obligatory PK/FK		
11	**PolicyDoc_Has_ iStarModel**	P_No	Integer	Obligatory PK/FK	PolicyDoc Has iStarModel	Many-to-many
		Model_ID	Integer	Obligatory PK/FK		
12	**LG_Linkedto_Policy**	LG_ID	Integer	Obligatory PK/FK	LG Linkedto Policy	Many-to-many
		P_No	Integer	Obligatory PK/FK		

#	EER / DB Schema Entity	Data Properties	Datatype	Constraints	Relationships with other Entities	Relationship Cardinality
13	iStarModel_Has_ Actor	Model_ID	Integer	Obligatory PK/FK	iStarModel Has Actor	Many-to-many
		Actor_ID	Integer	Obligatory PK/FK		
14	LG_Detracts_SGG	LG_ID	Integer	Obligatory PK/FK	LG Detracts SGG	Many-to-many
		SGG_ID	Integer	Obligatory PK/FK		
15	SGG_Detracts_SGG	SGG1_ID	Integer	Obligatory PK/FK	SGG Detracts SGG	Many-to-many
		SGG2_ID	Integer	Obligatory PK/FK		
16	LG_Detracts_LG	LG1_ID	Integer	Obligatory PK/FK	LG Detracts LG	Many-to-many
		LG2_ID	Integer	Obligatory PK/FK		

Appendix C

OWL Classes and Individuals Instantiation Applied to KHCC Cancer Care

Table C.1: OWL Classes and Individuals Representing Cancer Care Multiple Goal Levels

OWL Class	Global_Goal	SubGlobal_Goal		Local_Goal	
Individuals	**GG1:** **Fostering person-centric care and safety**	**SGG1:** **Improve patient experience**	SGG1.1: Maintain inpatient overall satisfaction to 92% and increase it to 95% SGG1.2: Maintain and increase inpatient satisfaction per each category above 88%	LG1: Improve efficiency (Utilisation) of beds availability	LG1.1: Enhance early discharge of patients
					LG1.2: Action home care service
					LG1.3: Enhance recovery after surgery
				LG2: Improve food services	LG2.1: Improve food quality
					LG2.2: Enhance patient preferences
				LG3: Decrease environmental noise	LG3.1: Monitor and analyse noise levels
					LG3.2: Organise timing of cleaning to avoid patients' sleeping hours
					LG3.3: Educate staff on environmental noise
				LG4: Improve the satisfaction of the international patients	LG4.1: Provide fast track admission for international patients
					LG4.2: Provide escorting for international patients from admission to discharge
					LG4.3: Provide culturally sensitive care

OWL Class	Global_Goal	SubGlobal_Goal		Local_Goal	
			LG5: Launching person centred initiatives	LG5.1: Brainstorming person-centred initiatives	
				LG5.2: Capture role models and highlight success stories	
				LG5.3: Integrate the approved initiatives into inpatient services and processes	
		SGG1.3: Increase outpatient overall satisfaction to 92%	LG6: Provide mechanisms to improve patient appointment at outpatient		
			LG7: Improve outpatient general environment		
		SGG1.4: Maintain outpatient satisfaction per each category above 88%	LG8: Improve outpatient pharmacy and laboratory waiting times		
			LG9: Down time policy for VISTA and ATS		
			LG10: Follow up of patient complaints and introduce proactive measures		
		SGG1.5: Minimise overall patient waiting times	LG11: Shadowing patients from first contact of KHCC throughout the process		
			LG12:		

OWL Class	Global_Goal	SubGlobal_Goal		Local_Goal	
				Improve overall pharmacy waiting times	
				LG13: Improve overall laboratory waiting times	
		SGG2: **Foster patient safety**	SGG2.1: 100% of KPIs on clinical and non-clinical levels to have attainable targets and measures	LG14: Review all KPIs forms to utilize IT capabilities to support system and KPIs	
			SGG2.2: Utilising the IT capabilities and business intelligence to support the quality systems at KHCC including the KPI	LG15: Improving all event reporting system	
			SGG2.3: All KPI's to be reported on-time by KHCC departments	LG16: Improve the process of following KPIs	
			SGG2.4: Ensure that an electronic event reporting system is in place		
			SGG2.5: A clear coordinated structure for Departmental Performance Improvement Committees is in place	LG17: All departments should have a quality improvement committee	

OWL Class	Global_Goal	SubGlobal_Goal		Local_Goal	
		SGG2.6: All Departmental Performance Improvements Committees' meetings to be held per the frequency set in the bylaws		LG18: Recognising involved staff	
		SGG2.7: Improvement on the scores of KHCC patient safety culture survey to meet the international benchmark in all domains		LG19: Improving patients' safety culture	
				LG20: Raise awareness and training on non-punitive culture, to encourage reporting	
		SGG2.8: Maintain KHCC current accreditations and expanding it to include new accreditations		LG21: Continuous follow up for all accreditation and certification indicators and assure full compliance with standards and find opportunities to improve	
		SGG2.9: Obtain ANCC (American Nursing Credential Centre) MAGNET Recognition		LG22: Attain ANCC MAGNET Recognition	
		SGG3: Provide the optimal portfolio of cancer care services			

Appendix D

Evaluation Interviews to Validate the Developed Strategic Goal-Management Tool

Evaluation interviews and tool walk-throughs were conducted with KHCC's main stakeholders and domain experts, while demonstrating the developed *Strategic Goal-Management tool* through applying Cancer Care test cases.

Section D-1   Evaluation of the "Goal Satisfaction Panel"

- **Usability and Usefulness:**

1) Do you find the tool easy to use?

2) Can you move between the goal levels and display the required goal information for any goal easily?

3) Can you display the related tree graph for each goal at any goal level easily?

4) Do you find the related tree graph readable and useful to illustrate the goal levels?

5) Do you consider using different colours to distinguish between achieved and unachieved goals in the tree graph useful?

6) Do you consider using different shapes to represent each goal level in the tree graph useful?

- **Completeness and Correctness:**

7) Is all the needed information related to goals (ID, description, depender and dependee actors, and achievement value) displayed by the panel?

8) Are all goal levels and the linkages amongst them (parent and child goals) displayed correctly by the panel?

9) Does the tool establish proper linkages between the goals at different levels with their depender and dependee actors (i.e. stakeholders)?

10) Does the tool establish proper linkages between the goals at different levels with their departments and Cancer Care systems?

11) Are the local goals at lower levels linked to their corresponding KPIs?

12) Are lower-level goals connected correctly to their upper-level parent goals in which they contribute to the satisfaction of?

13) Are you able to check the satisfaction/ progress of any goal at any goal level correctly?

14) Can the satisfaction of upper-level goals (i.e. global and sub-global goals) be inferred correctly using the tool?

- **Consistency:**

15) Are you able to change the achievement value of local goals (i.e. leaf goals)?

16) Is changing the achievement value of local goals reflected on related upper-level goals achievement value?

17) Is changing the achievement value of local goals reflected on all levels of the related tree graph?

18) Are the integrity and consistency of goals at all levels being maintained if any changes occur?

19) Do you have any other suggestions/ needs that are not covered currently by the developed tool to be implemented in future work?
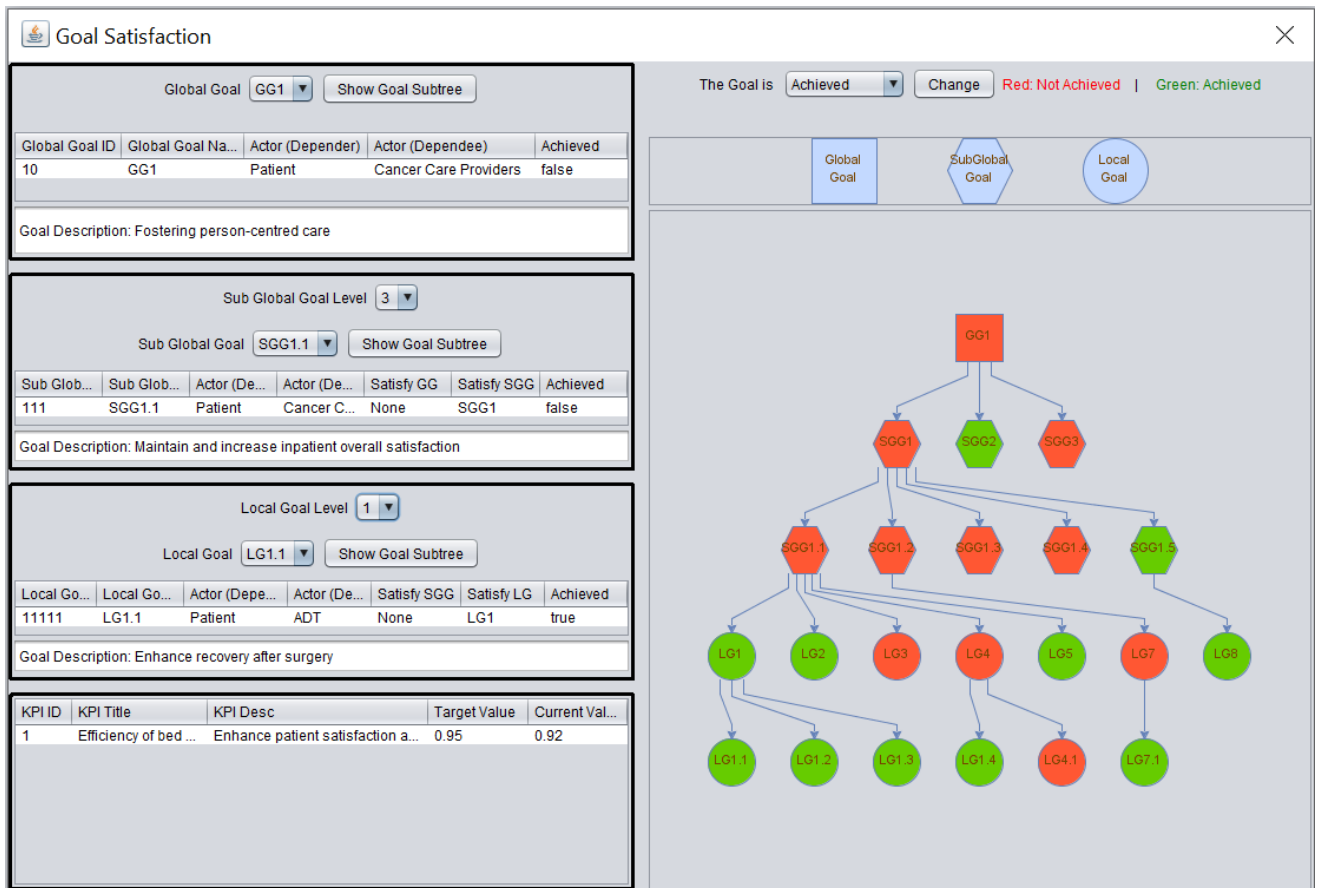
Figure D.1: Goal Satisfaction for Cancer Care Goals in SoS Context

Section D-2   Evaluation of the "Conflict Management Panel"

- **Usability and Usefulness:**

1) Do you find the tool easy to use?

2) Can you move between the goal levels and display the conflicts at the required goal level easily and efficiently?

3) Are the messages displayed for the user after resolving a goal conflict useful and informative?

- **Completeness and Correctness:**

4) Is all the needed information related to conflicting goals (ID, description, depender and dependee actors) displayed by the panel?

5) Are goal conflicts detected at all levels in the SoS organisation?

6) Are you able to check for conflicts that may occur amongst goals at any goal level correctly?

7) Is the tool able to resolve the occurring conflicts automatically and provide the user with the goal of higher conflict resolution outcome?

8) Do you agree on the factors used to analyse the complexity of conflicting goals and resolve goal conflict?

9) Do you suggest any other factors that need to be checked while resolving goal conflicts to be implemented in future work?

10) Do you have any other suggestions/ needs that are not covered currently by the developed tool to be implemented in future work?

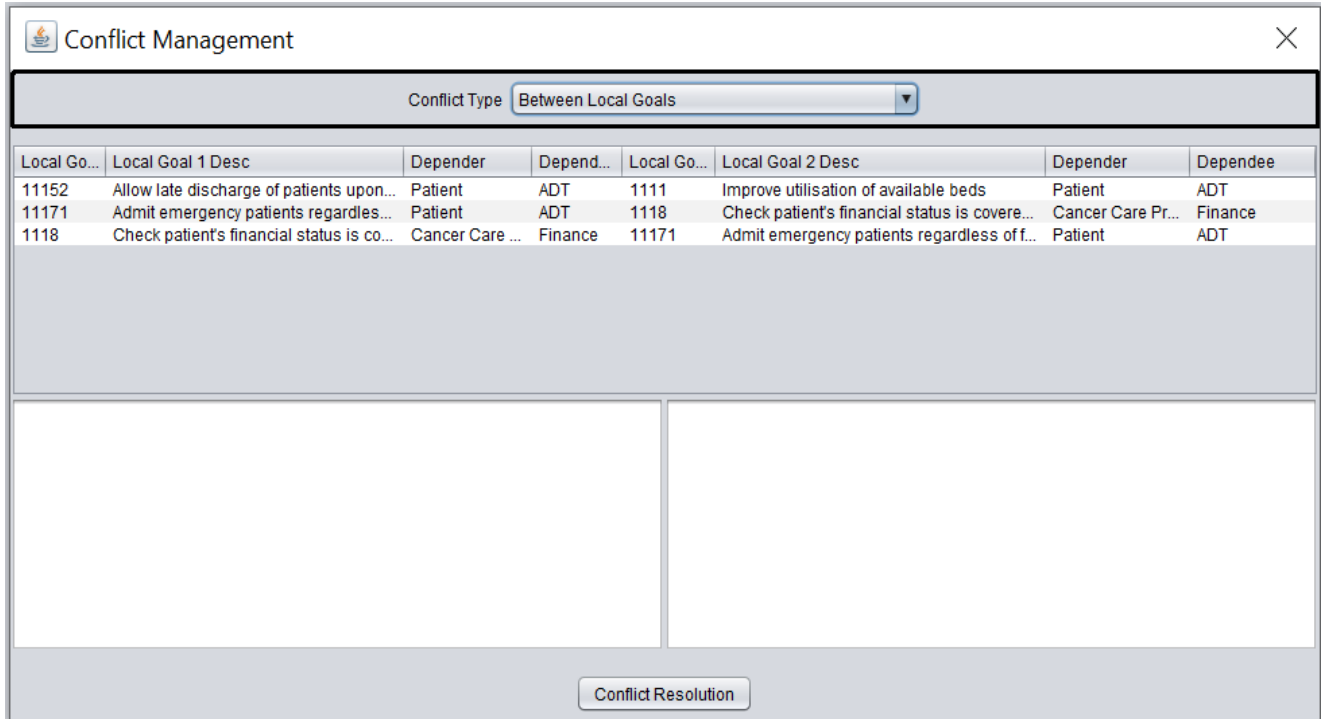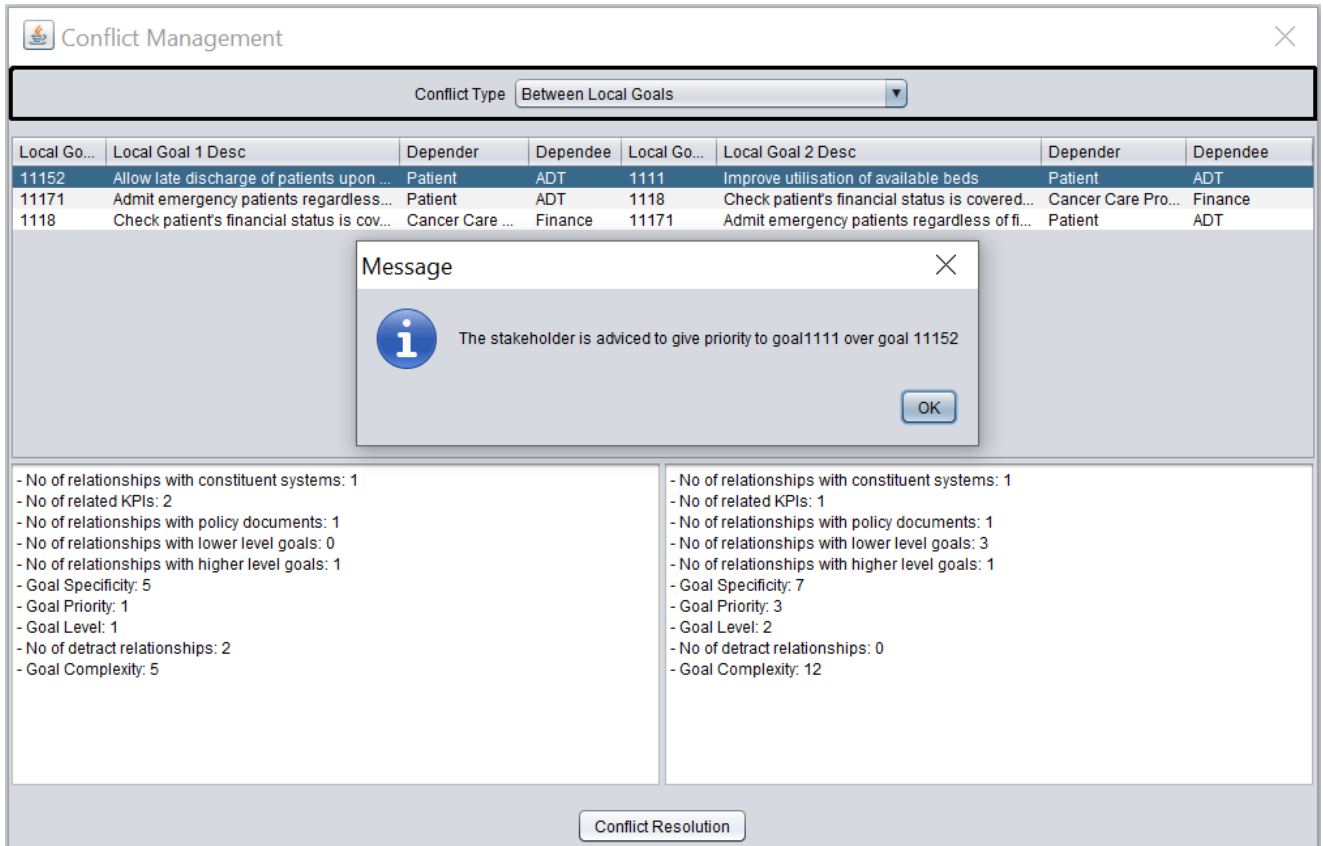Figure D.2: Goal Conflict Detection in a Cancer Care SoS

Figure D.3: Goal Conflict Resolution in a Cancer Care SoS

Appendix E

Evaluation Interviews to Validate the Developed SoSGORE Ontology-Based Model

Evaluation interviews and demonstration of the developed Ontology were conducted with KHCC's main stakeholders and domain experts, through applying Cancer Care test cases.

1) Do you find the knowledge offered by the ontology model for Cancer Care SoS strategic goal modelling useful for defining the linkages between multiple goal levels?

2) Does the ontology model build proper linkages between Cancer Care global and local goals at multiple levels with their depender and dependee actors (i.e. stakeholders)?

3) Does the ontology model build proper linkages between Cancer Care local goals with their KPIs?

4) Does the ontology model build proper linkages between Cancer Care local goals with their corresponding constituent systems?

5) Does the ontology model provide traceability and proper linkages between Cancer Care global and local goals at multiple levels back to their policy documents?

6) Does the ontology model provide traceability and proper linkages between Cancer Care global and local goals at multiple levels back to their developed i* goal models?

7) Are all the needed Cancer Care entities identified by the ontology model?

8) Is all the needed information related to Cancer Care goals (ID, description, depender and dependee actors, and achievement value) gathered and displayed by the ontology model?

9) Are lower-level goals connected correctly to their upper-level parent goals in which they contribute to the satisfaction of?

10) Can the linkages between upper-level goals (i.e. global and sub-global goals) and lower-level local goals be inferred correctly using the ontology model reasoner?

11) Can the satisfaction of upper-level goals (i.e. global and sub-global goals) be inferred correctly using the ontology model reasoner depending on the satisfaction of lower-level local goals?

12) Is changing the achievement value of local goals reflected on upper-level goals achievement value?

13) Do you have any other suggestions/ needs that are not covered currently by the developed ontology model to be implemented in future work?
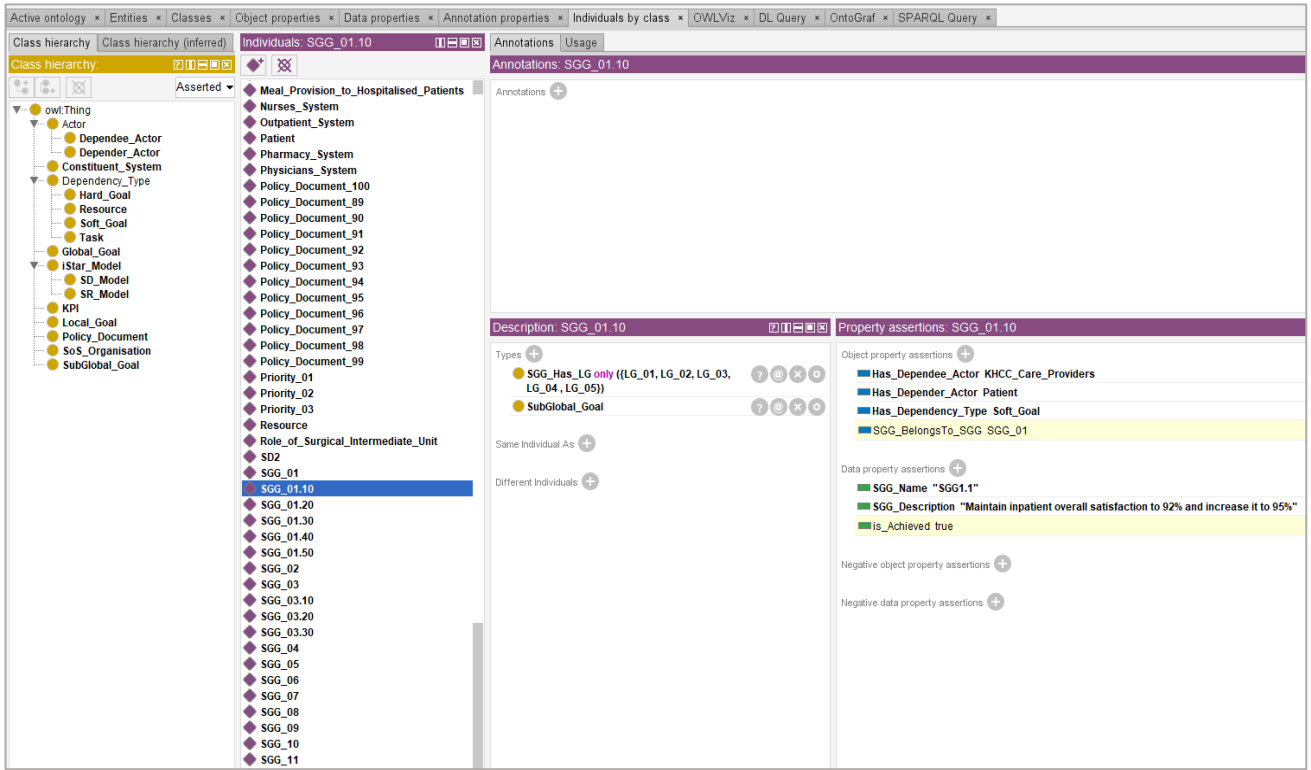
Figure E.1: Inferring Goal Satisfaction in a Cancer Care SoS Using Ontology

Appendix F

Participants Information Sheet and Consent Form

Participant Information Sheet

Faculty of Environment and Technology
Software Engineering Research Group

Introduction

This study -which is conducted through semi-structured interviews and requirements workshops- is part of a PhD research project named "A Goal-Oriented Requirements Engineering Framework for the Software Engineering of Systems of Systems Using the i* Framework Applied to Cancer Care".

The research study aims at investigating the implications of using Goal-Oriented Requirements Engineering (GORE) approaches, and in particular the i* framework to model Cancer Care from systems of systems perspective. KHCC's strategic documents, policies and procedures covering various Cancer Care constituent systems such as Treatment Centres, Patients Management Systems, Pharmaceutical Systems, Laboratory Systems, etc., are investigated, studied and analysed. Then, applying the i* goal-oriented approach, KHCC's Cancer Care goals of different stakeholders are modelled and managed at two levels: The Cancer Care SoS high-level global goals and the constituent systems-level individual goals. One of the main purposes of the research is to identify any conflicts and inconsistencies that might occur amongst goals and their owning stakeholders, and provide effective mechanisms to resolve such conflicts.

This also contributes towards proposing a Reference Cancer Care i* Goal-Oriented Model for Systems of Systems. This model is intended to be applied to different Cancer Care

organisations and provide them with a reference model covering the most generic goals, concepts and stakeholders' relationships in Cancer Care system of systems at both global and local levels.

Participants will be asked to answer different questions related to various elements of the developed goal models and their interactions; their answers constitute the interview data. Two intensive workshops and four interviews of 3-4 hours long each are anticipated to be conducted with participants. The feedback you provide through this study is highly valuable for the research and will allow to further develop and mature the research framework during the next stages of the research.

Confidentiality and Anonymity

Please note that to protect the participant's confidentiality, no personal information will be collected that would identify any of the participants. The results of this study will be used only for scholarly purposes and may only be shared amongst members of the research team, and the results cannot be used to identify any of the participants. The information provided by participants will be used in this research as an input to process and generalise findings that may be used in publications, conference presentations, reports, web pages, and other research outputs. However, all the collected data will be stored in a password protected electronic format, or in a locked locker in UWE depending on the type of the submitted data (paper-based, digital-based).

On completion of the research programme; the digital media will be destroyed after a period of 12 months following publication of the study results. Any manual collected data will be discarded following UWE related procedures. Moreover, the findings of the research will be made available online and KHCC participants will be informed through sending them an electronic link via email communication.

Participation

Please note that your participation in this study is completely voluntary. You may choose not to participate. However, if you do choose to participate, you may withdraw your consent and discontinue your participation at any time prior to submitting your answers. If you don't want to answer any of the questions you don't have to. There is no penalty for withdrawal of consent. Your manager/supervisor will not be notified whether or not you have withdrawn participation. If you withdraw your consent before submitting your answers, any recorded data will be discarded and will not be used in the study. However, by submitting your answers, you are agreeing to participate and cannot withdraw afterwards.

Questions about the research or your rights as a participant

Please do not hesitate to contact the research team should you have any questions or concerns regarding your participation in this research study/interviews/workshops.

Participant Consent Form

Research project title: "A Goal-Oriented Requirements Engineering Framework for the Software Engineering of Systems of Systems Using the i* Framework Applied to Cancer Care".

Please confirm that you understand and agree to the following:

- ➢ I am over the age of 18.
- ➢ I have read and understood the "Participant Information Sheet".
- ➢ I have had the opportunity to clarify any aspects of the research and I have had the study explained to my satisfaction.
- ➢ I understand that by consenting to taking part in this study, I can still withdraw at any time without any consequences prior to submitting my answers and without being obliged to give any reasons.
- ➢ I understand that after submitting the answers, I cannot withdraw my data.
- ➢ I understand that I will not be personally identified at any report, and the results communicated by this study cannot be used to identify me.
- ➢ I understand that this information will be used only for the purposes set out in the participant information sheet, and my consent is conditional upon the university complying with the duties and obligation under the General Data Protection Regulation (GDPR).
- ➢ I understand that the information I provide will be used in this research as an input to process and generalise findings that may be used in publications, conference presentations, reports, web pages, and other research outputs.

☐ I confirm that I have read and understood the aforementioned agreement, and I agree to take part in this research study.

Participant's Signature: _____ Date: _____

Researcher's Signature: _____ Date: _____

Appendix G

Java Coding Segments for Developing the Strategic Goal-Management Tool

a) <u>Goal Satisfaction Panel:</u>

```
[1] public class GoalAchievement extends JDialog {
[2]      /**
[3]       * Creates new form GoalAchievement
[4]       */
[5]     public GoalAchievement(Application parent, boolean modal) {
[6]         super(parent, modal);
[7]         this.parent = parent;
[8]         setTitle("Goal Satisfaction");
[9]
[10]         legend = new mxGraph();
[11]         legendComponent = new mxGraphComponent(legend);
[12]         legendComponent.setBorder(null);
[13]         setLegendStyles();
[14]         addLegend();
[15]
[16]         graph = new mxGraph();
[17]         graphComponent = new mxGraphComponent(graph);
[18]         graphComponent.setBorder(null);
[19]         setVertexStyles();
[20]
[21]         initComponents();
[22]         graphComponent.getGraphControl().addMouseListener(new MouseAdapter()
[23]         {
[24]
[25]                 public void mouseReleased(MouseEvent e)
[26]                 {
[27]                     Object   cell   =   graphComponent.getCellAt(e.getX(),
    e.getY());
[28]                     selectedGoal = (Goal) cell;
[29]
[30]                     if (cell != null)
[31]                     {
[32]                         System.out.println("cell="+graph.getLabel(cell));
[33]                         System.out.println(selectedGoal.getGid());
[34]                     }
[35]                 }
        });

[36]         ggCombo.addItemListener(new ItemListener() {
[37]             @Override
[38]             public void itemStateChanged(ItemEvent e) {
[39]                 fillSelectedGlobalGoalTable();
[40]                 fillSubGlobalGoalsCombos((Goal)ggCombo.getSelectedItem());
[41]                 fillSelectedSubGlobalGoalTable();
[42]                 fillLocalGoalsCombos((Goal)sggCombo.getSelectedItem());
[43]                 fillSelectedLocalGoalTable();
[44]                 fillSelectedLocalGoalKPIs();
[45]             }
[46]         });
[47]
[48]         sggCombo.addItemListener(new ItemListener() {
[49]             @Override
[50]             public void itemStateChanged(ItemEvent e) {
[51]                 fillSelectedSubGlobalGoalTable();
[52]                 fillLocalGoalsCombos((Goal)sggCombo.getSelectedItem());
```

```
[53]                         fillSelectedLocalGoalTable();
[54]                         fillSelectedLocalGoalKPIs();
[55]                     }
[56]                 });
[57]
[58]         sggLevelCombo.addItemListener(new ItemListener() {
[59]                 @Override
[60]                 public void itemStateChanged(ItemEvent e) {
[61]
   initializeSubGlobalGoalCombo((String)sggLevelCombo.getSelectedItem());
[62]                         fillSelectedSubGlobalGoalTable();
[63]                         fillLocalGoalsCombos((Goal)sggCombo.getSelectedItem());
[64]                         fillSelectedLocalGoalTable();
[65]                         fillSelectedLocalGoalKPIs();
[66]                     }
[67]                 });
[68]
[69]         private void fillGlobalGoalsCombo(){
[70]         List<Goal> goals = parent.getGoals();
[71]         //List<Goal> globalGoals = new ArrayList<Goal>();
[72]         DefaultComboBoxModel model = new DefaultComboBoxModel();
[73]         for(Goal g: goals){
[74]             if (g.getGoalType().equals("GG")) model.addElement(g);
[75]         }
[76]         ggCombo.setModel(model);
   }
[77]         private void fillSelectedSubGlobalGoalTable(){
[78]         List<Goal> goals = parent.getGoals();
[79]         Goal g = (Goal) sggCombo.getSelectedItem();
[80]         if (g==null){
[81]             setSubGlobalGoalDefaultModel();
[82]             return;
[83]         }
[84]         String[][] info = new String[1][7];
[85]         info[0][0] = ""+g.getGid();
[86]         info[0][1] = g.getName();
[87]         info[0][2] = g.getDepender().getActorName();
[88]         info[0][3] = g.getDependee().getActorName();
[89]         Goal satisfy_gg = ((SubGlobalGoal)g).getSatisfy_gg_Goal();
[90]         if (satisfy_gg==null)
[91]             info[0][4] = "None";
[92]         else
[93]             info[0][4] = satisfy_gg.getName();
[94]
[95]         Goal satisfy_sgg = ((SubGlobalGoal)g).getSatisfy_sgg_Goal();
[96]         if (satisfy_sgg==null)
[97]             info[0][5] = "None";
[98]         else
[99]             info[0][5] = satisfy_sgg.getName();
[100]
[101]         info[0][6] = String.valueOf(g.isAchieved());
[102]         sggTable.setModel(new      javax.swing.table.DefaultTableModel(info,new
   String[]{"Sub Global Goal ID","Sub Global Goal Name","Actor (Depender)","Actor
   (Dependee)","Satisfy GG","Satisfy SGG","Achieved"}));
[103]         sggDescText.setText("Goal Description: "+g.getDesc());
[104]     }
```

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b) <u>__Conflict Management Panel:__</u>

```
[105]    public class ConflictDetection extends JDialog {
[106]
[107]        private String[][] info;
[108]        private Goal[][] sgg_sgg_conflictTable;
[109]        private Goal[][] lg_sgg_conflictTable;
[110]        private Goal[][] lg_lg_conflictTable;
[111]
[112]        private Goal[][] selected_conflictTable;
[113]
[114]        private int complexity1;
[115]        private int complexity2;
[116]
[117]        public ConflictDetection(Application parent, boolean modal) {
[118]            super(parent, modal);
[119]            this.parent = parent;
[120]            setTitle("Conflict Management");
[121]            initComponents();
[122]            initialize_LG_LG_ConflictTable();
[123]            initialize_LG_SGG_ConflictTable();
[124]            initialize_SGG_SGG_ConflictTable();
[125]            setDetractsSGGCountForLocalGoals();
[126]            setDetractsSGGCountForSubGlobalGoals();
[127]            setDetractsLGCountForLocalGoals();
[128]            initializeConflictTable();
[129]            conflictTypeCombo.addItemListener(new ItemListener() {
[130]                @Override
[131]                public void itemStateChanged(ItemEvent e) {
[132]                    goal1ConflictInfo1.setText("");
[133]                    goal1ConflictInfo2.setText("");
[134]                    initializeConflictTable();
[135]                }
[136]            });
[137]         }
[138]
[139]        private void initialize_LG_LG_ConflictTable(){
[140]            Connection con = Util.getConnection();
[141]            try
[142]            {
[143]                String lg_lg_sql="select LG1_ID,LG2_ID from lg_detracts_lg;";
[144]
[145]                PreparedStatement statement = con.prepareStatement(lg_lg_sql);
[146]                ResultSet result = statement.executeQuery();
[147]                int goalsCount=0;
[148]                if(result.next())
[149]                {
[150]                    result.last();
[151]                    goalsCount = result.getRow();
[152]                    result.beforeFirst();
[153]                }
[154]                if (goalsCount==0) return;
[155]                lg_lg_conflictTable = new Goal[goalsCount][2];
[156]
[157]                int counter=-1;
[158]                while (result.next())
[159]                {
[160]                    counter++;
[161]                    int g1ID = result.getInt(1);
[162]                    int g2ID = result.getInt(2);
[163]                    Goal g1 = parent.findGoalByID(g1ID);
[164]                    Goal g2 = parent.findGoalByID(g2ID);
[165]                    lg_lg_conflictTable[counter][0] = g1;
```

```
[166]                     lg_lg_conflictTable[counter][1] = g2;
[167]                 }
[168]             result.close();
[169]             statement.close();
[170]             }
[171]         catch(Exception x)
[172]             {
[173]             Util.closeConnection();
[174]             x.printStackTrace();
[175]             }}
[176]
[177]   private void displayConflictInfo(int rowID){
[178]             Goal g1 = selected_conflictTable[rowID][0];
[179]             Goal g2 = selected_conflictTable[rowID][1];
[180]             if ((g1 instanceof LocalGoal) && (g2 instanceof LocalGoal)){
[181]             LocalGoal g11 = (LocalGoal) g1;
[182]             int constituentSystemsCount1 = g11.getConstituentSystemsCount();
[183]             int numOfRelatedKPIs1 = g11.getKpis().size();
[184]             int numOfPolicyDocs1 = g11.getPolicyDocuments().size();
[185]             int lowerLevelCount1 = 0;
[186]             ArrayList<Goal> satisfyList1 = (ArrayList<Goal>)
      parent.getGoalsMap().get(g1);
[187]                 if (satisfyList1!=null){
[188]                     lowerLevelCount1 = satisfyList1.size();
[189]                 }
[190]             int higherLevelCount1 = 0;
[191]             if (g11.getSatisfy_sgg()!=-1) higherLevelCount1++;
[192]             if (g11.getSatisfy_lg()!=-1) higherLevelCount1++;
[193]             int goalSpecificity1 = constituentSystemsCount1+
[194]                             numOfRelatedKPIs1+
[195]                             numOfPolicyDocs1+
[196]                             lowerLevelCount1+
[197]                             higherLevelCount1;
[198]             int goalPriority1 = g11.returnPriorityWeight();
[199]             int goalLevel1 = g11.getLevel();
[200]             int detractCount1 = g11.getDetractsLGCount() +
      g11.getDetractsSGGCount();
[201]             complexity1 = goalPriority1 + goalLevel1 + goalSpecificity1 -
      detractCount1;
[202]
[203]             LocalGoal g22 = (LocalGoal) g2;
[204]             int constituentSystemsCount2 = g22.getConstituentSystemsCount();
[205]             int numOfRelatedKPIs2 = g22.getKpis().size();
[206]             int numOfPolicyDocs2 = g22.getPolicyDocuments().size();
[207]             int lowerLevelCount2 = 0;
[208]             ArrayList<Goal> satisfyList2 = (ArrayList<Goal>)
      parent.getGoalsMap().get(g2);
[209]                 if (satisfyList2!=null){
[210]                     lowerLevelCount2 = satisfyList2.size();
[211]                 }
[212]             int higherLevelCount2 = 0;
[213]             if (g22.getSatisfy_sgg()!=-1) higherLevelCount2++;
[214]             if (g22.getSatisfy_lg()!=-1) higherLevelCount2++;
[215]             int goalSpecificity2 = constituentSystemsCount2+
[216]                             numOfRelatedKPIs2+
[217]                             numOfPolicyDocs2+
[218]                             lowerLevelCount2+
[219]                             higherLevelCount2;
[220]             int goalPriority2 = g22.returnPriorityWeight();
[221]             int goalLevel2 = g22.getLevel();
[222]             int detractCount2 = g22.getDetractsLGCount() +
      g11.getDetractsSGGCount();
[223]             complexity2 = goalPriority2 + goalLevel2 + goalSpecificity2 -
      detractCount2;
```

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```
[224]
[225]            goal1ConflictInfo1.setText("- No of relationships with
   constituent systems: "+constituentSystemsCount1+"\n");
[226]            goal1ConflictInfo1.append("- No of related KPIs:
   "+numOfRelatedKPIs1+"\n");
[227]            goal1ConflictInfo1.append("- No of relationships with policy
   documents: "+numOfPolicyDocs1+"\n");
[228]            goal1ConflictInfo1.append("- No of relationships with lower level
   goals: "+lowerLevelCount1+"\n");
[229]            goal1ConflictInfo1.append("- No of relationships with higher
   level goals: "+higherLevelCount1+"\n");
[230]            goal1ConflictInfo1.append("- Goal Specificity:
   "+goalSpecificity1+"\n");
[231]            goal1ConflictInfo1.append("- Goal Priority:
   "+goalPriority1+"\n");
[232]            goal1ConflictInfo1.append("- Goal Level: "+goalLevel1+"\n");
[233]            goal1ConflictInfo1.append("- No of detract relationships:
   "+detractCount1+"\n");
[234]            goal1ConflictInfo1.append("- Goal Complexity:
   "+complexity1+"\n");
[235]
[236]            goal1ConflictInfo2.setText("- No of relationships with
   constituent systems: "+constituentSystemsCount2+"\n");
[237]            goal1ConflictInfo2.append("- No of related KPIs:
   "+numOfRelatedKPIs2+"\n");
[238]            goal1ConflictInfo2.append("- No of relationships with policy
   documents: "+numOfPolicyDocs2+"\n");
[239]            goal1ConflictInfo2.append("- No of relationships with lower level
   goals: "+lowerLevelCount2+"\n");
[240]            goal1ConflictInfo2.append("- No of relationships with higher
   level goals: "+higherLevelCount2+"\n");
[241]            goal1ConflictInfo2.append("- Goal Specificity:
   "+goalSpecificity2+"\n");
[242]            goal1ConflictInfo2.append("- Goal Priority:
   "+goalPriority2+"\n");
[243]            goal1ConflictInfo2.append("- Goal Level: "+goalLevel2+"\n");
[244]            goal1ConflictInfo2.append("- No of detract relationships:
   "+detractCount2+"\n");
         goal1ConflictInfo2.append("- Goal Complexity: "+complexity2+"\n");
```