An Integrated Socio-Technical Enterprise Modelling: A Scenario of Healthcare System Analysis and Design

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Abstract

One of the crucial issues facing enterprise modelling (EM) practices is that EM is considered technical, and rarely or never has a social focus. Social aspects referred to here are the soft aspects of the organisation that lead to organic organisation development (communication, collaboration, culture, skills and personal goals). There are many EM approaches and enterprise architecture frameworks were proposed recently. These cover different enterprise aspects, perspectives, artefacts and models with different qualities and levels of details. Yet, the imperative determination has overlaid the declarative exploration in EM as a necessity of the design effort. Rethinking the assumptions underlying EM should bring a new and different understanding on how EM can be tackled within the enterprise, in particular the joint development and optimisation of socio-technical systems. This paper discusses EM from a socio-technical systems (STS) perspective, and towards forming a new model of EM that is driven from STS theory and combined with STS practices. Then proposes a conceptual integrated model that incorporates the new concepts of STS toward building an EM framework for balanced socio-technical joint development and optimisation. The approach is illustrated in a scenario from healthcare industry. A combination between modelling and STS practices proved powerful for holistic IT modernisation, future work discussed toward the end of the paper.

Keywords: Enterprise Modelling, Socio-technical Systems, Enterprise Integrated Model, Conceptual Modelling, Healthcare System

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1 Introduction

Whilst most organisations are currently moving towards full organisation digitisation, the complexity of this enterprise has increased dramatically due to the increase of point-to-point connections and interdependencies among the systems. In the coming few years we will witness a revolution of the use of emergent technologies in business and office, in a recent study by IBM, (Schneider 2017) suggests that by the end of "2020, 85% of all customer interactions will be handled without a human agent" and the cooperation between human and machine is rising to a new levels. Such complexity and interdependency cause services' reusability degradation and the quality of business processes documentation declines (Bossert and Laartz 2016). A recent study argues that "*by the end of 2017, 60% of digital transformation initiatives will not be able to scale because of a lack of strategic architecture*" (Rosen 2015), and that demonstrates the need of having a corresponding architecture to help organisations in managing complexity, make better decisions and continuously utilise and improve their capabilities.

In the last three decades, many enterprise modelling (EM) and enterprise architecture (EA) frameworks have arrived on the scene to aid enterprise analysis and design of both technical and organisational aspects. Some of these frameworks are well adopted and widely used, whilst some others are set aside in the theoretical or academic frame with little or no adoption from industry. Enterprise architecture (EA) is a technology that facilitates the translation of business architecture and information architecture within enterprises (Nakakawa, Van Bommel et al. 2011), and comprises of the principles, methods and models that underpin the enterprise's organizational structure, information technology, information systems and associated business processes (see Gorkhali and Xu 2017 for an extensive literature review of Enterprise Architecture). The deployment of an EA typically follows one of the well-known frameworks (e.g. Zachman, TOGAF, FEA and Gartner (Sessions 2007). These frameworks are also relying on methodologies/processes that have either adapted or developed as part of the framework specifications (e.g. ADM in TOGAF). Sometimes the implementation could rely on single or a hybrid framework to fulfil some specific organisation architectural requirement that is not covered within the one framework. Enterprise Architecture Frameworks (EAFs) are becoming significant as they guide the direction of business development and change. The reason for their growth in the last 10 years is the availability of global information networks with increasing complexity in distributed business environments.

Many organisations found it difficult to use EAFs as they require huge investment, programme teams and prolonged configuration processes (Bernaert, Poels et al. 2015) which, in return, might have a negative impact on achieving the transformation program objectives. One of the main challenges facing organisations is how to adopt and adapt EAFs to serve their specific business needs. Particularly, the focus on the joint development and optimisation of both organisation and information systems all together. Recent studies called for enterprise architecture and modelling that needs to deal with complexity and uncertainty, and furthermore to deal with enterprises' new realities (Lapalme, Gerber et al. 2016) and thus they called for widening scope of theoretical influences and solidifying theoretical foundations (Lapalme, Gerber et al. 2016). As discussed by Gorkhali and Xu (2017), EA encounters issues with integration, which can be modelled and potentially predicted through EM techniques. Since EA and EM efforts are seen as mechanistic (Hoyland, M. Adams et al. 2014, Lara, Sánchez et al. 2020) it cannot capture the complex and changing nature of the social system, the enterprise architecture should a) consider both and interchangeably the imperative and declarative work to understand and construct the enterprise system interchangeably b) correspond to the essential principles of socio-technical systems and considering its new realities.

STS theory was proposed in the early '50s, it has already matured adequately and many organisations have embedded STS principles within their organisation practices. There is a crucial need for a new approach to aid the analysis and design of STS. Earlier research study highlighted the need for streamlined, lightweight socio-technical artefacts to support management practitioners who are trying to balance the stake between investors, shareholders and workforce (Di Maio 2014). This paper focuses on the understanding where an organisation is seen as a socio-technical system embedding complex relations among social and technical aspects. STS theory and practices offer principles and guidelines of how such systems should operate and mutually optimised. In this paper, an approach integrates both socio-technical systems principles with EM effort to tackle digital transformation projects is presented. The authors develop and present a model consisting of eight perspectives. This model still requires the interpretivist view to deal with social/organisational aspects in line with the deployment of mechanistic (objectivist) aspects to ensure joint development and optimisation, and these challenges will be discussed in the paper to show why it is important to take STS organic aspects into consideration, particularly interchangeably with the enterprise modelling effort. In summary, this research will investigate the following research questions:

1- What STS practices need to be implemented interchangeably with enterprise modelling?

2- How can both EM models and STS practices be orchestrated in one single and coherent approach?

The following sections are organised as follows: Section 2 presents the background of this research and highlights the challenges facing the enterprise modelling and discuss the socio-technical system theory focusing on the main principles and concepts of STS joint optimisation. Section 3 presents a motivation example to modernise hospital information systems, then is followed by a discussion of the underlying assumptions of the suggested enterprise ontology framework represents the eight perspectives and discusses the blending between EM and STS practices in Section 4. Section 5 presents the application of the framework on the scenario presented in section 3. A discussion and lessons learned are presented in section 6. Finally, the paper concludes with a discussion of limitations and future work in section 7.

2 Related Work

2.1 Conceptual Enterprise Modelling

Conceptual modelling (CM) became a basis for enterprise modelling (Loucopoulos and Kavakli 1995, Loucopoulos and Kavakli 1999, Vernadat 2003), integration (Delen and Benjamin 2003), simulation (Robinson 2008, Robinson 2010), and information systems design (Rolland and Prakash 2000, Mylopoulos 2008, Fayoumi and Loucopoulos 2016). This was possible through mapping the syntax and semantics of concepts by: 1) generating code of conceptual models through model-driven development (Schmidt 2006), 2) logical formulation of these models using formal logic languages, and, 3) aiding models by algorithms and equations for quantitative and statistical representation of data parameters. The applications of these techniques are numerous and can be applied to any perspective or level of the enterprise architecture. Formal conceptual modelling can be manifested visually by using some graphical notations that have pre-specified syntax and semantics. It began in the early days of software engineering practice, particularly with the development of the relational model in the late sixties (Codd 1970). The main purpose of CM in that time was to better represent software domain requirements, with the intention of designing valid and verified software systems (Mylopoulos 2008). CM has continued to improve and has extended beyond its traditional scope of software engineering to cover areas such as business strategy and operation (Loucopoulos and Kavakli 1999, Robinson 2008, Samavi, Yu et al. 2009). Elsewhere, strategic information system (IS) practices were developed to guide and structure IS procurement, development, and deployment in organisations. One of the other reasons that strategic information system practices were developed was to improve the value alignment between business and information technology (IT) (Singh and Woo 2009, Hinkelmann, Gerber et al. 2015). The use of CM to aid business strategies and IT strategy, and the alignment between them, resulted in the developing area of enterprise architecture (EA) (Zachman 1987), where enterprise modelling (EM) tools play a major role in visually presenting enterprise architecture artefacts. In an enterprise, an artefact is defined as an object, product, or any physical piece of information used or produced by the enterprise, a part of the enterprise, or its behaviour.

The first attempts of EM research have focused on what knowledge is needed for enterprise design to be externalised, or knowledge that should be considered for developing enterprise information systems. Since then, enterprise modelling has continued to develop; more specifically, the implementation and code-generating side of these models using a model driven engineering approach (Schmidt 2006). It helps organisations in representing their enterprise architecture models and to manage change in the enterprise by providing both visibility and agility (Bernus, Goranson et al. 2016). EM also helps in understanding the systemic implications/risks in making timely decisions, optimising enterprises for expected outcomes, creating alignment between strategies, operation and IS implementation and finally, it will provide a foundation for continuous improvement. Enterprise modelling can represent structural and behavioural aspects of enterprise systems. These aspects are represented in models, types of which can be represented in various modelling languages.

The relations between organisation and IT with particular use of EM techniques was best illustrated in what is called enterprise architecture (EA) frameworks. A wide spectrum of EA frameworks has been suggested in the last three decades. Similarly, many enterprise modelling techniques have been proposed to address one or more of the enterprise perspectives/aspects. Despite the continuous development and advancement in EM practices, they have been seen as difficult to adapt and adopt, and therefore for their benefits to be perceived by organisations (Frank 2014), which requires reconsideration of the way organisations can use and adopt these practices.

Some of the well-known EA frameworks are: Zachman (Zachman 1987, Zachman 2004), TOGAF (TOGAF 2009), DoDaF/MoDaF (Martin 2006). Other newer enterprise architecture frameworks such as ARIS, CIMOSA and DoDAF/MoDAF have also attracted considerable attention whilst still evolving and being examined by practitioners (Berio and Vernadat 1999, Kosanke, Vernadat et al. 1999, Bernaert, Poels et al. 2015). Some architectures are supported by methodological processes (e.g. ADM for

TOGAF), and others focus on the structure of the main components of the enterprise. ArchiMate addresses enterprise modelling in three aspects: 1) structural, 2) behavioural, and, 3) information; and with three levels: 1) business, 2) application, and, 3) technology. Also we have the recently introduced OMG specification, the Unified Architecture Framework (UAF) (OMG 2016). This framework is a recent update of a DoDaF/MoDaF UML profile, which also integrates the NATO Architecture Framework (NAF) in addition to DoDaF and MoDaF. Other important enterprise architecture and modelling frameworks presented, such as UEML (Vernadat 2002, Vernadat 2003), EMM (Goul and Corral 2007), IEM (Bernus, Mertins et al. 2013) and EEML (Krogstie 2008), are enabling multi-aspect and multilayer enterprise integration. ArchiMate (Lankhorst, Proper et al. 2009) is considered as an enterprise modelling language that can be combined nicely with frameworks such as TOGAF.

The recent developments in EM research seem promising. Loucopoulos, Stratigaki et al. (2015) introduced capability oriented enterprise modelling focusing on the concept of capability and how it responds to the enterprise and changing needs (Loucopoulos and Kavakli 2016). Fill (2017) has developed a modelling framework from semantic annotation called SeMFIS (Semantic-based Modelling Framework for Information Systems). Multi-perspective Enterprise Modelling (MEMO) also shows a sophisticated development in terms of metamodel, notations and enterprise aspects integration. These frameworks were implemented using the ADOxx framework (Bock and Frank 2016). Boissier, Rychkova et al. (2016) proposed an extension of the EM practices for decentralised enterprise, e.g. corporate and holding companies, and the model contains a metamodel and practices for tackling enterprise efforts in a similar environment. Hinkelmann, Gerber et al. (2015) also proposed an approach using the metamodelling framework ADOxx (OMiLAB) and integration ontology to align business with IT. The same framework was used for creating domain-specific modelling languages (Karagiannis, Buchmann et al. 2016). Many of these initiatives were part of OMiLAB (OMiLAB), the Open Model initiative Laboratory. Two other interesting EM frameworks are DEMO (e.g., Dietz (Dietz 2006)) and 4EM, e.g. (Sandkuhl, Stirna et al. 2014). Other interesting metamodelling platforms are the eclipse modelling framework (EMF) (Eclipse 2009) which adopts the core of Meta Object Facility (MOF) for metamodelling and the MetaEdit tool.

Languages have also advanced. Object management group (OMG) has developed and adopted a significant number of enterprise modelling languages, such as Business Process Modelling and Notation (BPMN)(OMG 2013), Semantics of Business Vocabulary and Business Rules (SBVR)(OMG 2006), Organization Structure Metamodel (OSM)(OMG 2006), Decision Model and Notation (DMN)(OMG 2014), and the Business Motivation Model (BMM)(OMG 2010), and finally the mostly known the Unified Modelling Language (UML) (OMG 2007). These models have greatly enhanced the semantics and the integration of different aspects of the enterprise knowledge.

Another recent theme of EM research focuses on the integration or adoption of industrial best practices (Fayoumi and Loucopoulos 2016, Basios and Loucopoulos 2017). Best practices proved successful industrial implementations either at strategic level, such as the balance scorecard (BSC) (Goldman and Ahuja 2011), Rummler framework (Rummler 2007), Total Quality Management (TQM) for process improvement (Black and Porter 1996), or at operational level such as Six Sigma (Devane 2004), the Value Reference Model (VRM) (VCG 2012) and the Capability Maturity Model (CMMI) (Godfrey 2008), or in technical management and technical services maturity such as CoBIT (Goldman and Ahuja 2011) and ITIL (Steinberg, Rudd et al. 2011).

Enterprise modelling efforts can be classified into: a) Enterprise architecture frameworks, b) Enterprise modelling specifications, languages and techniques, c) Enterprise modelling frameworks, and, d) Modelling foundational platforms. Examples are not limited to these classes and are shown in Table 1 below:

Table 1. Summary of the enterprise modelling and architecting types

EA frameworks	EM specs & languages	EM frameworks	Modelling foundational platforms
Zachman, TOGAF, DoDAF/MoDAF, UAF, MAF, CIMOSA architecture framework	BPMN, SBVR, DMN, ARHIMATE, UML, SysML, ISO19440.	MIMO, SeMFIS, CODEK, DEMO, 4EM	ADOxx, EMF, MetaEdit, Actifsource.

Despite the importance of EM practices in offering a robust syntax and semantic for digital transformation and enterprise design there are many areas where the current enterprise modelling practices have not been covered in depth and have as yet significantly limited support. Still the dominant focus of EM approaches is on organisation procedure and technicality. The organisation in the day-to-day activities (run-time) is different than the optimum design that is created in the enterprise models where events and circumstances play crucial roles in diverging the activities from the actual design. For example, GERAM and NATO frameworks have addressed in limited way the social aspects such as human role, personnel, responsibilities and authorisation, motivation, skills, training needed etc. There is no doubt that all EA and EM practices are concerned with the technicality, even though many of these techniques and models describe actor, role, goal, skills, responsibilities, and other organisational aspects, yet these are still procedural and therefore under the technicality of the system rather soft social aspects which require more methodological and interaction procedure. Frank

(2015) argues that the EM domain requires more consideration of the context of traditional modelling, binding the modelling with the organisation practices and considering more inter-disciplinary research. The social optimisation is also weaker than the technical optimisation: organisations that have cultures and norms and operate within particular contexts that have social collective uniqueness. Sometimes the STS boundaries cross the geospatial and socio-economic boundaries and operate far from traditional space constraints using both physical and digital interaction mediums. The design of the interaction network is important (Kling and Lamb 1999). Understanding the degree to which level the physical interaction is required for a particular role (digital or physical) within spatial-temporal boundaries is crucial, as is how formal and informal interaction among the actors' networks shape the STS network behaviour. Managing a team requires more than assigning tasks and chasing staff to deliver the highest quality within the time set. Thus, a further insight from STS theory and practices is crucial to enrich EM practices

2.2 Socio-technical Systems Theory

A 'systems' perspective has provided a significant contribution in explaining many of the phenomena in Information Systems research, such as Enterprise Systems (Williams 2020) and Enterprise Architecture (Gorkhali and Xu 2019). The use of enterprise systems involves a large number of often standardised processes that require interactions between users (social agents) and the hardware and software technologies of the enterprise system, which manifests itself as a complex Socio-Technical System (STS). In fact, these large 'technical' enterprise systems are predominantly implemented in order to support the users of a large organisational enterprise to adhere to business processes and perform productive work in order to achieve the senior management's goals for the organisation (Checkland 1999).

STS refers to the intertwining relationship between the social and technical aspects of an organisation, or even a society as a whole, and this understanding has formed what is called the STS theory. STS theory adopts the understanding of an enterprise system where equilibrium, mutual optimisation and compatibility of both technical and social systems are considered with equal attention, in addition to a careful consideration of the work situation and workers' welfare beside organisation/work productivity and performance (Emery and Trist 1960, Appelbaum 1997, Ropohl 1999). The theory has permeated and derived systematic principles that helped in a large number of emerging STS analysis and design practices (Emery and Trist 1960, Emery and Trist 1965, Trist 1981, Mumford 1983, Mumford 2006, Alter 2012, Alter 2013, Alter 2015), and the aim of these practices is to support the organisation development activities. Some other practices have more software systems focus (Sommerville 2004, Bryl, Giorgini et al. 2009, Baxter and Sommerville 2011, Baxter 2011, Carlsson, Henningsson et al. 2011). Despite the numerous efforts to standardise STS practices, it is unlikely to happen. In fact, it is relatively better to have such a vast spectrum of practices that have different qualities with different focus on different scales and different perspectives. Rather, the focus of advancing the practices can be on the development of the meta-level of the artefacts and principles. Approaches relevant to STS theory presented in this research area are varied from mechanistic to organic, or a mixture of both. For instance, considerable research has been undertaken to explain, analyse and design socio-technical systems from several research areas as previously mentioned, namely business and information and organisation science fields “social focus” (Emery and Trist 1960, Cherns 1987, Appelbaum 1997, Mumford 2000, Carayon 2006, Elbanna 2016) and computer software engineering “technical focus” (Sommerville 2004, Bryl, Giorgini et al. 2009, Baxter and Sommerville 2011). There are some attempts to fuse both social/organisational change, and technical systems development has been proposed in (Baxter and Sommerville 2011, Baxter 2011) and in (Morris 2009), however, the social aspects understanding in these literatures are not social soft and rather focus on the organisational and procedural aspects which are considered more mechanistic than organic. While the social system perspective should investigate social relations, interaction, norms, competencies skills, job and life quality and the management of different situations. The technical perspective aims to improve reliability, efficiency, control, speed and the accuracy of information flow by integrating and enhancing knowledge sharing, process management and technology design and utilisation (Davis 1977, Mumford 2006, Klein 2014). The socio-technical theory proposes a number of different ways of achieving joint optimisation, and these are usually based on designing different kinds of organisational settings in which the relationship between social and technical elements and their environment leads to the emergence of productivity and wellbeing. Optimising any of the subsystems of the STS in isolation might cause failure in recognising the interdependent complex relations between the social, technical and environmental due to the conception of the open STS (Mumford 2006). As such, open systems became more complex, with people doing business collaboratively across organisational, cultural, temporal and geographical boundaries in a world that has become more connected. Externally, the open socio-technical system is a complex and ill-defined entity since social, environmental, technological, economic and legal systems have resulted in physical and virtual spaces that are more greatly fused than before (Whitworth 2009, Davis, Challenger et al. 2014). Internally, an important factor is relevant to how organisations employ technology, in particular hybridising information systems (IS) with other internal resources, in that organisations need to understand for how far the IS are strategic and play a crucial role in shaping their business model and innovate service design and delivery through a bottom-up approach.

2.3 Enterprise Modelling for Socio-technical Systems

EM have long time neglected the analysis of organisational organic soft and social aspects. Issues of trust, communication (collaboration and coordination), relations, culture, innovation, satisfaction, personal motivation, language, norms and values, competition, bias are frequently influencing enterprise performance and should be considered when designing enterprises. We anticipate that STS approaches can enrich enterprise modelling by bringing a balanced view of social and technical joint optimisation. Approaches to describe and analyse the relationship between social and technical aspects of the enterprise such as in (Emery and Trist 1965, Emery 1972) and (Mumford 1983, Mumford 2006) provide explanations as to how STS works, and guidelines on how to analyse and design them. Some other approaches tried to bridge the gap in analysing and designing social and technical systems as in (Graves 2014) and (James Lapalme 2014), graves and Lapalme see each enterprise as an open socio-technical system that has a unique teleology and experience that can be captured and presented in a way that aids the design of its activities and information systems. These socio-technical systems have open boundaries, which need continuous assessment of their social and technical subsystems and their environment. Such as open system has a large number of both internal and external interactions which presents opportunities for digitisation.

Such as context can also be seen as adaptive as proposed in (Dalpiaz, Giorgini et al. 2013), the authors see enterprise as an adaptive socio-technical system and proposes a requirements-based approach to developing information systems. One of the crucial challenges is that large scale IS development requires the involvement of multi-stakeholders who have requirements based on their experience and professional perspective. Human perception is a strong determinant in shaping the subjective view of reality, and this has a strong impact on ISs development in term of: a) the system's designer has subjective view, and, b) multi-views and perspectives are better for completeness, robustness and comprehensiveness of design requirements. Nevertheless, more systematic approaches using enterprise modelling correspond to STS aspects are required, thereby increasing the comprehensiveness and usefulness of enterprise analysis and design to develop information systems. In the following, we discuss the essential aspects of socio-technical systems in order to derive a unified EM model that fulfils the main constructs of these systems as described in Table 2.

Table 2. Main constructs of STS

Essential aspects of enterprise STS	Definition
Goal (Appelbaum 1997, Davis, Challenger et al. 2014)	The ST system or subsystem element goal (underlying intention) e.g. why a system or subsystem was formed and has been mentioned in literatures, sometimes as objective, goal, intention or aim. Literatures also focussed on the issue of goals alignment and compatibility with the undertaken work or task.
People (Appelbaum 1997, Davis, Challenger et al. 2014)	The autonomous entity in the STS environment, which can be an agent or an actor. Stakeholders can represent individual or collective agents/actors.
Value system and work welfare (Appelbaum 1997, Mumford 2006)	The design of the work should not focus only on the efficiency and performance; it should also achieve a high standard of work life quality, concerning human welfare and both their psychological and physical health.
Processes /Procedure (Davis, Challenger et al. 2014)	Emergent functional interactions toward achieving certain goals (organic) while procedural processes can be more formal and specific (mechanistic).
Structure (Appelbaum 1997)	The way that the social and technical elements/agents are organised and coached, and their roles within the system. Also, consideration of the agents' communication and coaching structure, roles, responsibilities and tasks that is related to goals.
Domain knowledge (Mumford 2000, Mumford 2006)	Knowledge is an essential element of the STS design. It can be about outer or inner system elements that are affecting the ST system or part of the system, triggering particular actions or motivating specific agents to act (events and knowledge).
Functional Capability (Appelbaum 1997, Mumford 2000, Mumford 2006)	The functionality that is expected to be induced by the agent (technical or human), the agent might use some form of resource (assets, infrastructure, technology or social information) to implement the work design for the system.
Culture, norms and rules (Trist 1981, Appelbaum 1997, Davis, Challenger et al. 2014)	The embedded rules and norms that determine the behaviour of the agent or collective of agents within the STS. It is also influenced by a regulatory system that is in the context of the STS. Rules should enable agents in the system to decide how to work in order to increase productivity. In addition, it should enable them to have control over process deviation for bottom-up system evolution.
Performance (Emery and Trist 1960, Trist 1981, Mumford 1983, Mumford 2006)	Optimising the team and the resources to achieve best possible work performance.
Environment (Trist 1981, Appelbaum 1997, Davis, Challenger et al. 2014)	In an open enterprise STS, the system context contains many influencers and influences, e.g. economic, financial, customers, partners, competitors, industry landscape, resources, regulatory framework and law.
Technology (Appelbaum 1997, Davis, Challenger et al. 2014)	Technology can be considered as a technical agent (enterprise-orientated technology) or as a resource (technology infrastructure), it is mechanistic and predictable. In this paper, EM practices lead to technology design (a technical artefact of a planning and design artefact).

The paper argues that some of the main characteristics of the STS can be captured and described through enterprise models. The enterprise socio-technical model can help organisations in capturing holistic enterprise knowledge, which can be used in socio-technical optimisation and developing information systems that are aligned with enterprise goals. The following are the research objectives:

- To provide comprehensive understanding of the general components of STS theory and approaches

- Whenever, mapping is unfeasible, to suggest STS practices that can blend coherently in coherence with EM effort

- Discuss how both model and practices can work interchangeably and in coherence

3 Motivating Example: Hospital Digital Framework Modernisation

The illustrative scenario pertains to the deployment of new technologies that forms part of a major strategic modernisation program being implemented by a large hospital. The Board of Directors of the hospital had initiated a major IS and IT change program that would improve their services, offer a better healthcare experience to patients, and provide increased support to family members of patients. In addition, the modernisation program is expected to facilitate significant cost savings through more efficient business processes, with particular focus on their back-office functions of Recruitment and Procurement, alongside using recent technological advances to reduce resource costs in providing initial frontline services to patients.

The scenario comprises a multi-partner environment, with: a global IT professional services provider acting as the prime contractor for overall Systems Integration and deployment of hardware infrastructure; a global software applications vendor who provides leading Human Resources (HR), Financials and Customer Relationship Management (CRM) modules within their Enterprise Resource Planning (ERP) software; a number of niche vendors who provide leading software around AI in healthcare, such as Telemedicine, Diagnostic Expert Systems, and Online Avatars. Alongside implementation of the ERP modules, the hospital Board of Directors concluded that they also required a large-scale digitisation program focused on their healthcare service network, in order to achieve their business drivers. As such, the strategic modernisation program comprised six main strands of work: 1) keeping up with emergent services and reducing the costs associated with IT deployment; 2) automation of call-centre and customer services; 3) digitising their recruitment processes and taking advantage of online talent pools; 4) developing in-house self-study learning resources to further develop the professional skills and knowledge of Junior Doctors; 5) improving their procurement processes and reducing costs associated with purchasing logistics; 6) reducing costs associated with medical operations and maximising collaborative resource utilisation. These different enterprise applications need to be integrated together in order to ensure they contribute to the success of the hospital's change program (see Gorkhali and Xu 2016 for a review of Enterprise Application Integration). Furthermore, in a similar way to the recent case study by Mo and Beckett (2019) into EM of hearing loss, we expect this new system to present challenges around how stakeholders interact with it and adhere to the new processes. The six strands of work are elaborated upon below.

Firstly, the Board of Directors are keen for the hospital to keep up with emerging technologies and emergent services but is acutely aware of the need to maintain control of overall IT and IS deployment costs. The implementation program will therefore deploy new software systems that are able to search and discover emergent online healthcare services that are offered by third-party providers. The hospital is expected to allocate a discovery agent to find suitable available services on the Internet, upon which the Board of Directors will select the most suitable for trialling and future rollout. The hospital needs to be able to optimise and sort their search in term of costs, capacity, functionality, technical support, security, etc.

Second, there is a requirement to automate aspects of their call-centre and customer services through ERP and AI software. This would provide the added benefit that the hospital could extend its call-centre service hours to patients and healthcare service requesters by adopting Telemedicine, Expert Systems and automated CRM. Specifically, the Board of Directors decided that the hospital should implement a chat-bot whose Expert System is pre-programmed and has a specific procedure for dealing with customers' requests both online and on phone.

Third, the Board of Directors wanted the hospital to digitise their recruitment process and take advantage of the online talent pool. They recognise the importance of recruiting new talent to the hospital and have therefore decided that the staff recruitment processes need improving, in order to ensure they recruit the best Administrators, Nurses, Doctors/Physicians and Clinical Support staff. Importantly, alongside implementation of the HR module within the ERP system, they believe the hospital should take advantage of emergent technologies in this area and would like to make use of Avatars to search for suitable candidates that meet the criteria of existing and predicted vacancies. This would reduce the hospital's dependency on expensive third-party recruitment agencies.

Fourth, the Medical Director has identified that a large proportion of the Junior Doctors within the hospital have low levels of confidence around their preparedness for practise when it comes to legal and ethical issues that they face when delivering healthcare to patients with complex needs (Corfield, Williams et al. 2020, Machin, Latcham et al. 2020). As such, the Board of Directors have agreed that the implementation of the new IT and IS systems provides an opportune time to develop and implement an in-house self-study learning portal. The intent is for the learning portal to be used by all hospital staff (e.g. Clinical, Administrative and Facilities) as part of their continuing professional development, but in the first instance, will be targeted towards the needs of Junior Doctors in order to assist them in developing confidence around challenging legal and ethical situations involving patients with complex needs and also to support them during their studies for their professional exams with their relevant Professional Body (e.g. Royal College of Physicians in the UK, or American College of Physicians in the USA).

Fifth, the Finance Director decided that the implementation of the new IT and IS systems provided an opportunity to for the hospital to improve their procurement processes and reduce costs with respect to suppliers and purchasing logistics. The regular and timely procurement of healthcare consumables and medical equipment is an essential business process for the successful running of the hospital. Historically, the hospital has been locked into a small number of suppliers, however they now wish to expand their supplier base. The hospital wants to assign an Avatar that can search for, and recommend, potential suppliers and business partners on the social media platforms. In addition, the Avatar will be required to communicate with suppliers' avatars (if deployed), setup and negotiate costs, and agree a draft contract. When the Avatars agree to a potential business partnership and draft contract, the hospital's Avatar then notifies the hospital's Procurement Manager for further instruction (to either proceed with the contract or continue searching).

Finally, the Medical Director believes that the implementation of the Financials and CRM modules within the ERP system may help reduce costs relating to elective medical procedures and facilitate collaborative resource utilisation. For example, the CRM module can be integrated with the existing Health Information System (HIS) system in order to streamline the exchange of structured clinical information within the hospital and among approved external providers who provide core healthcare treatment and facilities as part of the care pathway that the hospital follows for each patient (Platt, Tarafdar et al. 2019). A further example, is that in the event of a major local or regional incident that results in significant numbers of patients being admitted to the Emergency Department, or when the hospital is operating at full capacity (as seen during the recent Covid-19 pandemic), the hospital may need to rent additional Medical Equipment (e.g. ventilators) or space (e.g. operation rooms) in nearby medical facilities, such as private hospitals. In order to facilitate this in a timely manner, the hospital needs an online system to find out in real time what equipment/services can be secured, at what time, and at what cost. For instance, they may be charged per hour or day dependent on the nature of the resource that they are keen to rent.

4 The Framework: STS Driven EM Model Ontology

The review of STS literatures resulted of the following narrative, which describes our summarised understanding of the STS axioms that should be covered by the EM ontology framework.

"The enterprise STS is an open system consisting of heterogeneous ***agents*** which are varied in their autonomy. The autonomous agent has certain **goals** and is ***organised***/coached in a way to work towards achieving these goals. These agents ***interact*** with each other internally and externally for achieving some specific goals, using some specific tools or assets (***resources***), they organise themselves into ***groups*** to achieve collective goals. This goal requires a series of parallel and sequential ***timely*** tasks (***processes***) to be accomplished under specific ***rules*** to govern the behaviour, and these rules are either streamed from their ***internal environment*** or forced by their ***external environment***. The processes require specific functional ***capability*** for execution. The goal and action could be related to temporal or physical ***events***, and could be driven from the system/agent's outer or inner factors. At a macro level, the complex network consists of many STSs, and these STSs are representing ***collective agents*** and have embedment of the socio-technical aspects, which also been elaborated in ***technology***. Sometimes, STSs are overlapping and they influence each other negatively or positively depending on how tied the relation is."

The focus will be on separating the details of eight perspectives that respond to the propositions that emerge from the conceptualisation of STS features. The framework perspectives are linked through the semantics provided in the framework models. The perspectives consider social and technical features as well as systems' internal and external aspects. The mapping between these views and the original complex systems characteristics are described in Table 3:

Table 3. Linking STS characteristics to enterprise models

STS construct	Enterprise model
Goal	Goal Model
Structure	Organisational Model
Domain Knowledge (ontology)	Domain Ontology Model
People	Actor/Agent Model
Processes/Task	Process Model
Functional capability	Capability Model
Culture and rules	Rule/Decision Model
Technology	Technology Model

It is understood that enterprise modelling uses conceptual modelling and should consider multiple perspectives to cover the fundamental ontological concerns that were discussed in the previous section. The suggested models will reduce the complexity of the STS environment and help organisations in understanding and analysing the emergent behaviour, and designing effective ISs by answering questions regarding: a) the “where” and “when” (i.e. temporal and physical constraints), b) the “how”, c) the “what” and “when” that cause events, d) “what” to do and, e) “who” will do it. Corollary, this all will govern the emergent behaviour of the enterprise towards what is called the guided enterprise (Dekkers, Sauer et al. 2005). Perspectives of motivation/goal, actor, organisation/role, process, events, resources/capabilities, rules, and decisions need to be developed to offer a holistic view of enterprise artefacts. The suggested enterprise models should provide the foundation to develop the information systems components through either agent-oriented modelling, process-oriented modelling and, later, to code execution-levels based on service-oriented architecture (SOA) and ReSTful APIs.

These models are the terminological components of the ontological view through where the real world of socio-technical system can be seen. The semantic mapping among these perspectives is crucial and it was developed based on our experience of both STS aspects and enterprise modelling frameworks. These perspectives are linked through at least one concept from each perspective to ensure their interoperability. However, each particular STS might have a different motivation/reason for semantic connectivity, and thus, the semantic map may differ or alter based on some objectives. The perspectives models can be developed for any system or subsystem of the enterprise in further granular elaboration. Respectively, the following sections show the EM perspective models that are driven from STS conception. We relied on our experience that inline with previous EM frameworks to accomplish the building of these perspectives as described below:

4.1 Goal Model

The enterprise goals are situated to guide the enterprise to the reason why it has been formed and what should be achieved. The model presented is inspired by a number of models of sets of goal-oriented modelling methods (Loucopoulos, Kavakli et al. 1997, Lamsweerde 2003, Yu 2009, OMG 2010) with alterations that tailor it towards STS theory. The goals can be organisational, these goals confirmed by high-level managers in the organisation, owners and stakeholders; or divisional which are the goals established by departments managers, or group goals, assigned by team leaders, or individual goals, which are developed by individual employees for their own professional and personal purposes. As the actor, the person is autonomous, they have both assigned roles and natural roles, and they have formal and informal relations that can be either personal or professional, where the impacts of these are unavoidable. The actors are expected to have a personal goal; everyone sets personal goals as a way to focus their effort and energy, and when working towards these goals, actors form and shape their behaviour to conform to them. The goal could be shaped though partnership or teaming, in addition to individual goal shaping (Fayoumi, Kavakli et al. 2015). Therefore, the enterprise can define its goals to work towards their achievement. It is critical for the organisation and employees to match their goals. A negative work impact is caused when staff of the enterprise is working towards goals that contrast with the organisational goals. It is obvious that the existence of conflicting personal and organisational goals will harm the employees' motivation to achieve the enterprise's objectives. The goal usually is composed of several sub-goals of different levels of abstract and granularity, and where achieving these sub-goals results in the achievement of the parent goal (the goal in the higher-hierarchy). The more the goals are operationalised, the more they represent the tasks. The enterprise goal has two types: a) long-term goals, e.g. vision, and b) short-term goals, e.g. mission statement. The sub-goal is a refinement of the parent goal and operationalised by tasks (elements of a process and on the edge of the goal operationalisation), there is at least one task required to execute each sub-goal operation. The sequence of tasks combined together can be represented as a process, and the process should refer to a goal to verify the end result. The relationships between the goals can be defined from different perspectives, for instance, where the goal could be a hard type or a soft type goal. A hard goal is one that aims to be achieved with alignment to the top strategic goal, and it can be short or long term. Soft goals are typically used to model non-functional and objective without clear-cut criteria, and which relates to delivering or achieving the goal (Bresciani, Perini et al. 2004), as stated in (Mylopoulos, Chung et al. 1992, Firesmith 2004, Chung, Nixon et al. 2012, Penzenstadler, Raturi et al. 2014) security, quality and safety, availability, flexibility goals are sort of non-functional, this understanding has wide agreement in requirement engineering (RE) community. Some other non-functional requirements reported are sustainability, maintainability, serviceability, reusability and others. The soft goal is not actionable; however, hard goals can sometimes be established to achieve soft goals, e.g. creating a token that checks for Trojans to enhance system security. Sometimes, the actionable hard goal is achieved through the effectiveness of the soft goal. It is different from a sub-goal, which is still functional. The goal should be featured by identifying its maturity level, and also by specifying whether it is obligatory or optional. For example, security goals need to be defined clearly; what is security for the enterprise, and what is the acceptable level of security for the enterprise? What are the essential and optional aspects of the security?

In terms of influencing goal relation, the goal could be supportive of, or in conflict with, another goal. In some cases, the effect of the goal is not clear enough to decide the impact level of the goal until the goal execution has been put in operation, while in other cases the influence depends on the contextual situation of the environment where the goal is situated. Goal influencing relations can be of two types: 1) formal relation within the boundaries of the organisational design, and 2) informal influencing relation outside the design boundaries and considerations. Other factors proved by literature that have a direct influence on the situated goal are described below based on:

- Specificity: valuing how much the goal is specific; taking into consideration the fact that the goal should not be narrow or wide, but should be specific and aligned to the wider scope to ensure higher goal achievement.

- Time horizon: the period is an important aspect, as the goal should be within an optimum suitable time and should be assessed against the enterprise capacity and capability, with risk and opportunities assigned to set it up over a short or long period.

- Difficulty: the difficulty of goal achievement should be evaluated against the time, quality and resources (capabilities), challenging enough to stimulate interest but doable in the same time.

- Ethicality: this is a critical issue, as achieving the goal should conform to ethical behaviour and standards. At goal set-up, the organisation should answer, “What is the impact of violating the ethicality?”

- Learning: each goal achieving an activity has an expected learning scale, and experience to be gained during and after the process. What do we expect to invest in order to gain knowledge related to achieving the task (“knowledge as input”)? What do we expect to gain (“knowledge as output”)? Learning will gradually improve/optimise actions towards the goal.

- Relevant issues: usually goal activities will influence other activities, goals and resources used, therefore issues may emerge (Loucopoulos, Kavakli et al. 1997). Alternatively, sometimes goals are set up as a result of issues and challenges, and SWOT analysis should be performed before goal confirmation as the goal may drive new issues. It is necessary to assess the challenges associated with each particular goal, and propose a solution to overcome these challenges. What is the SWOT analysis for the goal, and how can we use it in an efficient way to support the business plan?

Figure 1 semantically presents a description of the goal model.

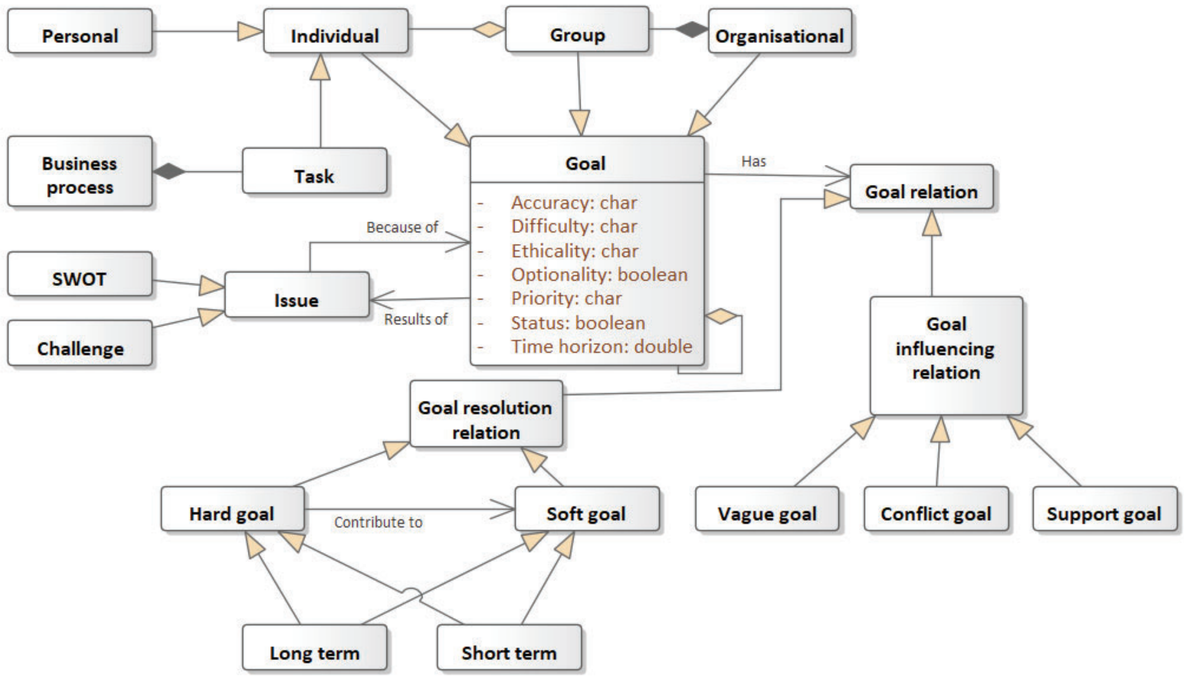

Figure 1. Goal Model

4.2 Organisational Model

The socio-technical system embeds organisational structure and coaching mechanisms. Much work done in the organisation-oriented approach relies on conceptual modelling in software engineering and enterprise modelling. It has a root in the old organisational theory (Waldo 1978) and the bureaucracy in division of roles and responsibilities. From a socio-technical viewpoint, there are number of research areas that have contributed to these organisational aspects. Examples of relevant approaches are role/group orientation from artificial intelligence (AI), and organisational structure aspects from organisational science. Organisations vary in their structure, therefore also in their capability, capacity and ability. Organisational structure should be designed-based on a high-level assessment of the goals, where organisational structure is part of the means toward a particular goal. Most of the focus in the organisational model is on the attributes and characteristics of the role, matching capabilities with skills and qualifications, and putting behaviour under the constraints of rules (Fowler 1997, Chapin 2008). Typically, organisations decide which optimum internal configuration is suitable for their business activities. The organisational model is presented in Figure 2.

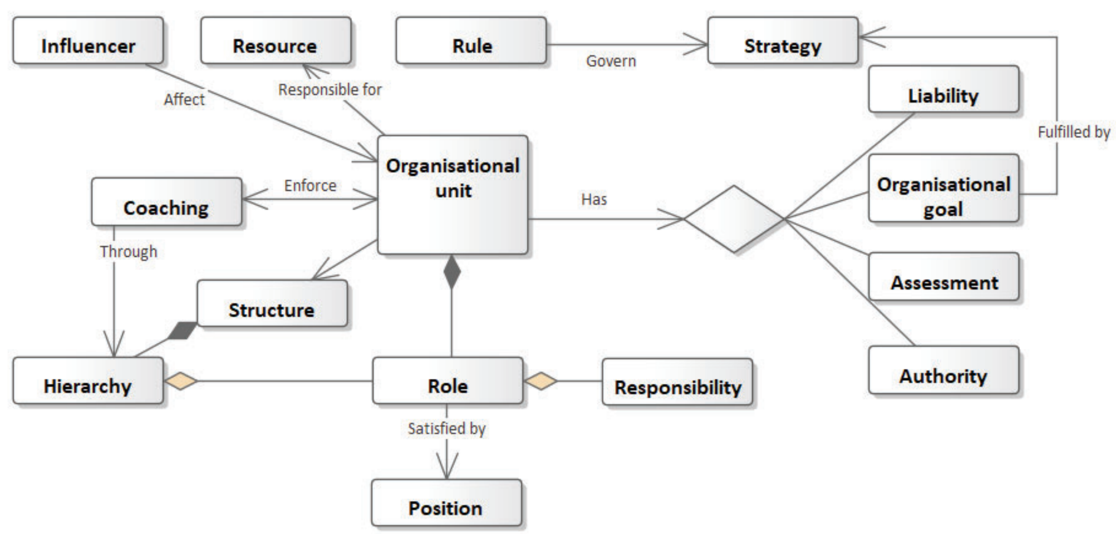

Figure 2. Organisational Model

4.3 Domain Model

Most human knowledge is represented and communicated by language; natural language is a basis for our communication requirements (Guizzardi, Wagner et al. , Loucopoulos and Kavakli 1999, Mylopoulos 2008). At the same time, all business concepts are documented by natural language as “explicit knowledge”, with some other types of knowledge kept in the human mind being 'tacit knowledge' e.g. experience and complex situational intelligence, but also this can be communicated verbally or written using natural language (Nonaka and Konno 1998). Thus, research in business and computer studies has focused on the semantic of concepts and the ontology of the domain knowledge. Since socio-technical systems consist of social system “organisation” and technical systems “technology and mechanisms”, it is required to consider both understandings of knowledge (Nadoveza and Kiritsis 2014). The research in management and business areas has mainly focused on business taxonomy, concepts and definitions and the lifecycle of knowledge. Some researchers in cognitive science focused on how human cognition is perceived and knowledge processed. Work in computer science has covered ontology development, natural language processing, fact-based modelling, textual models and semantics of business vocabulary and business rules (Fayoumi and Yang 2012). We constructed a simple structure of linguistic requirements in order to improve communications and planning. To achieve this, we saw that business has many concepts that need to be pre-defined with a clear definition before it can be communicated and used. These concepts offer some meaning through the semantic of a set of vocabularies (Karpovic and Nemuraite 2011). The connection of concepts can present factual statements, and these facts can be used to describe business rules and policies (directives) using quantifiers, logical operations and logical models (OMG 2006, Malik 2011). Moreover, the concepts and facts can help in defining services and describing sets of activities used in the business process model. The internal rules are imposed from inside the system, and external rules imposed by other systems, e.g. government, ecology, cultural norms, etc. Understanding causality and relations among these rules is very important in managing and updating them. Figure 3 shows the domain model.

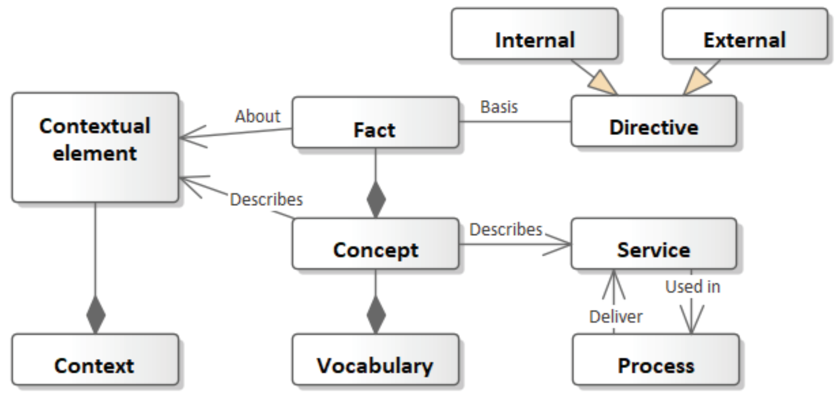

Figure 3. Domain Model

4.4 Agent Model

In agent model, agent is defined as an autonomous entity acting towards achieving some goal within its environment, most of the time the agent plays a role in organisation context. We take benefit from previous research presented in (Loucopoulos, Kavakli et al. 1997, Lamsweerde 2003, Yu 2009, Fayoumi, Kavakli et al. 2015) to form our understanding. An organisational unit is usually set up to support the achievement of some goals, by assigning some responsibilities to the unit using some particular capabilities. The responsibilities could be relevant to primary or secondary activities, and presented as hard goals and soft goals. These goals or sub-goals need resources to make them complete, and the organisational unit organises their resources in terms of roles and assets. Assets can be different kinds of resource (finance, tools, software, equipment, knowledge and information). Roles have several types of relation: 1) role to role, represented as a hierarchy and collaboration between the roles; 2) role to goal, which is intentional, assigning goals to a particular role; and, 3) role to resource dependency, using a particular resource to fulfil the role's responsibilities. In the case of knowledge resource dependency, the relation could be assigning work to another agent/role that will be considered as a resource for that role. Sometimes, in the case of a software agent role with dependency on knowledge, the knowledge base from where it will be acquired is the source in the general case, thus must be specified for each particular case. The roles need to be fulfilled by agents, using the resources based on their role privileges, to fulfil the role efficiently.

There are different agent types, for instance, the collective types can be defined if the agent is individual e.g. the agent is Smith who fulfils the role of sales representative. Alternatively, the role is the sales team who all have similar responsibilities. Furthermore, the agent can be a group; the group agent can be organisational, departmental or group-based, e.g. the finance department will be responsible in achieving finance control and goal stability. The other perspective is to look at the agent as either a human actor or a software agent, since advanced technology aims at developing intelligent autonomous artificial agents to fulfil particular automated jobs and perform specific tasks. The human actor is featured by higher uncertainty and is autonomist. At a particular stage of the socio-technical system analysis and design, it is necessary to decide whether it is better to build an artificial agent to fulfil this role, or whether a human actor should only handle it. It appears to be easier and more controllable to design artificial agents and smart ISs to do the job, since the system goals are instituted by the enterprise and this justifies the large movement toward digitisation, although, it is difficult to obtain a human sense of emergency and rationale reaction that might be needed to support some business needs. The actors (agents or human) will take the same relation types as the roles. For instance, agents have particular roles and the relations they have should conform to the role relations model. The agent model is strongly related to the goal model and their semantic relations. Figure 4 describes the agent model.

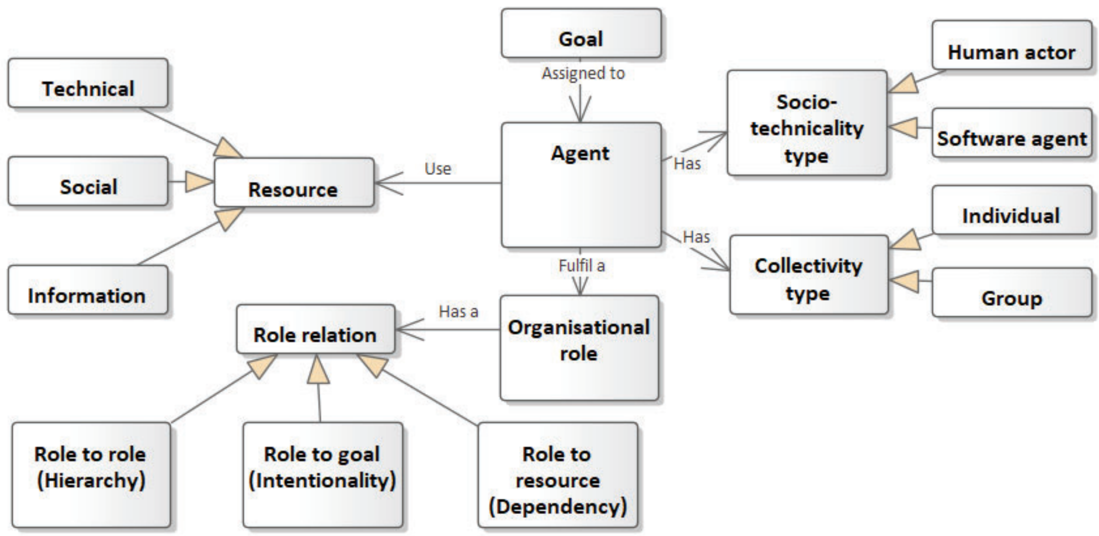

Figure 4. Agent Model

4.5 Process Model

The process is a series of activities, events and decisions which have a start and an end, with an aim to deliver a value, and which uses some capabilities and has some deliverables (Fill 2012, Sanz, Leung et al. 2012, Heidari, Loucopoulos et al. 2013, Koschmider, Fellmann et al. 2014). Process modelling has been widely considered for rationale understanding and analysis of inter and intra organisational work. Since business tasks flow in sequence and in parallel, the business view provides an easy and rational description of what the activities and tasks to be tackled are within the organisation. Each organisational unit is responsible for a set of processes relating to its core responsibilities and these will be labelled by the process owner. The process owner designs, develops or manages the process according to the specific goal, and the process is the operational means considered as a refinement of the business strategy and tactics. Quantification of the goal can provide a basis for the Key Performance Indicators (KPIs). KPIs are measurement elements to assess against the designed business processes (Krogstie 2008). The process is designed under specific rules derived from business polices, whether internal, such as company policies, or external, such as industrial policies and regulations. The processes can be encapsulated to present different levels of granularity and they can function simultaneously. Processes require some capabilities and resources to be executed, whether people or assets are required for executing the process in an efficient manner. Figure 5 shows the process model in relation to the other artefacts.

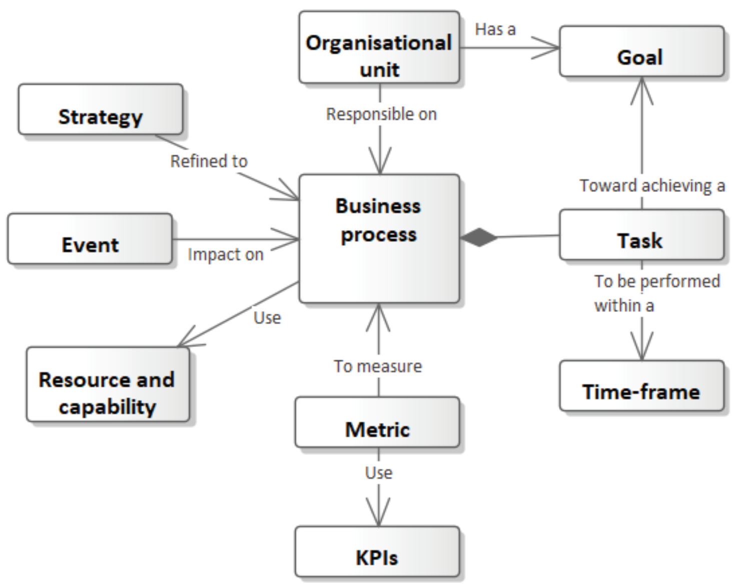

Figure 5. Process Model

4.6 Resource and Capability Model

Once the goals are confirmed and agreed on, an organisation should start developing and mapping their capability model with the goals, striving better understanding about where possibly a certain capability will not be able to satisfy certain goal, and an overall capabilities assessment can be carried out. There is no system that can function without capability, which is usually embedded in the agent or collective of agents, or can emerge from the interaction of these agents. Sometimes it can be equipped or used by an agent. When the capability is posed, the agent or the tool that offers this capability will be called the resource. A resource can pose one capability or more and possibly collaborate with another resource, or more. The capability can be posed from inside the system, or can come from an external system. A composition of capabilities can be called a service that will be delivered to the requester/consumer to fulfil some sort of goal. In this case, a service should comply with the service-level agreement (SLA) and can be employed within a process within a certain context and under some context constraints. The capability has a set of features, e.g. performance, capacity and cost. Capacity is the ability within a controlled environment, while capability is what an agent or set of agents is able to do within a particular environment/context. Capacity is their ability within a controlled environment (ideal), while the performance is their real measured day-to-day ability (Bērziša, Bravos et al. 2015, Loucopoulos, Stratigaki et al. 2015). When employing a capability within a system or enterprise, it implies having a cost that should be paid by the requester/consumer. Figure 6 presents the resource capability model.

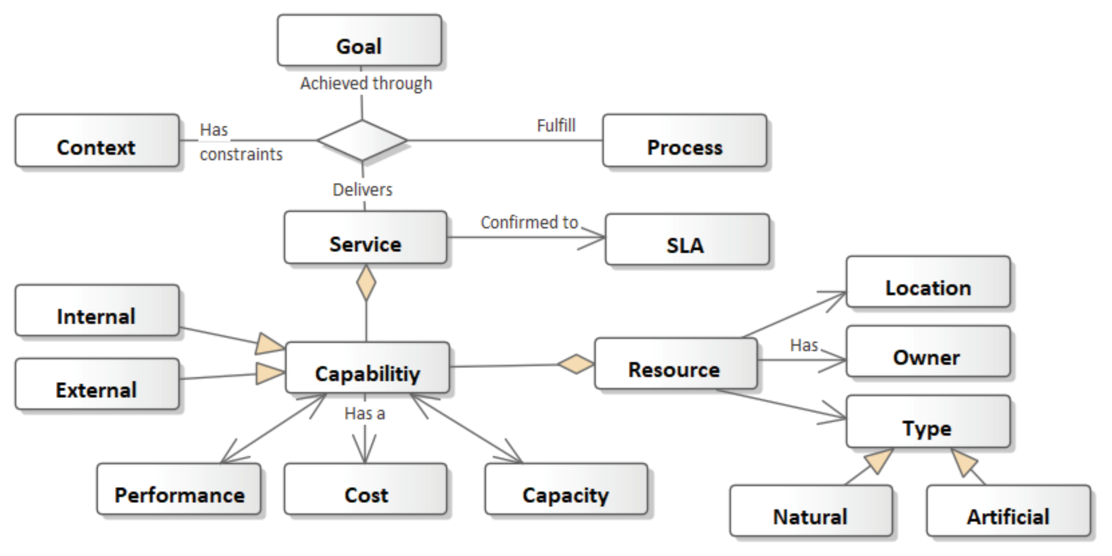

Figure 6. Resource and Capability Model

4.7 Rule and Decision Model

In socio-technical systems, the agents in the system act under a set of rules and policies to govern their behaviour toward achieving some goal or to keep the survival means. The rules have a different type and different level of enforcement. For instance policies can be less enforceable than regulations and the operational rules, while guidelines have a moderated level of enforcement compared to policies (OMG 2006, Fayoumi and Yang 2012). Business forecasting is a critical practice but is unlikely to always be accurate. However, as long as the forecasting models can bring some understanding that cannot be gained without it then it can be called useful forecasting. The methods used in decision-making should be comprehensive and consider the ripple effect of internal or external factors and unexpected events. The model constructed also distinguishes between two important activities: the input and the output of the assessment. The assessment should consider internal and external factors, some of which are influencers of the decision. Some of the influencers of the decision to be made are based on the assessment and can influence the achievement of the drivers (goals, objectives and strategies) (OMG 2010, Fayoumi and Loucopoulos 2014). The assessment could be used to assess influencers of the goals, strategy, processes, capabilities or any of the enterprise aspects. Assessment can take different forms, for instance, design rationale for qualitative assessment, which has a different reasoning structure. Two of the most used structures of reasoning are Goal/Options/Criteria and Issue/Position/Argument (Louridas and Loucopoulos 2000). The other form of assessment can be quantitative, for example, system dynamics modelling, statistical analysis, stochastic simulation and many others (Fayoumi and Loucopoulos 2014, Fayoumi and Loucopoulos 2016). Examples of internal influencers/influences are resources, infrastructure, habits, management style, assumptions, and corporate value, while external influencers/influences could be, and are not limited to, customers, government, the economy, partners, competitors, environment, suppliers, technology and ecology. The assessment output will show the impact level and type on the enterprise activities, which can be expressed in terms of rewards or risk that the enterprise could experience by making a particular decision. The rule and decision model is shown in Figure 7.

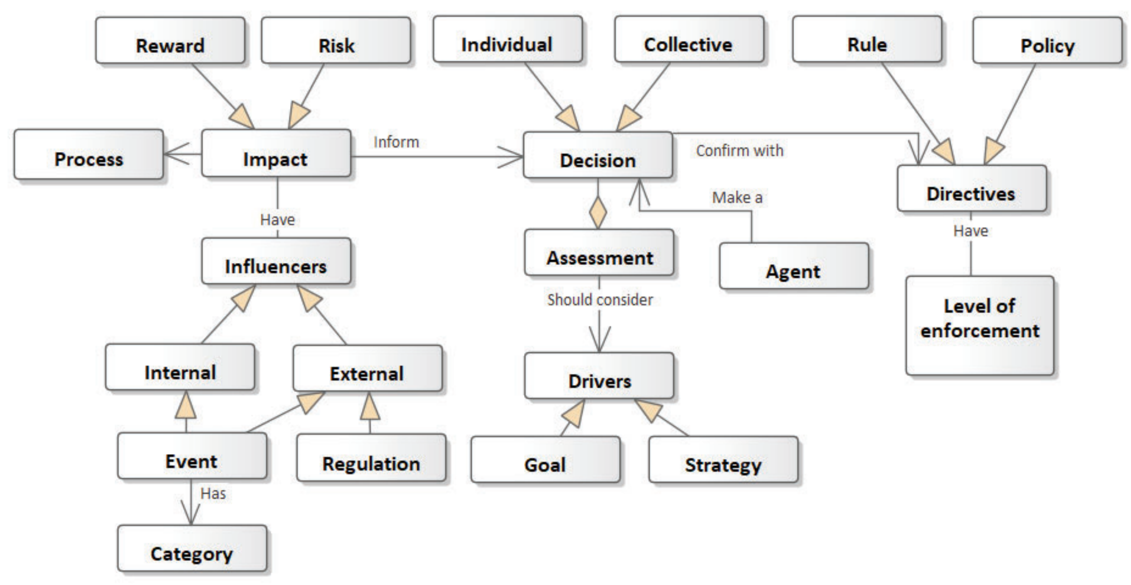

Figure 7. Rule and Decision Model

4.8 Technology Model

The technology model is the core of the hard-technical aspects of the STSs. In this model a possible abstraction was presented to avoid limiting the concepts to a specific class of technology, rather the abstract model can be used for the notions of emergent technologies. For example, IS platform might deliver capabilities of distributed general ledger, a combination of hardware systems and machines that are integrated to software that can deliver cyber-physical systems, while artificial intelligent (AI) capabilities can be in the core of the functionality and embedded in the distributed micro services. Information systems platforms are developed to aid enterprises in executing their business processes. Typically, business processes are hybrid of both social and technical actors. Social actor can be a provider/owner, administrator or consumer of the technical artefact. While the location in the physical space could be relevant, in contrast the location in digital space might be less important. IS platforms are linked together and with processes through the APIs and micro-services, thus will connect large data sets (both traditional data and big data sets) and functions across the open STS boundaries. Such as platforms can be either public or enterprise specific platforms and they use in their underlying architecture a mixture of software and hardware systems. Software can represent emergent IS of distributed ledger, artificial intelligent and virtual reality. Physical systems or hardware can be internet of things (IoTs), robots, controllers and physical hardware or devices fused to consist what is called cyber-physical systems. These sets of technologies can offer the promise of delivering sustainability, all fall either under the umbrella of

AI and Cyber-Physical Systems, or more generally as Industry 4.0 (Geisberger and Broy 2015, Geissbauer, Vedso et al. 2016). Figure 8 illustrates our technology model conceptualisation.

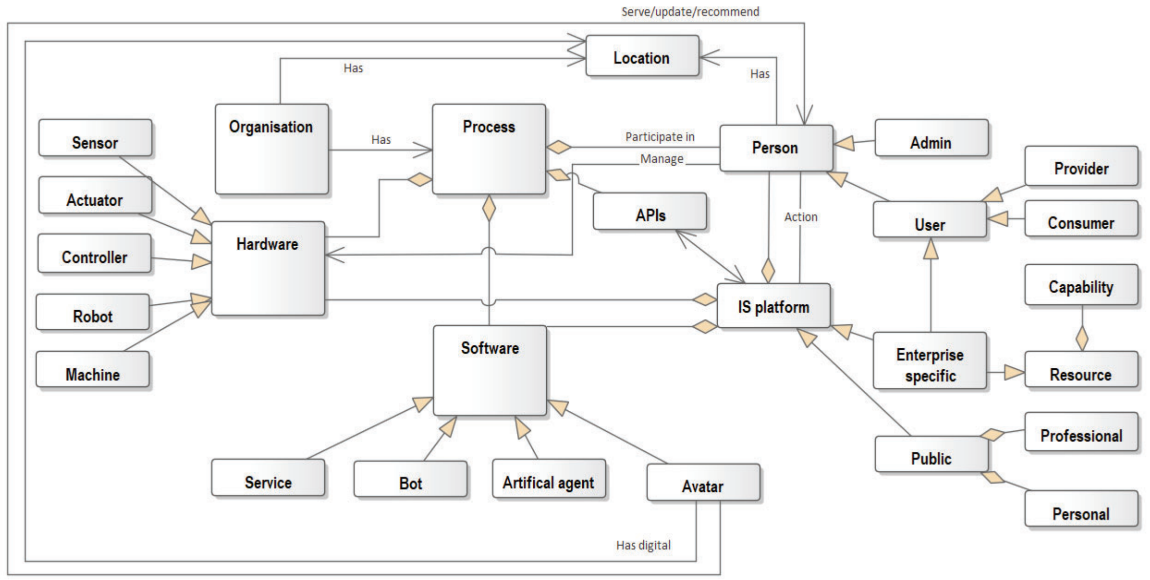

Figure 8. Technology Model

4.9 Blending STS approach with EM practices

It has been noticed that EM is successful in capturing and using many of the enterprise artefacts for both successful operation and information systems design. Yet, pragmatic social focus approaches are still required to handle enterprise complexity. There is a strong need to incorporate socio-technical methodologies with the EM analysis, design and operation processes to ensure optimal social development from the technical side. Ideally, enterprise (social and technical) behaviour should intertwine with modelling in the process of adaptation and configuration. The literature shows that setting ambitious goals, sharing objectives, clarifying direction and guidelines and motivating the workforce will bring better results and better work performance (Heslin, Carson et al. 2008, Ordóñez, Schweitzer et al. 2009). Although leadership and management science try to understand the individual staff on a minimal scale, the situation will remain the same as long as the managers keep focusing on fulfilling the tasks and forget about the harmonistic of the organisation team. Social awareness (staff and self), organisational integrity, emotional intelligence, conflict management and collaborative teamwork are important factors for successful organisation management. Moreover, issues relevant to conflict and disputes, requirements conflict, and power are strongly social, subjective, and qualitatively understood and resolved. Emotional and behavioural uncertainty will remain an issue even for management or social-centric approaches, however, some practices might also mitigate any emerged discarded behaviour (Cummings 1978). Some socio-technical practices to increase distributed organisation intelligence can be suggested, as follows:

- Sharing the organisational goal in multi-levels of collaborative business network, and with internal employees/workforce
- Sharing a common understanding of goals and objectives among all stakeholders
- Involving all employees including workforce at all levels in some sort of strategic design and implementation input (voice heard)
- Understanding workforce/employees' needs and aligning them with organisational strategic goals
- Incorporating individual employees' intelligence in strategy improvement
- Rewarding employees by attempting to meet their goals
- Ensuring overall life quality and wellbeing (professional, personal, environmental, etc.)
- Considering the wider community welfare and wellbeing while achieving organisational goals including responsible innovation, research and development
- Consider global resources as shared pool that can be utilised to achieve sustainability
- Considering deployment of recent advanced technology and practices to improve both work performance and workforce wellbeing
- Deployment of practices and mechanisms that increase governance, control and social responsibility (e.g. blockchain for distributed ledger)
- Considering the deployment of advanced technology to improve social and technical integration (virtual reality, augmented reality, cyber-physical systems, mobile apps, wearable technology, Internet of Things (IoTs), etc.)
- Move repetitive tasks to machine and enhance collaborative decision-making between human and computer
- Adopting advanced data analytics tools and technology to enhance services to all stakeholders, also to identify and sort urgent socio-technical issues in the real time (machine learning, artificial intelligence, deep learning, etc.)

- Use AI to supervise and monitor other technical systems, ultimately, the other AIs (machine-to-machine control). But also, to analyse and interpret large data sets in the real time.

5 Using STS Enterprise Modelling Framework for Modelling the Healthcare Scenario

Understanding the goals and objectives within the hospital and with the stakeholders in the complex healthcare network is crucial. Goal model should be developed to map strategic, tactical and operational goals all together with IS design and development. Consequently, the goal model should be shared and agreed on with the other stakeholders in the network who own part of the shared capabilities and services. Understanding and aligning these goals will offer an early indication whether or not some stakeholders have unmatched goals toward better communication and distributed decision-making on what best can be done and this can come from both staff in the operational level or from the external stakeholders. On the other hand, the hospital will take a drastic approach toward social responsibility and the way such as costly IS project could bring in return patients a return value. Moreover, the new IS solution should address sustainability through establishing sustainability goals that should be cooperated to the stakeholders' goal model.

The hospital might decide to make use of external capabilities whether it is domestic or global to achieve their goals. Which in this case they have decided to make use of Siemens' capabilities as a strategic partner. Yet the capabilities model should be communicated and agreed on by developing a shared capabilities model defines clearly the roles and responsibilities of each party. Contingency plan should be developed as in case if Siemens fall shorter on delivering their responsibility. Responsibility transferring should be captured by the enterprise model, the contingency plan should take into consideration the capability and the corresponding resources requirements which must be in place to offer some sort of tactical agility to the hospital.

Empowering staff to have sense of ownership by delegating responsibilities and share decision-making on their own tasks should have been done using a transformation roadmap. In early stage of the development, the management should work with both of the hospital and stakeholders to understand the proxy of communication between both organisations, which will lead to increase team cohesiveness. In addition, the management should communicate to the team the time when they should move to the new system, a potential reward system should be communicated to the staff affected by the transformation. Organisation model defines all roles and responsibilities of the agents should be developed and mapped to the rule and decision model. The domain ontology model should be shared to make sure all stakeholders have common understanding of context of the project. All key stakeholders involved in the design should be able to access the enterprise models and offer feedback or amend according to their privileges.

The healthcare environment could also benefit from the IoTs and cyber-physical systems, which can greatly automate large number of the manual or semi-automated processes. The current focus of the project is to create digital healthcare collaborative services that utilise emergent IS trends including intelligent systems. All to help in decision-making process, taking advantage of the large amount and types of data that can be captured by sensors and digital devices placed in both houses, hospitals and care-houses.

5.1 The Conceptual Model

As expressed by the hospital's board of directors, the implementation will make use of emergent information systems such as cloud computing, analytics, intelligent system and components that can be imported through the network using APIs (Figure 9).

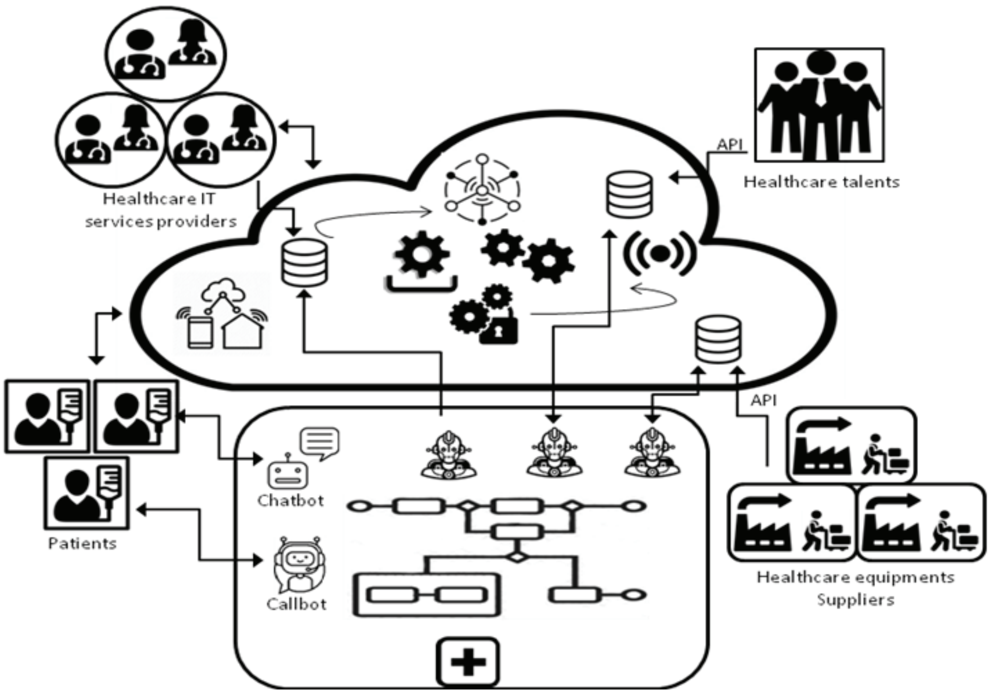

Figure 9. Target Deployment Environment (Conceptual Model)

While well-established enterprise systems will be sensibly acquired as commercial-of-the-shelf such as ERP, CRM and SCM, there is an increased need to bridge functionality gaps of these systems by new add-ons that can be acquired or develop using modern practices. For instance, Supplier Relationship Management (SRM) application enables supplier to update their offering directly into the system of their customers. Using the technology might be overwhelming and time consuming for suppliers, typical supplier will server hundreds of customers and if all customers have either SRM or use traditional supply-customers practices. A new approach to overcome this challenge is using APIs that connect customers' applications with the supplier's application where supplier needs to update their offering (products, services, prices, quantities) and customers use the API to retrieve data in real-time. Another example, Facebook now allows the creation of chat-bots (which can be further developed as avatars by adding more data integration through APIs and intelligent analytics). The current functionality of chat-bots is simple: when a user sends a message to a hospital, the hospital's chat-bot answers the message. The user cannot tell the difference, as the chat-bot uses artificial intelligence and deep learning to understand natural language. A patient may realise that the call-bot s/he is talking to is not human only if it does not answer in a human way. A chat-bot can lead patients to provide answers which are in the bot's interest and which could lead the discussion. When patients or customers ask for a service, an avatar can inform them whether the service is available on social network platforms or not. For example, when a patient asks whether the temperature in a certain place would be harmful to her, the avatar checks both the temperature (in real time) and the patient's state of health and recommends whether or not she should avoid that place. When a company requires new IT services, they are not necessarily looking to develop them from scratch, as other options might be available either free or for a small charge on the Internet, and all they need is to use API to hook up with that service. P2P communication can be presented for example in Patient-to-Patient communication to form a support network. A hospital can communicate with another hospital to form a recommendation network. A person can connect to a thing to request data or analysis on a particular topic, for example forming an allergy network. It is also possible for a thing like an expert system to connect to another thing such as a biometric sensor to get data to help diagnose a patient's condition. Hospitals can have ambient sensors for automatic temperature control, life support machines can have RFID tags for better tracking, and 'smart wrists' allow the real-time transmission of patients' vital signs to appropriate recipients. Distributed data storages on the cloud can help in reducing the upfront cost, scalable with high potential saving of the computing infrastructure and can be easily accessed from any locations with average internet connection speed. Moreover, to increase transparency and interoperability in overall health and compliance aspects, a distributed ledger technology can be implemented within the business applications platform to ensure that the control can cascades and information and progress ascend between different organisational levels and cross-organisational activities. Government bodies should also be granted an access to the distributed ledger, likewise public should be able to have an access on part of the transactions and medical data.

5.2 The Goal Model

In designing the complex healthcare network, we need to model the goals and different perspectives of interaction of all the stakeholders involved in the network. The goal model will establish the intentional elements of forming the healthcare industry network for the multi-partner environment depicted in our scenario. In the goal model shown in Figure 10, we consider the main goals associated with the various stakeholder interactions. Focus is applied to the customer-specific service requirements, in particular the hospital, suppliers, talents (i.e. potential new recruits) and patients' goals. It can be seen that the individual Social Actors (e.g. Supplier, Talent and Patient) have their own unique goals and that they interact with the Technical System in order to fulfil their respective goals. Similarly, the hospital has its own goals which in effect represent the business drivers for deploying the new technology as part of their technology modernisation program. The goals are fulfilled through the implementation of predefined Tasks and Business Processes within the organisation-wide environment, such as through the work-based interactions between Hospital staff or Divisions/Work Groups.

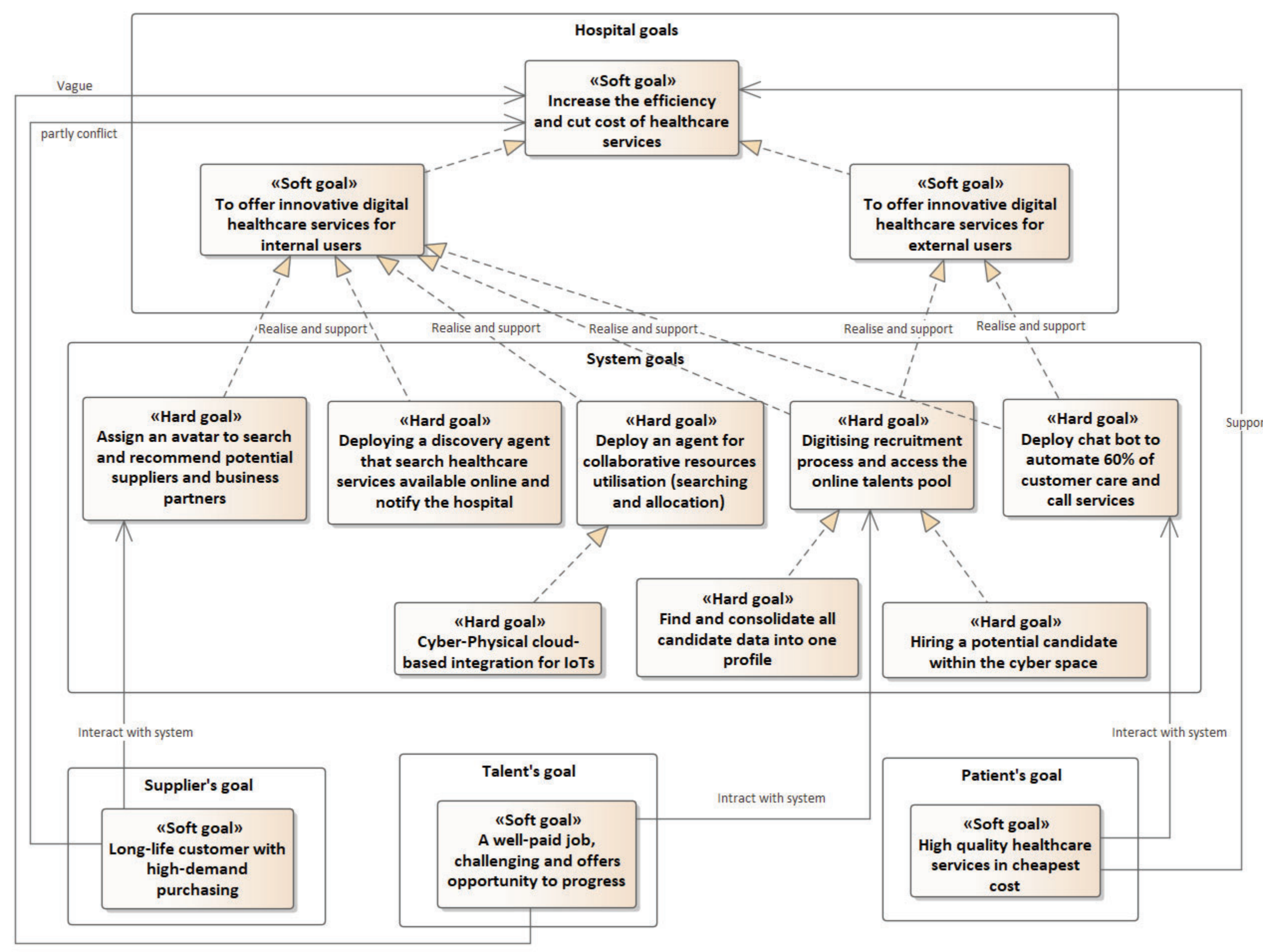

Figure 10. The Healthcare Organisation Goal Model

Information system platform act as a mediator between the hospital as an owner and the recent of the stakeholders as consumers. The complexity lies in the sensitivity of various actors' goals matching and mismatching where typically a certain level of compromising is required to satisfy stakeholders and achieve modernisation efficiency goals. We conjecture that the multi-partner environment within which the Technical System is being implemented, has the potential to lead to significant conflict between the Human Actors from the various organisations (e.g. Hospital, Prime Contractor, ERP Software Vendor, and Niche Vendors). For instance, task conflict may arise due to differences in opinion of how the various technologies should be designed and implemented; process conflict may arise due to overly bureaucratic administrative processes within the project implementation, or due to poor change management across the hospital, including training on the new systems and processes; and relationship conflict may arise due to interpersonal differences between the staff from the hospital and the different third parties

5.3 Organisational Model

The Organisational Model in Figure 11 shows the different Divisions within the hospital and their work-based interactions with external stakeholders. Typically, all Divisions report to their Executive(s) and ultimately the Hospital Board of Directors, with the Board being accountable for the Divisions adhering to the governance standards and procedures of the Hospital, which are implemented to ensure compliance to Government and Regulatory Body policies and regulations.

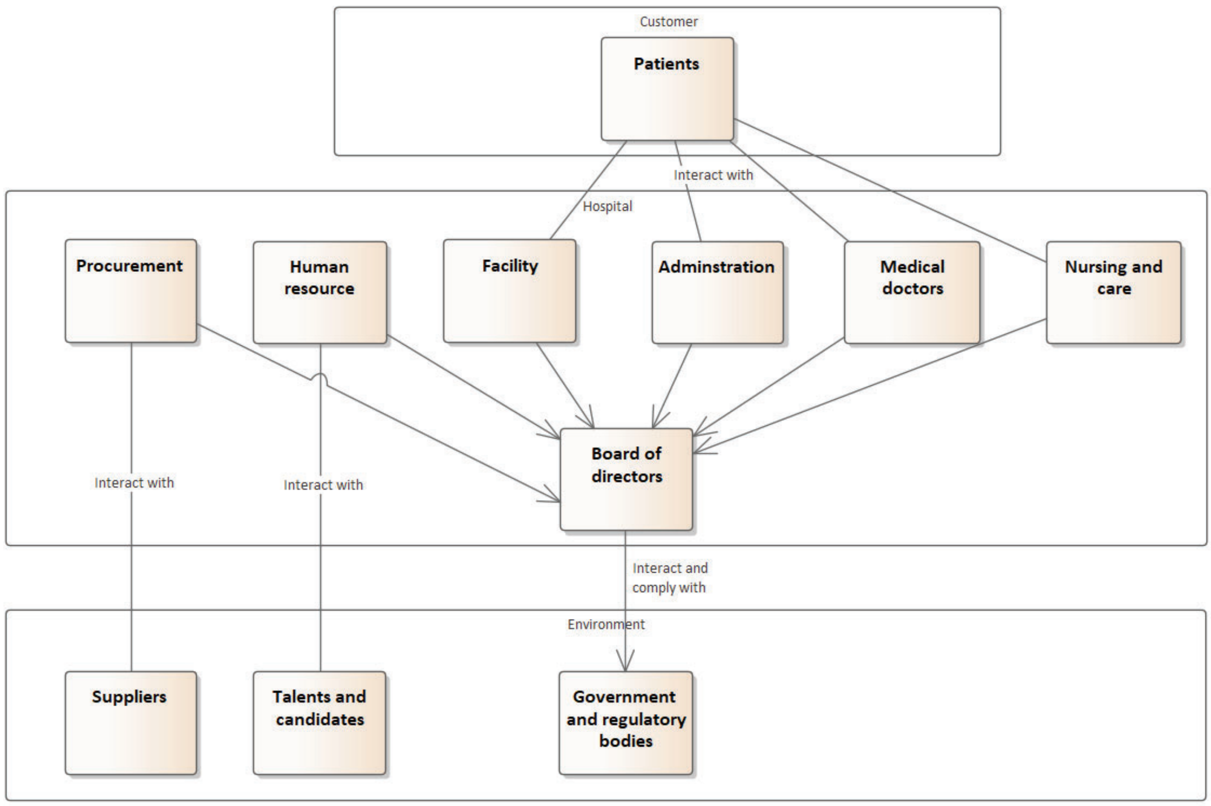

Figure 11. Healthcare organisational Model

The model shows the high-level organisational structure of the hospital and their interactions with external stakeholders (patients, suppliers, regulatory body, and talents), further detailed organisational hierarchy, responsibilities, accountabilities and liabilities in both team and individual levels.

5.4 Domain Model

The Domain Model represents an ontological map of the concepts and facts of the multi-partner healthcare industry network within our scenario. Due to the number of stakeholders involved and their various interactions between each other and with Technical systems, this model can quickly become large and complicated. For illustrative purpose, Figure 12 provides a high-level fragment of our Domain Model, which highlights the various relationships that the Actors (i.e. Patients, Talents, Equipment Suppliers, and Healthcare Staff) have with the Hospital and how they interact with the Digital Systems.

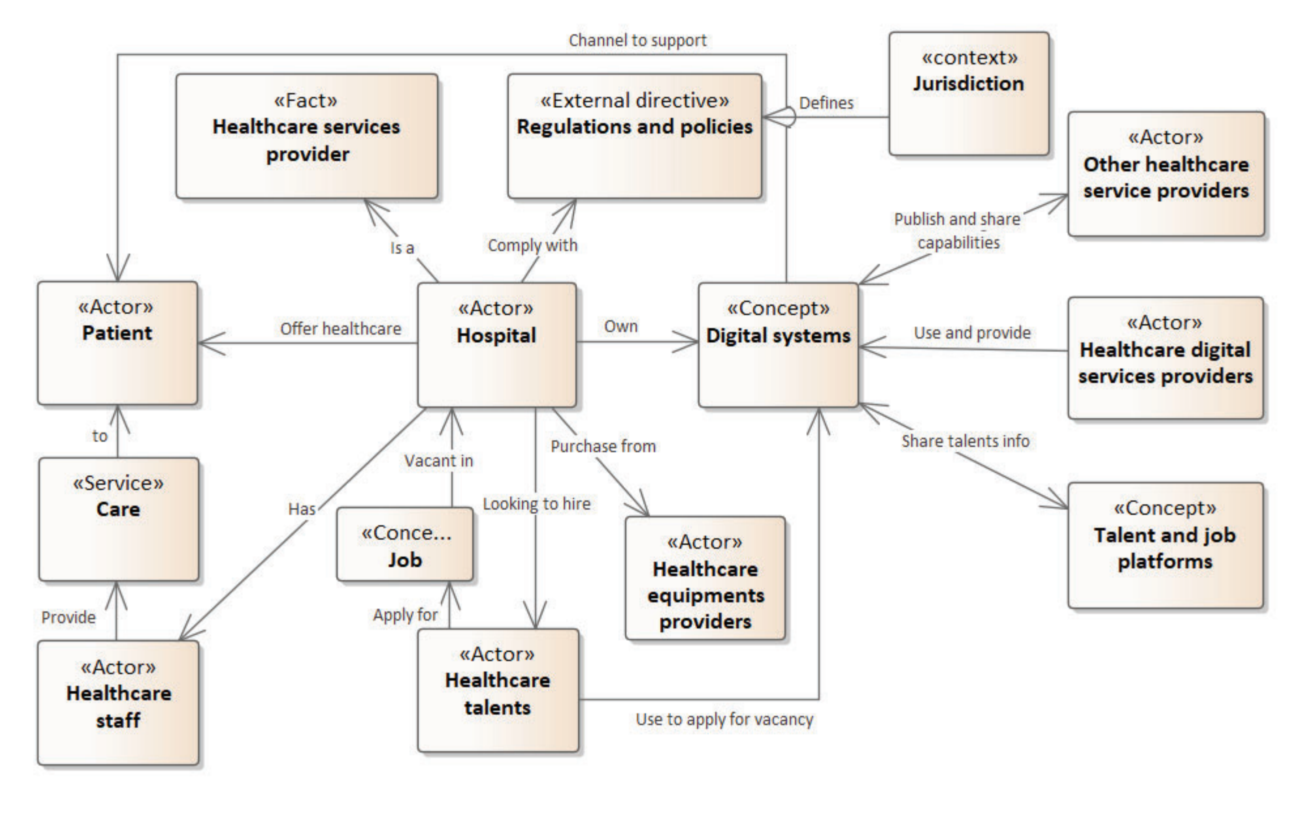

Figure 12. Domain Model

Further elaborations of the directives e.g. external regulations and guidelines or internal policies and rules is presented in Rule, Decision Model. The fragment shows limited factual elements and their relation with other concepts.

5.5 The Agent Model

This model presents all the stakeholders, termed Agents, who may be social or digital, and are involved in the socio-technical healthcare network. The model is focused on two elements, which correspond to the types of actor and the role(s) that they may play. The relationships between the actors and their associated roles are also captured, which is illustrated at a high-level in Figure 13.

Agents also can be individuals e.g. patient and talent, or organisations e.g. HC equipment's provider or digital services providers. Hospital invests in automation for increasing efficiency and reducing cost, efforts made by organisations in searching and approaching talents, IT services, suppliers, and ultimately dealing with the increasing number of patients due to the increase of life span, increasing population, pandemics, and healthcare cost cut. Utilising artificial agents is very crucial to deal with the neverendingly increase of demand. Intelligent technologies that utilise logic, natural language processing and Machine Learning (ML) are maturing and increasingly adopted by different enterprises. It has been noticed that social agents are increasingly worried about losing their jobs to intelligent systems, however our experience with call-centre automation shows that experienced call-centre agents and physicians became a valuable source for designing the chatbots and callbots, with skills uplifting and ease-of-use of modern tools that enabled social staff to be the main designers and maintainers of the digital agents.

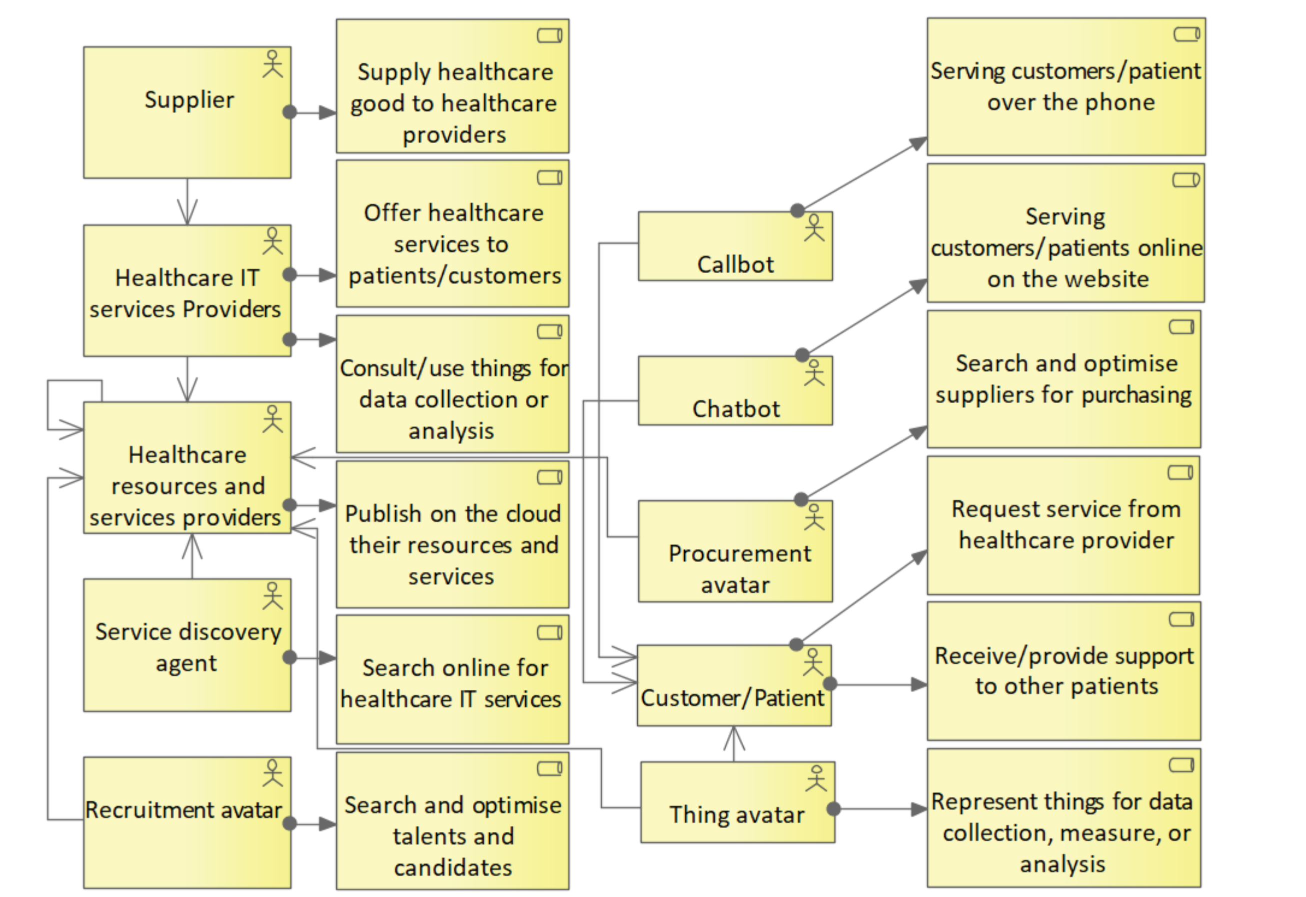

Figure 13. The Healthcare Agent Model

We postulate that the Socio-Technical System involving the various Technical Systems, Virtual Agents and Human Actors, also has the potential to introduce conflict. Furthermore, due to the complexity associated with the Technical-Technical, Technical-Human and Human-Human interactions, we believe that the dynamics of the Socio-Technical System may give rise to a number of feedback loops (positive and negative feedback) with respect to conflict (task, process and relationship), which can result in complex emergent behaviours at the enterprise level. Finally, we conjecture that these complex Socio-Technical System dynamics can be regarded as a Cybernetic System. Chat-bot and call-bot language must be designed in a way that show understanding, sympathy and soft tone as they correspond to patients who are under stress, pain and difficult time.

5.6 The Process Model

The process model uses the UML sequence diagram notation (OMG 2007) to define the interactions between all of the stakeholders involved in the sociotechnical healthcare network. Our example process model (see Figure 14) shows the typical process logic that is followed to deliver the services and artefacts for the healthcare industry network as defined within our illustrative scenario.

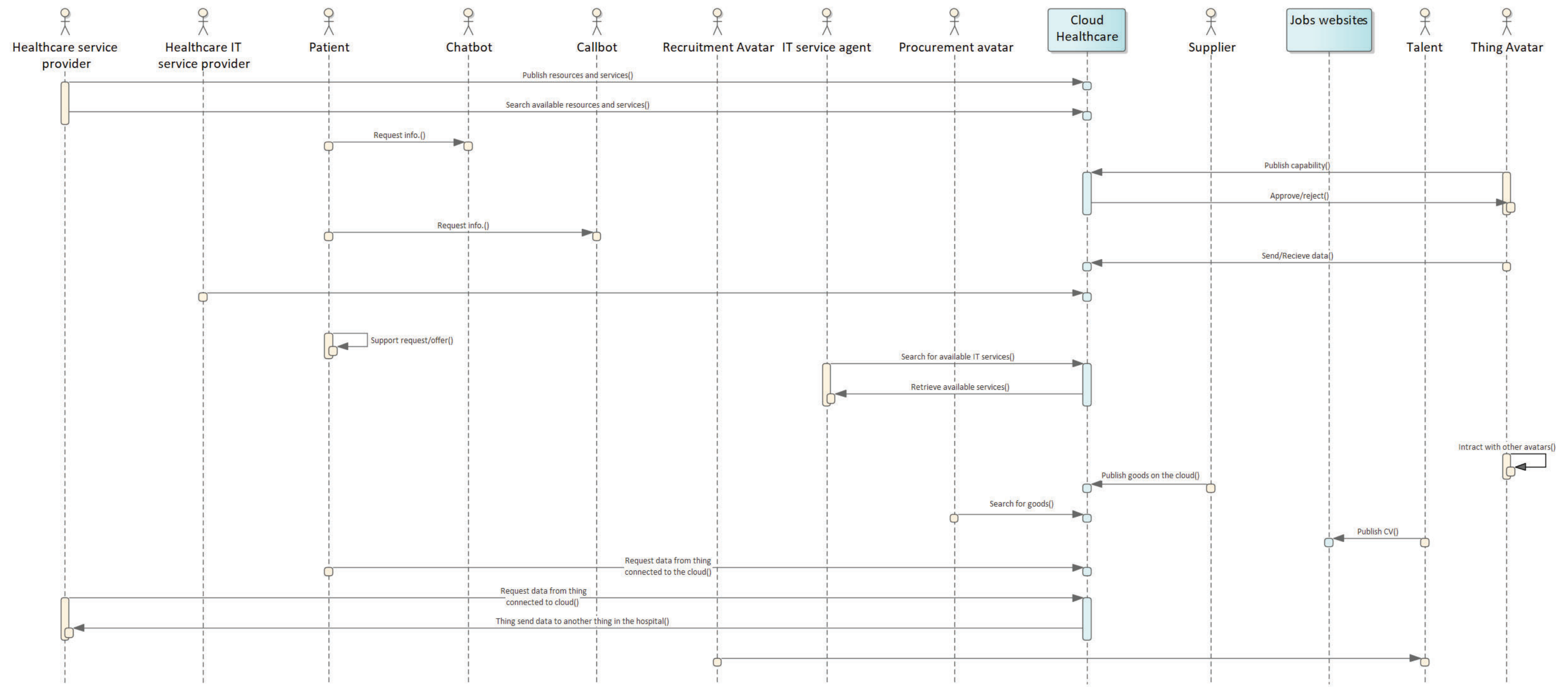

Figure 14. The Healthcare Process Model

5.7 The Resource and Capability Model

The resource and capability model defines the resources and capabilities that need to be established in order to facilitate implementation of processes, interactions between Actors, and delivery of the required services. The capability model presented in Figure 15 shows the internal and external capabilities that are required to build the Socio-Net of Things platform in our healthcare industry network scenario.

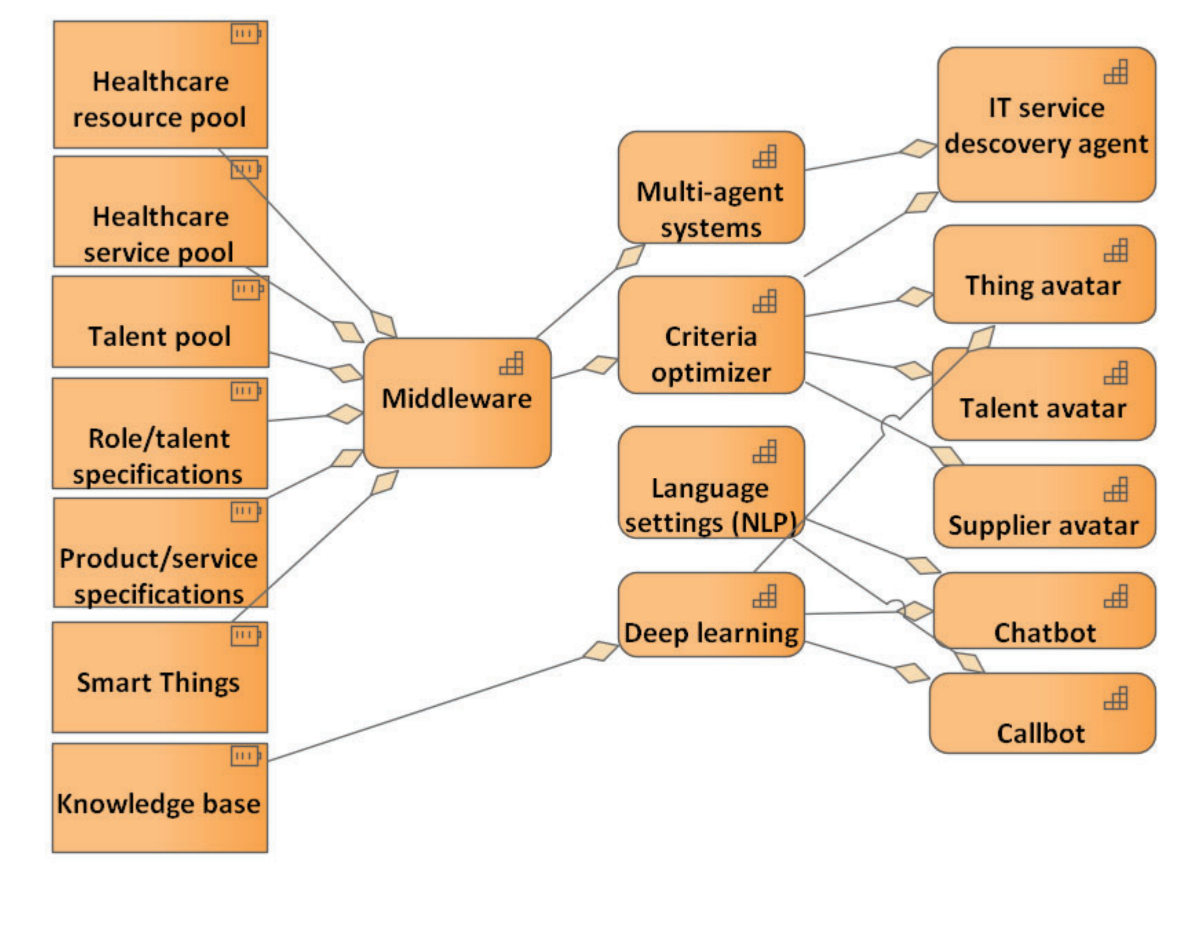

Figure 15. The Healthcare Capability Model

The Model focuses on the technical capabilities, from left to right, the model describes the technical and information resources that the hospital is going to utilise to build level 1 capabilities which will be aggregated further to develop level 2 capabilities that are ready to participate in the workflow.

5.8 The Event, Rule and Decision Model

The event, rule and decision model captures the governance aspects of the network interactions. Table 4 provides a section of the rules and decisions relevant to this case study.

Table 4: Section of the Event, Rule and Decision Model

Rules	Related events	Decisions needed
Healthcare service provider must comply with ethical, moral and quality standards	Service request Service provision	List of complex acts and ethical practices to consider
In patient - hospital interactions, forward calls to human agent only when bot cannot handle the request	Patient call	When and why to transfer the call
Social avatar can be activated and deactivated by social owner	Present or absent from cyber space	When and why to switch on/off the avatar
Recruitment avatar must not consider gender, race, age or sexual orientation in talent selection	Vacant position	Capabilities-based shortlisting. Including the analysis of qualifications, experience and attitude.
Suppliers and IT services providers must provide only certified services	Request and provide IT service Request and provide equipment	Purchasing decision: approve or reject
Smart IoTs allowed on the platform should be secured and verified	Request connection and data (send or receive)	To connect or deny connection of the smart thing

5.9 The Technology (IS Service) Model

The interactions between actors have the aim of exchanging artefacts and services. Some of these services are offered offline while others are digital IS services. Table 5 shows the IS services that are offered for healthcare actors based on the available capabilities:

Table 5: The Components of IS Service

IS service	Provider	Consumer
IT service publishing	Health IT service provider	Healthcare service organisation

IT service administration and billing	Platform admin	Health IT service provider
IT service search engine	IT agent	Healthcare organisation (IT)
Talent search engine	Recruitment avatar	Healthcare organisation (recruitment)
Talent skills and resumes publishing	Healthcare organisation	Healthcare talents
Self-study Learning Portal	Health IT service provider	Healthcare organisation staff
Equipment publishing	Healthcare equipment provider	Healthcare service organisation
Equipment search engine	Procurement avatar	Healthcare service organisation
Handling patient requests	Chat-bot/call-bot	Patient
Patient support	Chat-bot/call-bot, patient	Patient
Measurements, recommendations, updates	Things/ avatars	Patients, Healthcare organisations

6 Reflective Discussion

The illustrative Scenario shows the importance of considering socio-technical aspects before, during and after the EM initiative development and execution. Enterprise modelling and, similarly, socio-technical systems are not bound by the enterprise system, rather it influences and is influenced by the whole enterprise ecosystem. Clearly, the enterprise progression through the socio-technical streamlining is greatly influenced by the type of technology and information systems deployed by that enterprise. Systems for portfolio management, dashboards, monitoring, control, advanced data analytics, decision support systems, rapid integration and development through the APIs and DevOps will increase the efficiency and effectiveness of the socio-technical aspects. To sum-up, a process that intertwining enterprise modelling and STS analysis and design process is shown in Figure 16. It includes three major phases (Design-time, Run-time and Adjustment time). **Design-time** is where the analysis and design of the enterprise takes place. It includes activities relevant to enterprise modelling, where the seven models can be used and the interrelation between these models is expressed. After the enterprise models have been designed, an assessment against the enterprise's internal and external factors should be carried out to ensure that the enterprise models correspond accurately to the programme objectives. Design-time phase should also include an early consideration of the socio-technical aspects in optimum configuration to harmonise between both technical and social aspects. **The Run-time** phase will include a day-to-day socio-technical aspects consideration and reassessment. The assessment should take two stages: a) assessment of the harmonising of the socio-technical aspects between each other, and, b) assessing the socio-technical aspects against the designed enterprise models and both of the already developed or underdevelopment information systems. In the **Adjustment-time** phase, the evaluation of both internal and external factors should be continuous during the programme. If needed, after evaluating both internal and external factors including socio-technical design requirements, a refinement of the enterprise models or information systems will be taken, due to the limitation of insight on how the enterprise, environment and socio-technical aspects will evolve after starting the programme.

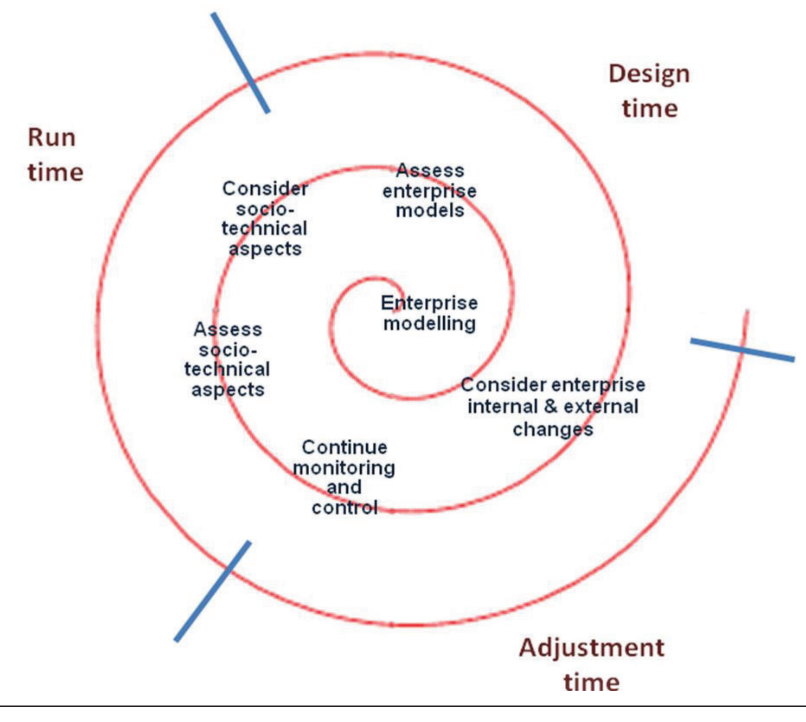

Figure 16. STS Analysis and Design Process

The implications of this work for professionals involved in the design and development of information systems can be demonstrated in bridging the gap between two important research areas of information systems analysis and design, namely enterprise modelling, which can systematically and semantically be mapped to IS development, and socio-technical systems approaches for designing organisation work including IS. It can enable both mechanistic and organic enterprise evolvement and keep uncertain factors under control by having continuous assessments and evaluations, particularly for the socio-technical aspects. Thus, more collaborative and continuous enterprise designs are required; this argument confirm with other researchers' view (Jarke, Loucopoulos et al. 2011) who argued that there is no complete design, requirements are always intertwined with the context, and design artefacts gradually evolves with the changing ecology. We are heading toward different open socio-technical system that has evolved differently, and in speed rate toward more corporate social responsibility, collaborative value creation and delivery, distributed decision-making, responsible research and agile enough to deal with the change rate thus to ensure sustainability. Thus, social optimisation and fulfilment is as equally important as the procedure and technicality of the work for the enterprise success. We recognise the limitations of this work in demonstrating how emergent technologies can balance between control, flexibility and transparency in social system. Particularly, how it can promote satisfaction and motivate progressive sustainable socio-technical integration. While this paper focuses greatly on design-time, to answer these questions we plan to further extend this research to cover run-time and adjustment-time.

7 Conclusion and Future Work

The current digital landscape has made socio-technical systems more complex. This is not only due to the advancement of technology; it is also because of the increasing interaction between various social agents. Dealing with socio-technical complexity becomes necessary for enterprises' success where companies are compelled to react to wider systems changes in their business environment. Continuous adoption of new information systems must cope with current business demand and expectations. Enterprise modelling practices introduced three decades ago were proved successful and crucial in offering enterprises the necessary insight to streamline their information systems development. However, these still have limitations and are subject to failure in some businesses due to differing reasons e.g. the balance between deterministic imperative design and dynamic declarative design that meets business evolution. In this paper we focused on depicting STS theory to these practices, however many aspects could not be mapped to a model and wider consideration of STS aspects was needed. Here we have presented an enterprise modelling model based on seven models that are driven from the socio-technical system theory. The paper also discusses the socio-technical aspects that still cannot be handled by traditional enterprise modelling techniques, and reveals the need for managerial, social and qualitative practices to deal with these aspects alongside the enterprise modelling techniques. A combination of both can be considered a powerful approach to tackle socio-technical analysis and design and can actually overcome the limitations in each approach. We illustrated a Scenario that highlights the importance of having both practices fused together. One of the main limitations of this work is relevant to the illustrative scenario, as it did not use the models to capture the declarative aspects, which requires either post-implementation study or action research to better capture the socio-technical dynamic interactions and their impacts. It is suggested that when abstract models are sound, a potential application using action research will potentially demonstrate a robust validation. Expanding this work in future research could be through using a case study to implement the EM models that are enhanced with case-relevant social and managerial practice (behavioural aspects). In addition, further examination in action research settings is deemed possible. Further formalisation of the behavioural aspects is also deemed possible and the models need more formalisation to create metamodel towards creating tool and methodology for STSs practices through the EM discipline.

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