A methodology for modeling healthcare teams and an evaluation of Business Process Modeling Notation as a Modeling Language

By

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Abstract

Whether it is offering services, delivering solutions or driving innovations, team work has been a hallmark of efficiency and effectiveness in various industries. The healthcare industry is not left out as its service delivery process involves numerous interfaces, information flows and patient hand-offs among professionals with different educational training, differing knowledge levels and possibly working from different locations as well.

As healthcare delivery evolves to being more patient-centered, so does the team settings as well, becoming more collaborative. Such changes also translate into a need for support systems to evolve to be able to provide support for the extent of collaboration that would be needed. A framework is needed to guide in the development of such systems. However, due to the varying needs of patients, team types and make-up would generally differ, so we explored the different types of team settings studying what they entail based on their various degrees of collaboration.

We therefore present in this thesis a model of team based concepts, an ontology formalizing the model, team based scenarios designed using the ontology and then application of the

scenarios to test the ability of BPMN (Business Process Modeling Notation) to model healthcare teams.

To **God Almighty** who in His infinite mercies and wisdom brought me this far.

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Nomenclature

Acronym	Definition
BPEL4WS	Business Process Execution Language for Web Services
BPMN	Business Process Modeling Notation
EHR	Electronic Health Records
EPC	Event-driven Process Chain
HTTP	Hypertext Transfer Protocol
IT	Information Technology
MD	Medical Doctor

OASIS	Organization for the Advancement of Structured Information Standards
OS	Operating System
OWL	Web OntoLogy
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
W3C	World Wide Web Consortium
WHO	World Health Organization
WSDL	Web Services Definition Language

XML	eXtensible Markup Language

Chapter 1: Introduction

1.1 **Problem statement**

Medical science has witnessed a great deal of improvement in recent times, thanks to tremendous technological advancements over the years. Today, medical science can identify, treat and track the progress of diseases unknown 50 years ago with tools that have become more precise and easily used by patients each passing year. On the other hand, there's been a steady rise in chronic and complex illnesses; such increasing complexity requires a different approach to care delivery.

Although the reasons have not been clearly highlighted, literature has suggested possible strategies to alleviate the problems and probably re-build and re-design the system. The Institute of Medicine (IOM) in its 2001 publication- "Crossing the quality Chasm: A new health system for the 21st century" highlighted that supportive payment and regulatory environment, facilitation of patient-centered teams and high performing patient-centered teams would give rise to a safe, effective, efficient, personalized, timely and more equitable healthcare system.

It also highlighted some challenges imperative for a redesign that will lead to positive change, which include:

- Reengineered care processes
- Effective use of information technologies
- Knowledge and skills management

- Development of effective teams
- Coordination of care across patient-conditions, services, sites of care over time.

Advances in healthcare has brought some changes and complexities which cannot be catered to by older and previous structures where practices are highly individually driven (professionals working separately as silos), (IOM, 2001; Chesluk and Holmboe, 2010) and multidisciplinary infrastructure is lacking especially in chronic illness conditions, such complexities tend to reduce healthcare safety.

While we highlight the seemingly inadequate use of technology in this regard, it is however pertinent to mention that the same technology holds remarkable potentials for transforming (re-building or re-designing) the industry and perhaps such transformation is impossible without the support of technology (Southhard P. *et al.*, 2000). This goes to underscore the fact that it is not about the technology but the way and manner in which it is put to use.

According to Oandasan I. *et al.*, 2006, a healthcare system that supports effective team work can improve the quality of patient care, enhance patient safety and reduce workload issues that cause burnout among professionals.

Improved teamwork and collaborative care have been shown to enhance performance in many aspects of healthcare, leading several governments to identify the need to implement teamwork while also calling for improved collaboration among healthcare professionals, (Oandasan I. *et al.*, 2006). A good example is the Canadian government which has emphasized access to team-based care (Kelly and Bill, 2010).

However, the recommendations suggested by The Institute of Medicine in its 2001 publication- Crossing the quality Chasm are a challenge to implement as healthcare is largely built around individual tasks and silos, which is clearly unsuitable for the level of collaboration and integration the modern healthcare system needs to provide coordinated

care across distributed settings. Since healthcare teams comprise interdisciplinary professionals that make complex decisions and require the co-ordination of different processes and information sources often across distributed settings, collaboration is crucial.

We seek to thoroughly understand teams in its entirety (what they comprise and how they function) in a bid towards employing technology to re-design the system.

1.2 **Thesis Motivation and Contribution**

The advantages brought into the healthcare industry from technology in recent years have not been adequately suited to cater to the needs of healthcare professionals working in teams. A key reason for this is the fact that there is no comprehensive model on which such technology can be built. Yet such development and improvements in support systems for teams holds promises for better managing and delivery of care.

This research aims to address the above shortcoming by creating a methodology for modeling healthcare teams.

This study will contribute to the body of knowledge in the following ways:

- Highlighting the types of healthcare teams and dependencies within different team types
- Providing a mind map which depicts categorization of entities for healthcare teams
- Formalizing the mind map in an ontology
- Evaluating the suitability of BPMN (Business Process Modeling Notation) to adequately model the healthcare team entities

The research attempts to answer the following questions:

1. What are the types and dependencies of healthcare teams?
2. What are the challenges associated with modelling processes of collaborating teams?
3. Can BPMN satisfy the modeling needs of the different team types as regards their dependencies and the processes involved?

The figure (fig. 1) below gives a graphic presentation of how the research questions map to the contributions of this thesis. These are all expounded upon in the rest of the work. The progression show the phases through which the work would evolve.

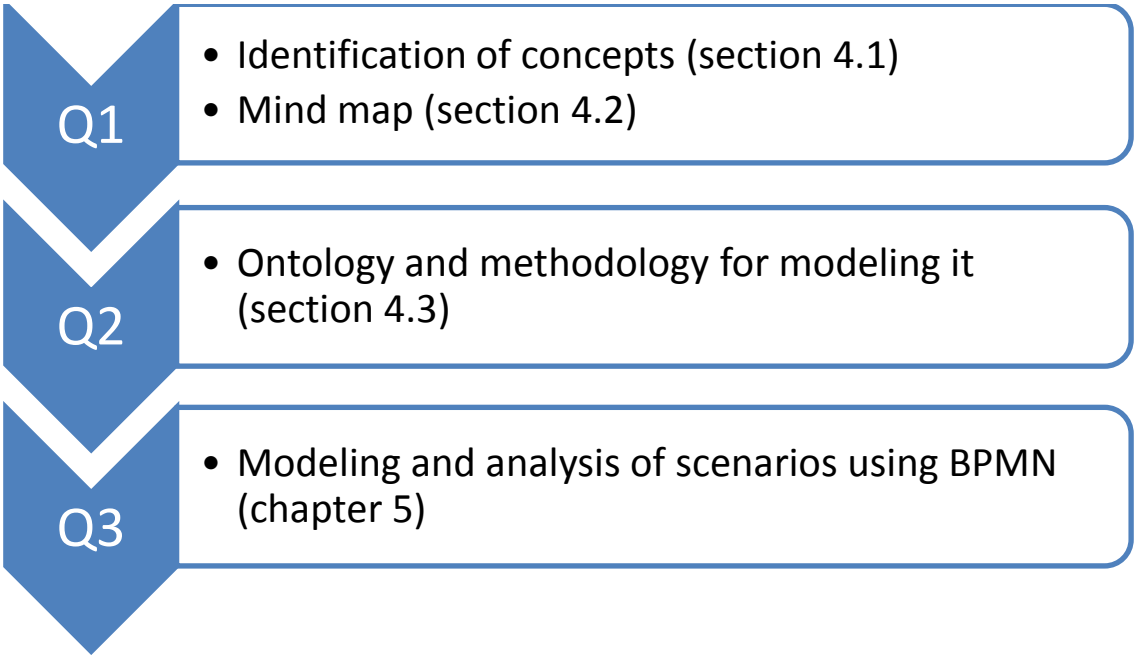

Figure 1. Contributions matching research questions

1.3 **Methodology**

As healthcare delivery evolves from being delivered by professionals working in silos to more interactive settings, this emphasizes that more communication and collaboration among healthcare professionals is needed now than ever before. However, a great deal of importance lies with how well support systems are built to support such collaborative team interactions.

Design science will be used and in summary the following steps will be taken:

- Extensive literature review on teams; definitions of the term, need for teams, challenges, types, as well as other related factors.
- Identification of generic team concepts; before we can develop a model of healthcare teams we require a thorough understanding of the processes and information needs of healthcare teams, what comprises teams, the type of exchanges, processes (and what constitute processes), formal and informal relationships, influence of the varying knowledge and skill levels and other possible factors in such scenarios. This will be achieved by an extensive literature review including case studies.
- Study of teams and highlighting how they interact with one another as well as other influencing factors; after team concepts are identified, further work will be done as to understand how collaboration takes place as well as its possible effects. This will be done by using concept maps to show the relationships between concepts derived from literature.
- Develop the ontology to formalize the mind map.
- Development of BPMN models using scenarios developed from the ontology that highlights the relationships for the different team types.

- Assessment of the suitability of BPMN for modeling healthcare teams; recommendations to enable BPMN to better model healthcare teams.

1.4 **Thesis Organization**

This thesis begins by presenting the literature review in chapter two continuing with an explanation of the methodology used in chapter three. Chapter four discusses the various stages and applications used in modeling, as well as the results. While chapter five features some modeling scenarios based on the ontology in an attempt to study how well BPMN supports the modeling of characteristics for different types of teams. Conclusions are presented in chapter six.

Chapter 2: Literature Review

As expressed in the previous chapter, the healthcare industry has witnessed a lot of changes in the last few decades. Most of these changes in care delivery have been facilitated by technology.

In this chapter, we first briefly introduce the word ‘healthcare’, we also elaborate on the term 'professional(s)' and what definition it holds in this research. Next, we go on to explain the concept of teams and how it relates to collaboration. We also look at the types of teams in healthcare based on the degree of collaboration that occurs, followed by a brief glance on how teams function in other industries, what similarities occur and what lessons can be learnt. Afterwards, we look at how information technology has and is being employed to support information and communication systems in healthcare. Then, an introduction is given on mind maps and ontologies which are discussed in details in chapter four. Finally, some of the gaps in existing work are presented.

The literature was acquired using various academic search engines, databases for journals, and articles (majorly on Management Information Systems- MIS, computer science and healthcare). Some of the search terms used include the following or the combination of any of the following: ‘team’, ‘teams’, ‘health’, ‘healthcare’, ‘groups’, ‘teamwork’, collaboration’, ‘processes’, ‘management’, ‘design’.

2.1 **Healthcare**

Health according to the World Health Organization (WHO) is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO- Alma-Ata, 1978). Healthcare involves activities that are endeared towards sustaining and maintaining health.

Just like other industries, the healthcare industry involves several processes in its delivery.

2.2 **Healthcare Professionals**

The term '*Health care professionals'* has been used synonymously with other terms such as healthcare workers, healthcare providers, healthcare practitioners. But, according to WHO (2010), healthcare workers are all people whose main activities are aimed at enhancing health. They include the people who provide health services -- such as doctors, nurses, pharmacists, laboratory technicians -- and management and support workers such as financial officers, cooks, drivers and cleaners. Whereas healthcare professionals as defined by WHO in its Classification of health workforce statistics- include health professionals who study, advise on or provide preventive, curative, rehabilitative and promotional health services based on an extensive body of theoretical and factual knowledge in diagnosis and treatment of disease and other health problems. They may conduct research on human disorders and illnesses and ways of treating them, and supervise other workers.

2.3 **Teams**

2.3.1 Concept of Teams

The term 'team' has been used loosely both generally and operationally (healthcare inclusive), also there has been several attempts to thoroughly define teams in the healthcare context which itself poses a challenge to studying and measuring the effectiveness of teams as the term is usually been inadequately conceptualized, (Opie, 1997; Schofield and Amdeo, 1999; Katzenbach and Simth, 1993; Oandasan I. *et al.*, 2006).

Although there has been several definitions for the term, most of the definitions given in literature agree on some common factors which include; the variation of the structure depending on the purpose, setting and task, the sharing of common goals and the possession of skills by team members, (Katzenbach and Simth, 1993; Clements D. *et al.*; Saltman D. *et al.*,2007; Oandasan I. *et al.*, 2006).

While the oxford dictionary simply defines the term as two or more people working together, Katzenbach and Simth, 1993 gives a generic definition of teams as "a small group of people with complementary skills committed to a common purpose and set of performance goals".

Cohen and Bailey (1997), gives a more specific one and defines a team as: "a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems and who manage their relationships across organizational borders".

It is noteworthy to mention that the distinction between 'teams' and 'groups' have not been clearly demonstrated in the translation of team structures to healthcare (Saltman D.

et al., 2007). Authors such as Katzenbach and Simth, 1993 and Saltman D. *et al.*, 2007, gave some distinctions between 'teams' and 'groups' such as accountability being individual in a group setting and individual, collective and mutual in a team setting. Also, commitment in a group is said to be individual and shared in a team, while skills may be overlapping in a group, they are discrete for each member of a team.

2.3.2 Teamwork and Collaboration

It is necessary to note that 'teamwork' and 'collaboration' are sometimes used synonymously whereas they are not synonymous. Teamwork is the ongoing process of interaction between team members as they work together to provide care to patients, (Clement D. *et al*.), while collaboration has been cited as a process affecting teamwork (and its outcomes) as well as a major need for effective care management, (Dorr D. *et al.* 2007).

Oandasan I. *et al.* (2006) highlighted that effective teamwork rarely happens where there is no collaboration. That is to say that collaboration plays a vital part in teamwork.

Several definitions of the word collaboration abound in literature ranging from simple generic definitions such as working together (Webster's New World Dictionary), working jointly (Canadian Oxford Dictionary) to more specific ones in interdisciplinary settings and to suitable operational definitions as applicable to healthcare teams.

A review of literatures in healthcare reveals similar definitions for collaboration. Lindeke and Sieke (2005) define collaboration as a complex process that requires intentional knowledge sharing and joint responsibility for patient care.

Wells N. *et al.* (1998) summarized collaboration as the "interactions among healthcare professionals that enable the knowledge and skills of all professionals to synergistically influence the patient care being delivered" (cited in Weiss and David, 1985, p.299).

Another definition given by Houldin A. *et al.,* (2004). defines collaboration as a complex phenomenon bringing together two or more individuals, often from different professional disciplines working together to achieve a common purpose.

2.3.3 Healthcare Teams

A suitable operational meaning would be the one as given by Sicotte C. *et al.* (2002) that what we today refer to as interdisciplinary collaboration corresponds to the WHO's Health Manpower definition of the primary healthcare team: A group of healthcare professionals who share a common health goal and common objectives determined by community needs, to which the achievement of each member of the team contributes, in a coordinated manner, in accordance with his/her competence and skills and respecting the functions of others (World Health Organization- WHO, 1985).

Despite early promotion for interdisciplinary collaboration made in the mid-1970s by the World Health Organization (WHO Alma Ata, 1981), earlier research only focused on physician-nurse relationship (Sicotte C. *et al.,* 2002), but current trend in healthcare delivery involves collaboration among professionals with different specialization.

Moreover, according to Korff M. *et al.* 1997*,* experimental studies have shown a gap between the healthcare services intended to improve outcomes in chronic illness and the care that patients usually receive, the gap being attributed to lack or ineffective collaborative relationships.

Also, research has found a relationship between collaboration, increased quality of care for patients (Fewster-Thuente and Velsor-Friedrich, 2008, Vahey D. *et al.*, 2004), increased satisfaction of the healthcare professionals (Vahey D. *et al.*, 2004) and decreased cost of care.

In spite of the obvious gap to be bridged by collaboration, an extensive literature review revealed that there are no specific models that offer a base for interdisciplinary collaboration (Fewster-Thuente and Velsor-Friedrich, 2008).

2.3.4 Relevance of teams in Healthcare

It is pertinent to note that we do not attempt to study or define the concept of teams or collaboration in its entirety, as the goal of this research is not on the concept itself rather how it affects healthcare delivery and therefore only the aspect that concerns this research would be touched upon.

The use of teams to deal with complex problems can help healthcare respond to challenges it faces as practiced in other industries. Some industries boast of designs and processes that are team centered and could aid the understanding of team-based initiatives and how they are employed in organizations to effectively and efficiently meet the needs of consumers as much as possible, (Pronovost, 2009; Lawrence, 2002).

Studying principles that have been applied in other high-tech, complex industries where daily functionality is team-based (such as aviation and aerospace) and yielded success should also achieve positive results if such structured teamwork improvement strategies are adopted towards healthcare. Also, medical accidents can be prevented leading to improved quality of care when care is provided as a team (Pronovost, 2009).

Teams do not just happen; they work as a result of planning, attention and resources. The right people with constant re-enforcements clearly defined and understood rules, effective communication are some of the needed components, (Lawrence, 2002).

Without teams, work is more likely to be fragmented and more expensive especially for patients with chronic or complex illnesses because the care requirement could be challenging (Spath, 2011). Also, interdisciplinary collaboration (focused on patient's needs) was, and is perceived as the kind of model which enables global and integrated approach to patient care delivery (Sicotte, 2002). Although, the overall outcome of delivered healthcare however would most likely also be affected by other factors such as organizational culture, government policies, physical resources, etc. (Spath, 2011). It is also important to note that teams are not the solution to every medical situation, they are not a panacea. Some situations may be best addressed as by an individual or groups of individuals without forming a team (Lawrence, 2002).

The team tools if rigorously applied to healthcare will improve quality and help build a delivery-system infrastructure into which science and technologies can properly fit as better solutions will only come from better understanding and better design of care processes (Lawrence, 2002) as such transformation is almost impossible without the support of technology (Southhard P.B. *et al.*, 2000). This goes to underscore the fact that it is not about the technology but the way and manner in which it is put to use.

We see a need for healthcare support systems to be able to support the various types of teams accordingly.

2.3.5 Types of teams in Healthcare

There are basically four types of teams identified in literature, they are:

- Unidisciplinary; unidisciplinary teams are mainly individualistic with emphasis based on professional boundaries and roles are highly segregated along these boundaries (Satin, 1994). The professionals involved function independently with a high possibility of unawareness of the other professionals involved in the same case. In this type of setting, communication and collaboration is very minimal.

- Multidisciplinary; in a multidisciplinary team, professionals with different specializations are usually involved in the delivery of care (Frattali, 1993). Similar to the unidisciplinary model, professional boundaries exist. Information sharing and communication on approaches to care delivery may however occur, team members practice relatively independently with respect to goal setting and treatments. Members of the team may meet regularly or communicate in other ways, but they do not share common goals and collaboration is largely parallel (Choi and Pak, 2006).

- Interdisciplinary; in an interdisciplinary team setting, team members are from different professional backgrounds (could be different disciplines or different sub-specialities of a single discipline), they have shared goals and focus on meeting these goals (Satin, 1994). They contribute assessment data and convene to synthesize information and identify issues. Collaboration among members of this kind of team is largely integrated. Implementation of shared goals in care delivery often yields better results than could be accomplished by separate profession-specific approaches (Frattali, 1993)

- Transdisciplinary; transdisciplinary (or cross-disciplinary or pandisciplinary) teams bring in a new dimension and takes collaboration and teamwork a level deeper. In such team settings, role boundaries are often blurred and skills transferred across professional boundaries (Choi and Pak, 2006; Satin, 1994).

It is necessary to note that the differences do not necessarily lie in the team make-up, but in the way and manner in which the professionals share and access information, interact and carry out care processes as well as the working relationship that is formed. Several factors including patient need, availability of resources, and professionals would usually determine what one type of team setting would be preferred over another.

Choi and Pak (2006) highlighted several reasons why teamwork involving multiple disciplines is more desirable, below are some of the reasons given:

- It helps in resolving real word issues
- It helps in resolving complex problems
- It helps in providing different perspectives on a problem
- It also helps in providing comprehensive services such as it is found in healthcare

2.3.6 Teams in other Industries

As with other complex sectors such as aviation and aerospace, nuclear power generation, military, healthcare is typically risky, complex, uncertain, time and location constrained. In addition, differences such as background, area of specialization and availability do play a part, decisions and actions taken could have severe consequences. Healthcare however has additional characteristics making it even unique from other complex sectors as it is subject to stringent government and legal policies in most cases.

Team communications as it is performed in aviation is often proposed as a model for healthcare to adopt. Although, research in aviation and aerospace cannot directly be applied to healthcare as both industries have their different intricacies. Howbeit, lessons

learnt from aviation and aerospace could give valuable insights which can help to better model collaboration in healthcare. An understanding of the similarities and differences between the two types of teams as well as environmental and industrial impacts will provide a guide in applying the lessons (Nemeth, 2008).

Both the aviation and healthcare industries have safety has a major goal, both being high-stress, high-risk environments. Technology has also been intensively applied in building systems which require professionals with different responsibilities, expertise, and information access to work together to make these respective systems work, and in which coordination and collaboration are sometimes completed synchronously and sometimes asynchronously, as decision making could be dynamic (Nemeth, 2008). In addition, literature has shown that teamwork is not only essential but imperative in delivering quality service (Helmreich and Davies, 2004).

The differences between the two types of industries stems out from several factors as well as the very distinction between the types of services provided by both industries. In healthcare, as well as the demand being uncertain, and almost as widely varied as the individuals who demand care, there are more professionals involved in its delivery than in aviation and they often train and practice in their own professional "silos," thereby making communication and cooperation challenging. Also, these professionals interact with a greater variety of devices than in aviation, and the object of their work, the human body, is more complex than an airplane (Thomas, 2006). Finally, regulation of healthcare is more fragmented than aviation in addition to the fact that there is no standardization like aviation where every airplane or flying routine has same or similar settings and routines (Thomas, 2006; Nemeth, 2008).

On the other hand, training, open-communication and collaboration have helped a great deal in improving efficiency and safety in aviation (Helmreich and Davies, 2004). These factors also holds hope for healthcare if adequately applied. In this research we hope to

build a model (having considered all or most of the entities involved) that will assist in building systems which will foster more effective and efficient team communication and collaboration.

2.4 **IT for Healthcare Teams**

Innovations in IT (Information Technology) have the potentials for improvements in efficiency, safety and quality in care delivery in several aspects particularly in supporting information systems (Medpac, 2004; Bates, 2002).

With an increasing drive for better collaboration and communication among healthcare professionals comes a rising need for healthcare systems to be able to support such collaboration and communication among professionals effectively and efficiently (IOM, 2001).

Several IT schemes, platforms and standards have been applied to developing healthcare systems and it is crucial that these systems be built in a way that enhances teamwork (Lorenzi, 1995). Systems and applications such as EHR (Electronic Health Records), EPR (Electronic Patient Records), HIS (Health Information Systems) and others have been developed based on some technological platforms, such as SOA, web services, WSDL, SOAP, XML, etc. However, most of these systems and applications have not been geared towards meeting the needs of healthcare professionals working as teams (Moss J. *et al*. 2007).

In the IOM (2001) publication, a couple of issues to be addressed were identified for a better healthcare system; among them were effective use of information technology and development of effective teams. While IT plays several roles in healthcare, its use to support systems to be used by teams is highly imperative if care is to be effectively and efficiently delivered.

Seeing that literature shows a dearth in the support of teams by existing systems, we seek to develop a methodology as such that would support developing of systems to enhance teamwork. According to Laires M. *et al*. (1995), more attention has to be paid to developing systems which support information sharing between members of multiple disciplines working as a team in healthcare rather than encourage professionals delivering care in silos. Furthermore, current information system applications and their frameworks (such as EHR- Electronic Health Record) are not predisposed towards supporting team-based care delivery but rather unidisciplinary mode of practice (Dorr D. *et al.*, 2007).

Interdisciplinary teams have not been able to adequately manage and seamlessly exchange information as there is no much system support in that regard (Bates, 2002). It also went further to say that improvements in IT would lead to high-quality health information systems that would greatly enhance communication and information exchange among team members. Also, as explained by Burns L. *et al*., 2011, information technology systems built to support teams is necessary to make teams effective. Ghaye (2006) called for a redesign which is needed to better enhance support of teams by IT.

Moss J. *et al.* (2007) highlighted the fact that information technology has not been properly suited to support teams but also emphasized the need for system analysis and design which will enable such systems to adequately support teams. It is in this light that we examine some types of models and how and why we used them in the succeeding paragraph.

We seek to develop a model that will aid the highlighted systems and platforms in being used to build technology that will enhance teamwork as emphasized by Moss J. *et al*. (2007) that increased progress in efficiency and effectiveness of healthcare teams will depend heavily on better system analysis and design.

2.5 **Types of Models**

As mentioned in the previous paragraph, system analysis and design play an integral role in any system development as it provides a foundation for the system to be built. In ensuring that support systems be developed to support teams, an adequate model is required.

In developing any model, there are necessary steps. In this work, the applications used for the phases involved are discussed- the subsequent sub-sections only give a literature review introduction to the concepts, context, and relevance as they are expanded upon in the following chapters. Mind maps, ontologies and process modeling are used at different phases in this research. While mind maps help in giving an articulate representation of the identified concepts, ontology building provides a formal representation and process modeling supports the developing of scenarios in order to assess the suitability of BPMN (Business Process Modeling Notation) as a modeling language for team-based systems.

2.5.1 Mind Maps

A mind map is a diagram showing concepts and how they are organized around a central theme. Mind maps are used to visualize, structure, and classify ideas, and could aid in studying and organizing concepts, describing a domain, designing complex structures, solving problems, making decisions, and developing a good foundation for knowledge representation (Buzan, 2006).

The elements in a mind map are arranged intuitively according to the importance of the concepts, and are usually classified into levels and sub-levels, with the goal of representing semantic or other connections between entities. Such arrangements are usually done hierarchically.

Mind mapping is similar to concept mapping; the former is based on hierarchical arrangements denoting relationships around a central concept, whereas concept maps are based on connections between concepts in more diverse patterns.

A vital advantage of mind mapping is the visual representation which allows for development of a holistic understanding that words alone cannot convey while providing a sound balance between structured definitions (concepts) and comprehensive models.

In healthcare, mind maps have been employed as an effective teaching and communication tool (Michelini, 2000) as well as for research purposes. It has also been suggested for use in healthcare planning (Tattersol, 2007). Garde S. *et al.*, (2006) also employed mind maps in their work towards improving semantic interoperability in EHR. Different mind maps have been developed for different aspects of healthcare; we however did not find any on healthcare teams in relation to how professionals work to deliver care. So we employ mind maps in this research to help in gathering and arranging the identified concepts on healthcare teams which is the starting point for the developing of our ontology.

2.5.2 Ontology

An ontology as given by Gruber, 2009 is "*a set of representational primitives with which to model a domain of knowledge or discourse. The representational primitives are typically classes (or sets), attributes (or properties), and relationships (or relations among class members)*".

Generally, ontologies are a formal representation of knowledge as a set of concepts within a domain and the relationships between those concepts. They provide shared vocabulary; identify concepts and highlights their properties and relations, hence can be used to model a domain. In this research, the mind map sets precedence for the ontology. Prieto-Díaz (2003) mentions that ontology is an explicit conceptualization of a specific

domain, thereby providing a shared and common understanding of the domain. It could be a structural framework in organizing information which aids knowledge representation. Ontologies usually involve extensive research and analysis.

In some domains, ontologies are developed to facilitate knowledge management, serving a purpose of representation, (Noy and McGuiness). As a concept widely used in domains asides informatics, computer science, semantic web, and software engineering such as philosophy, it has several explanations.

In healthcare though, it has been applied in a various capacities; such as modeling for system development, knowledge base, analysis of domain knowledge (Noy and McGuiness). In this work, it is employed basically for domain knowledge.

Despite the many applications of ontology in healthcare, there is no ontological model that focuses explicitly on teams in healthcare. Whereas, the availability of such a model would provide a formal representation of concepts in healthcare teams.

Ontology Development

Ontologies are developed built for different reasons, these reasons might however influence how and what steps are taken to build the ontology. Several methods to build an ontology exist in literature (Corcho O. *et al.*, 2003). However, in many cases, the steps are similar form one method to another. Typically, building an ontology would consist of identification of concepts, building of taxonomy, designing and describing of instances (Uschold and King, 1995; Fox M. *et al.,* 1998; Cihalova M. *et al.*, 2009). These steps were closely followed in this research.

2.6 **Business Processes**

The earlier discussed types of modeling- mind maps and ontology are theoretical representations of real life scenarios and focus more on the composition and organization of teams. This is where the need for business processes and business process modeling comes in; like any other industry, healthcare delivery involves processes. It is in the modeling of these processes that we study the actual execution procedures and needs of teams.

Business processes are vital to any organization- small or large. As products or services created by an organization are usually based on the outcomes of numerous activities. An organization`s success hinges a great deal on how well its business processes are carried out. The common understanding of business processes is; activities that turn input into value creation for consumers.

Business processes are the set of steps taken by businesses to create value for customers, such processes consist basically of three components (Harvard business press, 2010):

i) Inputs; that start the process

ii) Activities; that transforms the inputs into outputs

iii) Output; results of the activities.

Business processes would usually have an order as well as information needs, it may integrate several activities between or among different departments and even organizations and it as well be limited to one activity and one department.

2.6.1 Business Process Management

This is aimed at considering the organization as a set of coordinated and managed activities carried out in a specific order toward achieving set goals and objectives.

This initiative requires at least three steps (Briol, 2008):

i) The analysis and design of business processes in order to achieve strategic objectives

ii) The implementation and execution of business processes

iii) The monitoring of business processes

2.6.2 Business Process modeling

Business process modeling allows common understanding and analysis of business processes. An organization can be analyzed and integrated through its business processes. Hence the importance of correctly modeling its business processes (Havey, 2005).

Developing the right model involves taking into account the purpose of the analysis and, knowledge of the available process modeling techniques and tools. Business process modeling aims to produce business process models in a business-oriented detailed level.

A model is an abstraction of reality, a business process model identifies the essential elements that drive an organization as well as other factors that influences the organizational results (Briol, 2008).

Some business process modeling best practices:

i) It is necessary to have sufficient modelling means associated with model maintenance even after implementation.

ii) The model should be defined without ambiguity having adequate accuracy.

iii) The model when completed and validated should be easily executable.

iv) Selecting a good modelling tool is vital

According to Erickson and Penker (2000), some goals/benefits of business process modeling are: To give a simple understanding of the key mechanisms of an existing business, to serve as a foundation for the creation of appropriate information systems, to improve on business structure and operation and to facilitate the alignment of business specifications with the technical framework that IT development needs.

Several modeling languages have been developed, some of which are Petri Nets, Event-driven process chains (EPC).

2.7 **Modeling Languages**

Modeling languages are generally used for expression and/or representation of knowledge and systems. They are used to document organizational procedures/processes (Muehlen and Indulska, 2010). There are several of them with each one differing in their dynamism, flexibility, expressiveness, adaptability and complexity. Some of the common ones include; BPMN- (Business Process Modelling Notation), RAD (Role Activity Diagram), Petri Net, UML (Unified Modeling Language) among others (List and Korher, 2006)**.** Amidst some reasons which are highlighted below, one of the main reasons why we chose BPMN as the language of focus in this research is that it has been and is still being widely used in healthcare (Allweyer, 2010).

2.7.1 Introduction to BPMN

The Business Process Management Initiative (BPMI.org) developed and published the Business Process Modeling Notation (BPMN) in 2004. The BPMN specification only covers the description of the notation's element; it does not offer definitions for specific process design.

The BPMN notation aims to be readily understandable by all entities involved in business process drafting, implementation, integration and management, it focuses on business processes without covering organizational aspects such as business rules, information data model, organizational resources and strategy.

BPMN comprises a set of core elements: artifacts, connecting objects, flow objects and swim lanes. These elements are shown and explained in table 1 and figure 2.

Table 1. BPMN core elements (OMG.org)

Category	Description	Elements
Artifacts	Provides additional information to assist in better comprehension of model	Data object Group Annotation
Flow objects	Main graphical elements expressing the behavior of a business process	Events Activities Gateways

Connecting objects	Defines the way flow objects are connected together	Sequence flow Message flow Association
Swim lanes	Depicts and highlights the various entities participating in the process	Pools Lanes

The BPMN specification differentiates three kinds of business processes:

- Private (internal)
- Public (external)
- Collaboration (global)

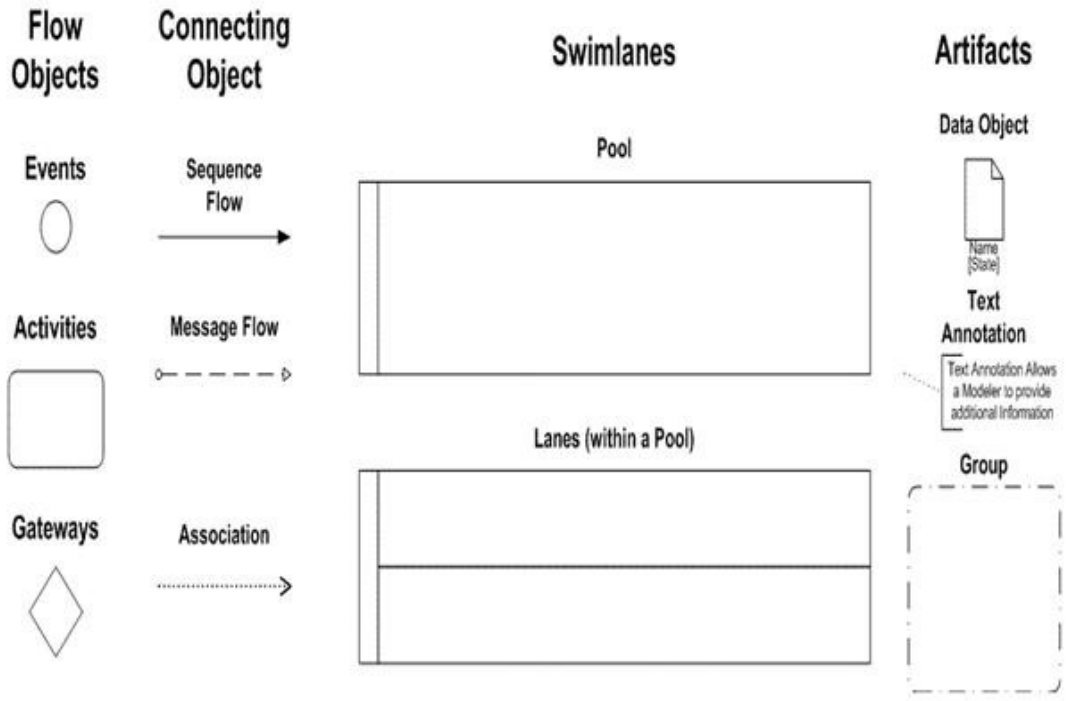

Figure 2. BPMN core elements- graphical (OMG.org)

2.8 **Modelling of healthcare processes**

Healthcare process delivery by teams is complex and variable, and their graphical visualization facilitates understanding and management towards improvement.

Process modeling has been used in other domains as well as in healthcare. The nature of healthcare processes is inherently complex particularly in team types other than unidisciplinary. At the same time, BPMN has been broadly accepted as the new standard for business process modeling having gained widespread adoption in practice across various industries including healthcare (Allweyer, 2010; Erickson and Penker, 2000). By

design, BPMN is made to be comprehensible by both IT specialists and professionals making it a promising candidate for modeling in healthcare (Muller and Rogge-Solti, 2011).

As the processes and activities leading to value creation differ from industry to industry, so do the modeling needs. BPMN, being robust enough has proven to be able to cater to most of these varying needs. Also, as flexible modeling language, BPMN allows for the addition of attributes and use of extensions, this has been capitalized upon in different quarters allowing modeling of processes to be more suited to meeting needs. BPMN has also been used in healthcare with several researches on its completeness, shortfalls and suitability to model healthcare processes as well as for process improvements and optimization (Rojo, 2008). However we did not find any research focusing on the ability of BPMN to model the different types of team settings.

2.9 **Related Works and Gaps**

According to Reddy M. *et al.* (2008), healthcare information systems are inclined to sustain collaborative (teamwork) activities. However, Dorr D. *et al.* (2007) pointed out that information systems such as EHR are more inclined to support individual needs rather than team based ones. Sicotte C. *et al.* (2002) also pointed out that research has basically focused on single team settings. Also, Workflow Management Systems (WMS) exist and have been applied in healthcare (Ganslandt T. *et al.*, 2000). They have however focused on workflow coordination of patient specific guidelines in single settings and not on interdisciplinary collaboration. Similarly, group decision support systems exist which are designed to support predefined tasks and not for aiding collaboration among interdisciplinary teams.

- Furthermore, Edwards (2009) highlighted that the actual dependencies of team types in collaborative settings have not been adequately catered for as collaborative systems tend to focus more on synchronous care delivery.

- Due to the complexity of healthcare teams and the need for information systems to support team-based care delivery, (IOM, 2001). It is imperative for health information systems to be designed to support this reality. This however requires the study and understanding of what teamwork actually constitutes (Caroll J. *et al.*, 2009).

- In the light of the above intended design, modeling becomes essential as highlighted by Moss J. *et al.* (2007). A fundamental understanding of the structure and co-ordination of the system that would be built using the model is highly essential.

As emphasized in literature review, the need for team and teamwork is highly important, at the same time, support structures for teams in the area of IT systems is also essential for the effective and efficient workings of teams.

We discuss the methodology used in the next chapter.

Chapter 3: Research Method

In a bid to create a framework of collaboration among teams, there are several possible methods. Having identified the intended aim of this research, design science methodology was used as the central methodology while ontological engineering was used for modeling the ontology.

Design science methodology with its guidelines was followed in order to produce a viable artifact leading to a solution which relevant and important to business problems, (Hevner A., *et al.* 2004). Our research consisted of the following "activities" (Peffers K. *et al*., 2008):

(1) Identifying the specific problem and justifying the value of a solution

(2) Defining the objectives for the solution

(3) Designing and developing

(4) Demonstrating

(5) Evaluating

Step 1- (Identifying the specific problem and justifying the value of a solution) which required knowledge of the state of the problem and the importance of its solution was conducted through an extensive literature review. This literature review helped to

identify gaps between healthcare delivery by a system which does not support collaboration and one which adequately does based on the extent to which information systems are built to facilitate professionals working in teams. Building such support systems would require a model developed with an intrinsic understanding of the entities involved in care delivery, what roles they play, how they interrelate and their information needs. As a system is only as good as the model form which it was developed.

The next step (defining the objectives for the solution) which involved the defining of objectives was achieved by further literature review. This step required insight on previous research, current research, solutions, results as well as challenges helping to define a possible and feasible scope for the research as several literature abound on what teams should comprise, how team members interact/collaborate, and their needs in the different types of team settings. However, there is little or no modeling approach for teams (healthcare), this research aims to develop one. In the previous chapter, we explored three modeling approaches highlighting their strengths and weaknesses with respect to modeling healthcare teams. In the next step (this chapter and chapter 5) we elaborate on the design and development of a model of healthcare teams.

Designing and developing (step 3) involved some sub-steps as well as developing a methodology for building the ontology. A literature review as well as case studies helped in identifying the various team concepts which were highlighted. Using these team concepts as a starting point, we progressed to developing a mind-map- which captures all the concepts; giving a high-level view as well as portraying categorization and hierarchies. Then we went ahead to developing an ontology- providing a formalized model for teams as well as helping to highlight dependencies and needs. After that we went ahead into process modeling using BPMN, we modeled various team scenarios although the focus was on two healthcare team types (multi and interdisciplinary teams).

Step four (demonstration) saw us demonstrating with the ontology for solutions by highlighting what would comprise needs for different teams based on the team types.

The last step, (evaluation) involved testing the ability of BPMN to model some scenarios as an assessment as to how well such a language can support modeling the processes involved in the different team types. The assessment of BPMN is presented in chapter five.

Chapter 4: Results: Methodology and Modeling

In this chapter we present the results of the research, through the phases described in the previous chapter. The concepts presented below are resulting from ideas developed through an extensive literature review as emphasized in the research method.

Healthcare processes consist of numerous actors working together towards achieving an improvement in patients' health condition and well-being. While 'working together' may vary in different situations, based on team set-up and other factors, the goal, processes for care delivery, influencing factors, information needs, government policies would generally be similar.

In order to develop a methodology, the first step would be to identify the entities involved in healthcare processes while taking note of their relative importance and the value they give in the delivery of healthcare.

Using our methodology (explained in chapter three) and having discussed the first two phases in previous chapters. This chapter explains the design and developing phase. The research drew from several articles and case-studies to identify team entities. The design includes three levels of development and formalization of the model; a list of identified concepts, a mind map and an ontology. Each one showing more details of relationships and dependencies than the previous.

This chapter has three main sub-sections, with 4.1 describing team concepts and how we came about them, 4.2 describing the mind map and 4.3 the ontology.

4.1 Team Concepts

We use the term 'concept' because some of the words were not exactly found in literature but would connote the same or almost the same meaning (based on the context) as the words used in this research.

In a bid to develop a model for healthcare teams, there comes an underlying need to identify the entities (concepts) involved and perhaps the relationship between them.

It is with this knowledge that we researched several articles and case-studies.

In the first step- identification of concepts, we discovered several factors that characterize healthcare teams. In literature, professionals involved in care delivery would usually have a location, act or interact with other professionals or persons as well as with systems in the practice of delivering care. They would usually communicate and have information needs in addition to been guided and influenced by organizational factors as well as policies or regulations.

The major categories of team concepts are:

- Processes
- Location
- Time
- Information

- Support systems
- Team types
- Organizational management
- External factors

The table below presents the concepts and the similar terms in literature.

Table 2. Concepts and their related terms in literature

Concepts	**Terms in Literature**
Processes	Tasks, activities, stages, processes, phases (Lawrence, 2002; Chesluk and Holmboe, 2010; Omachonu and Einspruch, 2010) *Meet*; Meet, interact, (Lawrence, 2002; Chesluk and Holmboe, 2010) *Infer*; examine, assess, 'make decision', 'individual clinical judgments', 'gather essential information', recognition, 'assessment, 'identification of patient's issues', current consequences, complications, underlying conditions and illness etc', diagnosis (Lawrence, 2002; Chesluk and Holmboe, 2010; LTCPLC, 2008)

	Treat; 'Make treatment decisions', 'recommend prescriptions', treatment (Lawrence, 2002; Chesluk and Holmboe, 2010; LTCPLC, 2008) *Inform;* Communicate, 'information sharing/transfer', educate, advise (Lawrence D., 2002; Chesluk and Holmboe, 2010; Omachonu and Einspruch, 2010) *Evaluate;* Measure, review, 'make adjustments', monitor (Lawrence, 2002; Chesluk and Holmboe, 2010; LTCPLC, 2008) *Knowledge acquisition;* Learn, Develop, evolve (Lawrence, 2002; Chesluk and Holmboe, 2010; LTCPLC, 2008)
Location	*Same;* 'Physical presence', 'same location', (West M. and Poulton, 1997; Demiris, 2006) *Different;* 'different locations', 'spatial locations', 'virtual healthcare teams', (West and Poulton ,1997; Demiris, 2006)
Time	*Synchronous;* 'working synchronously', (Berlin, 2010; Eder, 2000) *Asynchronous;* 'working asynchronously', (Berlin, 2010; Eder, 2000)

Information	*Needs;* 'Information requirement', 'patient record', (Raghupathi and Tan, 2002), Patient record, medical history, test results, allergies, prescriptions *Security;* 'security/safety of patient information' (Raghupathi and Tan, 2002; Omachonu and Einspruch, 2010) Confidentiality, integrity, authentication, authorization *Management;* 'information management', 'information availability', (Raghupathi and Tan, 2002) Availability, access controls *Privacy;* 'information privacy', (Raghupathi and Tan, 2002; Omachonu and Einspruch, 2010)
External factors	Insurance policies and payment issues, other healthcare providers, government regulations (Lawrence, 2002; Spath, 2011)
Organizational management	*Team Constituent;* 'Who is involved', 'what type of team', 'what a team consists' (Jun G. *et al*., 2009)

	Team goals; Goals (Spath, 2011) Organizational defined, team defined *Team properties;* 'team behaviour', 'team characteristics', 'degree of collaboration' (Spath, 2011) Collaboration could be parallel, integrated, holistic
Support systems	*Technology enabled;* Technology enabled systems (IDA, 2005; Bates and Gawande, 2003) Telephone, telefax, decision support systems, electronic health records, health information system, email *Non-Technology enabled;* Non-Technology enabled (Kvedar, 2007) Paper records

To clarify, several terms in literature could be identified with one concept as they carried the same meaning (in context). Taking 'processes' as an example, other similar terms that were found include; tasks, activities, stages, phases. We however used 'processes' as it carries enough meaning necessary for this work and the fact that it is easily understandable. The same principle was used for other listed concepts.

Although the settings, patients' needs and reasons for research differ from one article to another we analyzed the data to develop a set of common concepts (introduced in table 2) in the following sub-sections.

4.1.1 Processes

As we carried out the literature review we noticed that care delivery was not just one process but a make-up of processes.

Therefore we attempt to define the phases involved which help in describing healthcare delivery activities engaged in by professionals at one point or the other in the course of providing care. As identified in the above table, some of the terms that were found in literature include: 'examine', 'transfer', 'communicate', 'interact', 'make treatment decisions', 'meet', information transfer/sharing' 'individual clinical judgments' etc.

They are:

- **Meet**

  Processes that describe the interactions (physical, virtual, synchronous, asynchronous or otherwise) between team members fall under this category.

- **Infer**

  This describes all the processes that help healthcare professionals come to a reasonable conclusion on the state of the patient such as diagnosis, analysis of signs and symptoms, test results, health records, family history, etc. It may be further divided into two.

  - **Assess**: Processes that aids the professionals to get an optimum understanding of the patient's situation.

  - **Make decision**: Processes that enables professionals to determine a course to follow after assessing and weighing options.

- **Treat**

  These involve all the processes towards an improvement in the state/well-being of the patient or a relief (e.g. palliative) as the case may be.

- **Inform**

  This involves all the processes by which information is transferred. To the patient, family members, other team members, updating of health records, etc.

- **Evaluate**

  This involves the assessment of the other phases vis-à-vis the expectations, outcomes, standards, etc.

- **Knowledge Acquisition**

  This explains the course by which professionals and others involved in care delivery and management acquire knowledge about the patient, the illness, other members of the team, etc. thereby increasing his /her knowledge base. This could be difficult to expressly define as it is mostly tacit in nature.

This model is in no way all-encompassing and only emphasizes the interactions among healthcare professionals. It in no way attempts to describe all the activities involved in delivering care although they could form the building blocks. It could also provide a good start for other models and solutions as it gives an in-depth yet concise make-up of team based activities.

4.1.2 Location

This refers to the actual settings (in terms of place/position) of professionals. Some of the terms in literature which exactly reflected location include; ‘emergency room’, ‘offices’,

‘laboratories’, ‘nursing home’, ‘hospital wards’ and ‘ICU (Intensive Care Unit)’. We however noticed that professionals were sometimes physically present together and were not at other times.

- **Same**

  This refers to the setting whereby the professionals are physically present at the same location.

- **Different**

  This refers to the setting where professionals are not physically present together, in such cases they rely on support systems to provide an effective communication means.

4.1.3 Time

This refers to the timing during which care activities are performed by professionals.

- **Synchronous**

  This refers to the setting whereby the professionals work at about the same time with/without been physically present at the same location.

- **Asynchronous**

  This refers to the setting where professionals work at different timings.

  Asynchrony (conveying healthcare information across time and locations) is growing as the number of participants, and pace and complexity of the care process grows.

4.1.4 Information

It should be noted that this is different from 'inform' which was mentioned above which depicted the act or events involved in sharing information.

Terms such as 'patient record', 'allergies', 'prescriptions', 'laboratory results', 'privacy', depicted information/data and it's necessary features in literature.

- **Needs**

  This encompasses all the information needs of care professionals; It is however pertinent to mention that information is a very broad area and that it could however be tacit or explicit. While both hold great significance, we only model that of explicit because tacit information could be really intricate in nature as its models are intangible.

  - **Patient Information**

    This holds information regarding the patient.

    - **Record**

      This document identifies the patient and would usually contain information regarding the current state of the patient along with other information as the case may be. The following references indicate the varied definitions.

      It has several aliases such as medical record, health, record, clinical record, office record, client record, patient's chart (Ball, 1992).

      It could be manual or computer based. Dick and Steen (1991) define a computer-based record as an electronic record that resides

in a system. It is designed to support users through availability of complete and accurate data, vis-a-vis a manual record in the past that was only used for storing and retrieval of data involving delivery of care.

A patient record could be referred to a business record for a patient encounter containing documentation of all healthcare services provided and is a repository of information that could include demographic data and documentation to support diagnoses, justify treatments and record results of patient (Green and Bowie, 2005).

A patient record could as well be defined as a single collaborative record containing a patient's personal information, diagnosis or condition, assessments, plans, care and treatment while the record is supported by a dynamic evidence base created and added to by all who interact with the patient, the patient inclusive (Thompson and Wright, 2003).

- **Medical history**

  This document would usually contain information available relating to the patient's health, where possible, such information from birth would be available.

- **Test/lab. Results**

  These are results of tests ordered by care providers.

- **Patient's prescriptions**

  Medications prescribed for the patient.

- **Management**
  - **Access Controls**

    This refers to the means of granting control access to resources by authorized users. It can be used to define what conditions/positions necessary for access and how such resources should be modified.

- **Security**

  Security has traditionally been defined as the processes involved in ensuring information confidentiality, integrity and availability.

  - **Confidentiality**

    This is intended to ensure protection of information

  - **Integrity**

    This is the assurance that what is received is exactly what was transmitted. That is the data/information has not been tampered with in any manner such as insertion, deletion, replay or modification.

  - **Authentication**

    Authentication is a means to guarantee the genuinity of an entity giving the assurance that an entity is truly what it claims to be.

  - **Authorization**

    This is the process of granting access to resources.

4.1.5 External factors

This entails other factors that impact healthcare professionals and processes; they include actors and organizations such as insurance companies and policies as well as government legislations and regulations.

4.1.6 Organizational Management

This depicts intangible factors that directly or indirectly affect how professionals work as a team.

- Team Constituent

  This differs from team types as this focuses on how any type of team is

  made up. It relates to factors such as team leader, number of team members, etc.

- Responsibilities/goals
  - Organizational defined
  - Team defined
- Team properties
  - Collaboration
    - Parallel
    - Integrated
    - Holistic

4.1.7 Support systems

This classifies resources, systems, means, etc. which enables the processes to be performed.

- **Technology enabled**

  Support systems based on information technology.

  - Health information System (HIS)
  - Electronic health records (EHR)
  - Email
  - Telefax
  - Telephone
  - Decision support system

    An information system supporting decision making activities,

- **Non-technology enabled**

  Support system that is based on manual medium rather than on information technology.

  - Paper records

    This depicts patient records that are on physically on paper.

4.1.8 Team Types

This explains the possible categorization of teams based on composition and goals.

- **Multidisciplinary**

  In this team type, team members are from one or more professional backgrounds. Collaboration is parallel and goals are individual.

- **Interdisciplinary**

  Team members are from more than one professional background. Collaboration is largely integrated and goals are shared.

- **Transdisciplinary**

  Team members are from more than one professional background. There is a lot of synergy and collaboration is largely holistic.

After identifying the entities associated with team settings, we proceeded to developing a mind map using the concepts that have been identified.

4.2 Mind Maps

The mind map is based on all the concepts highlighted in the previous section with the concepts retaining their classes and categorization and sub-concepts maintaining their ranking. As with mind-mapping, the central concept is placed in the center which is 'Healthcare' in this case with the sub-concepts branching off. The sub-concepts are further sub-divided. For example, 'Processes' as a major branch would have sub-branches for every other concept identified under it; in this case- 'meet', 'infer', 'treat', 'inform', 'evaluate', 'knowledge acquisition'. Then each sub-branch would further be sub-divided until all concepts are touched upon. Given that, 'infer' would then be sub-divided into 'access' and 'make decision'. This is how all the identified concepts are translated into the mind map.

For a detailed, concise illustration of the hierarchies and dependencies we adapted the mind map, to display the data graphically.

The mind map gives us a good formal transition between a list of the concepts and the ontology (by providing a good foundation for knowledge representation).

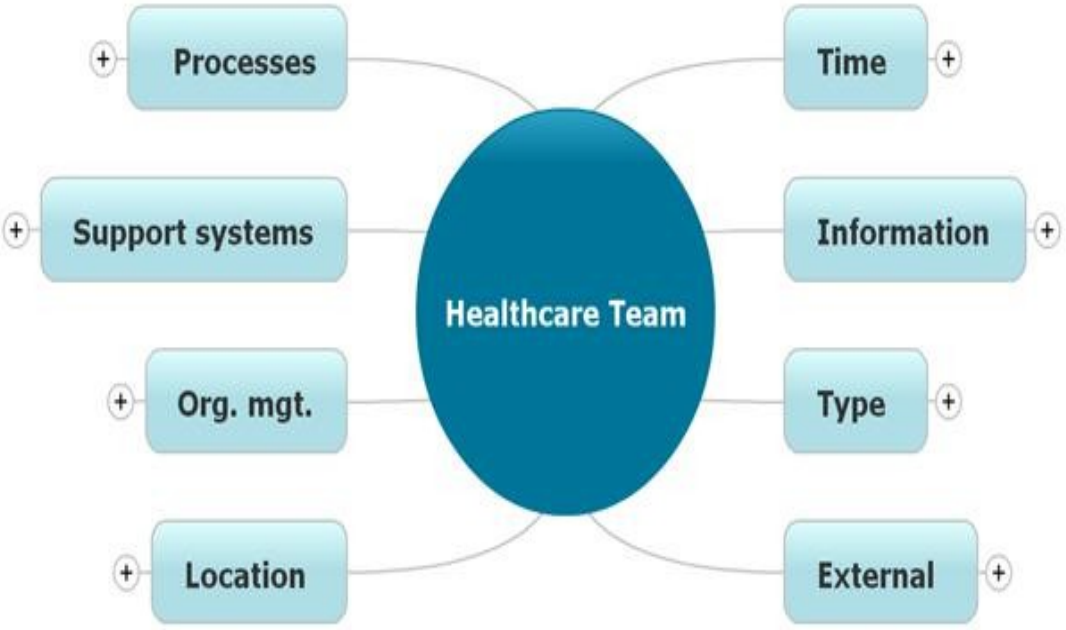

Figure 3. Mind map showing major classes

Figure 3 above shows only the major sub-classes around the central concept, while figure 4 below highlights the first-level sub-divisions.

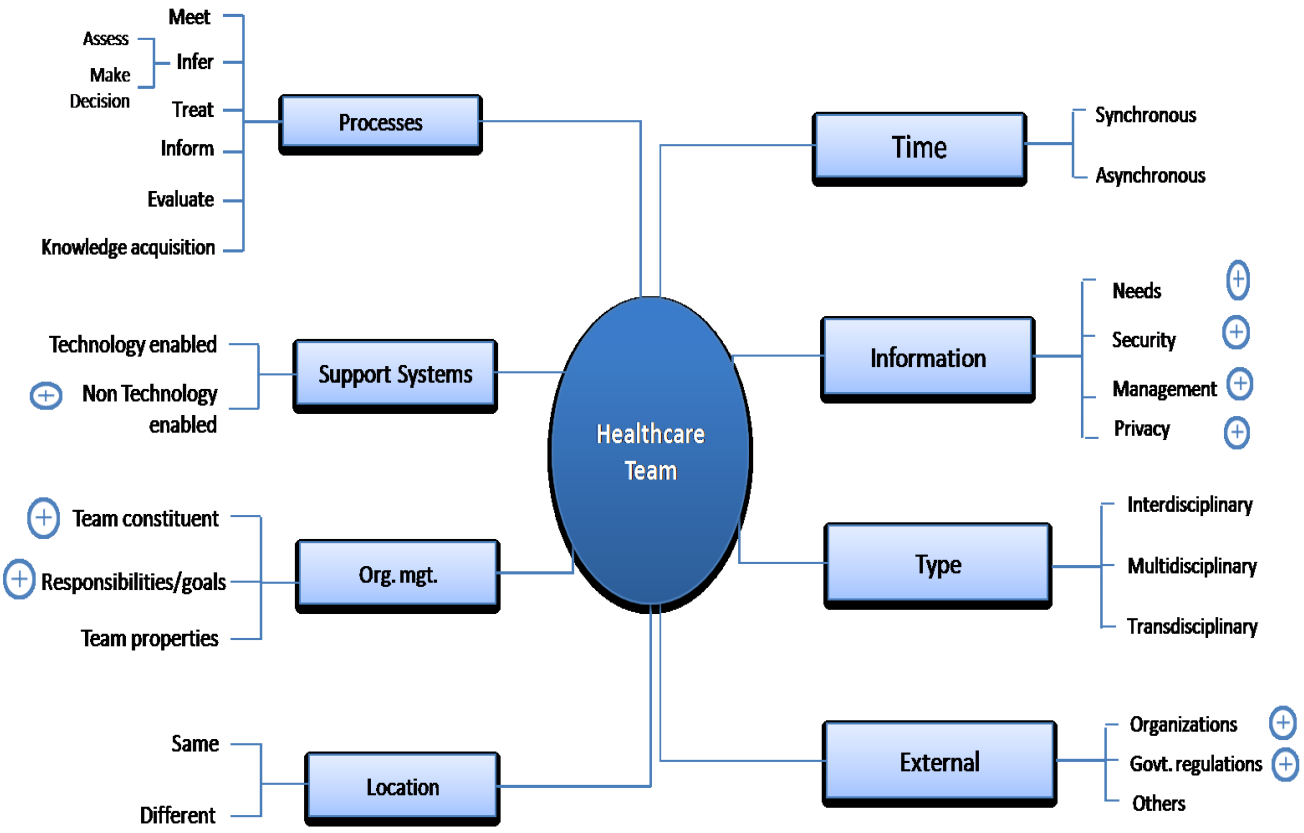

Figure 4. Mind map showing first level subclasses

4.3 Ontology

Having illustrated the identified concepts, we went ahead into the phase of developing the ontology, using the mind map as a starting guide.

In this research, the ontology was developed for the following reasons:

- To formalize the domain

- To define classes and assert properties about them
- To 'reason' about the classes and individuals
- To provide a knowledge base on the domain
- To highlight the relationships and dependencies of the entities that were identified.

An ontology editing tool was required for the purpose of developing the ontology. For the purpose of this research, OWL DL was used as it provided the needed functionality such as 'reasoning'.

- In developing the ontology, the concepts which were earlier identified were conceptualized, some as classes others as sub-classes.
- The sub-concepts in the mind map were defined as classes under 'owl:Thing' (Figure 5). There was however a change in nomenclature (as shown in table 3) to add meaning, demonstrate context (healthcare) as well as to adhere to the syntax in owl. The significance of each concept remained unchanged.

Table 3. Change in nomenclature between the mind map and ontology

Mind map concepts	Ontology concepts
Type	HealthcareTeamType
Patient's Needs	PatientCareNeeds
External	TeamExtFactors

Information	TeamInfoReq
Location	TeamLocation
Org. Mgt.	TeamOrgMgt
Processes	TeamProcesses
Support Systems	TeamSuppotSys
Time	TeamWorkTiming

- Then each class was further distinguished into varying number of sub-classes based on the number of sub-divisions identified in the list of concepts. E.g, 'TeamProcesses' was further sub-divided into 'Meet', 'Infer', 'Treat', 'Inform', 'Evaluate' and 'KnowledgeAcqusition'.
- This sub-division continued until the last elements in the rank from the list of concepts had been touched upon as shown in Figure 6. This figure is similar to figure 4 (mind map) as they both depict the ranking of classes and sub-classes in the different applications.

- In order to have a robust ontology, properties such as ‘rdfs:comment’ and ‘rdfs:isDefinedBy’ were assigned values which basically explained and defined the meaning of the classes, this was done for each class that was defined.

- Afterwards, we created properties (based on the literature review) which help to relate classes and subclasses to one another as required.

- Then boundaries were set on classes and the assertion of properties on them by assigning ‘domain’ and ‘range’ for each property as deemed necessary.

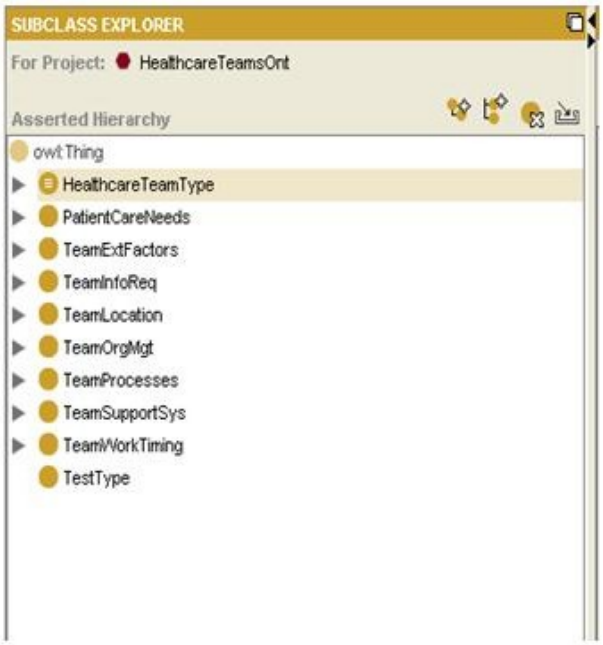

Figure 5. Snapshot showing classes

- Setting the properties, domains and ranges helped in highlighting relationships and dependencies (as shown in fig. 7). For instance, ‘meet’ could occur in ‘synchronous’ or ‘asynchronous’ manners. Each team regardless of the ‘type’ (‘multi, inter or transdisciplinary’) would carry out care ‘processes', professionals

participating in the team might be in the ‘same’ or ‘different’ ‘locations’ to ‘interact’ and ‘communicate’ with one another, they would have ‘information’ ‘needs’ which have to be met through ‘technology’ or ‘non-technology enabled’ ‘support systems’. These ‘information’ would need to be properly managed as to be ‘available’ to the right parties at the right time and must adhere to ‘privacy’ and ‘security’ regulations. ’Access’ to ‘information’, knowledge and experience of the professionals are some of the factors that would help to ‘infer’ on the state of the patient. This will guide the professionals in making treatment decisions.

- However, properties, ranges and domains were not sufficient enough to expound upon all organizational management aspects. Factors such as ‘collaboration’ (though explicitly defined as any of parallel, integrated or holistic) could not be implicitly incorporated to the ontology because of its intangibility. Nonetheless, we imposed conditions on aspects such as team constituent.

- Finally, conditions (restrictions) were imposed on some classes and relationships, in addition to designating property characteristics; this was done to further constrain the range of a property in specific contexts in a variety of ways.

- The conditions were imposed to make the ontology objective and to assert characteristics found in literature. Some of the conditions include: i) a team must have a leader, ii) multi, inter and transdisciplinary teams must comprise of professionals from more than one area of specialization, and iii) an individual cannot make a team, etc.

- Protégé allows for plug-ins, some of which were used in this research for various reasons. The two main ones used were 'reasoner' and 'OWL Viz'.

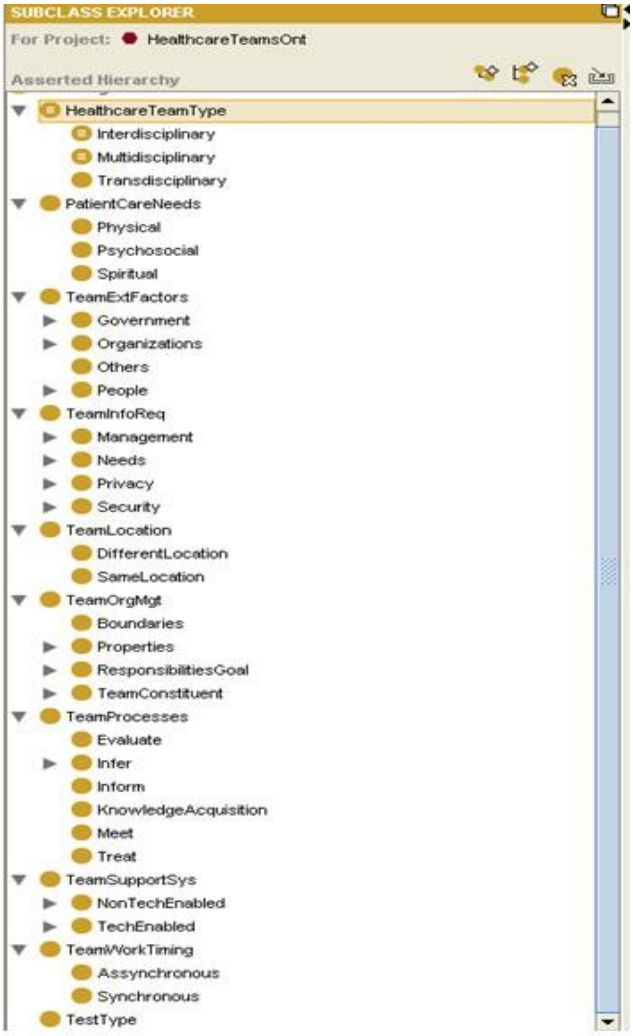

Figure 6. Snapshot showing class hierarchies

- Reasoner: One of the key reasons why OWL DL was used in this research is its ability to be processed by a 'reasoner'. We used a 'reasoner' to:
    - Check consistency; after describing a class, the 'reasoner' was used to check the feasibility of the class having instances.

- Check taxonomy; this helped in verifying if a class was described in a manner that made it a sub-class of another class
- Check inferred types; this computation would give an inferred class hierarchy. The mind map was really helpful at this point as we would check the given computation by the 'reasoner' against the mind map.

The 'reasoner' used in this research is “RACER”.

- OwlViz was used at different points to provide a graphical view of the classes and their relationships.

Properties are used as defining criteria for inference helping to set boundaries and define limits.

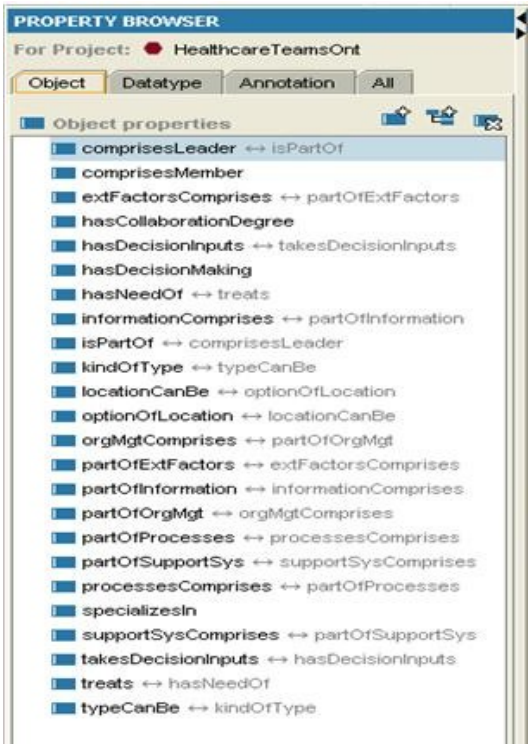

Figure 7. Snapshot showing ontology properties

4.3.1 Modeling Scenarios

After relating classes with properties, asserting domains and ranges on such properties, the ontology helped in highlighting concepts, their relationships and dependencies. It is interesting to note that the major differences in the results of the ontology for the different team types lie in their organizational management factors. Building upon the descriptions in this chapter, we modeled some processes.

These processes try to differentiate between both types of team settings using BPMN. However, the workflow is conceptual as we only attempt to depict the differences in the aptness of BPMN to adequately cater to modeling the degree of collaboration in both types of team settings rather than explaining in details the advantages or short-comings which might require real-life cases.

As depicted in the figure below (figure 8), the degree of collaboration in multidisciplinary teams is parallel.

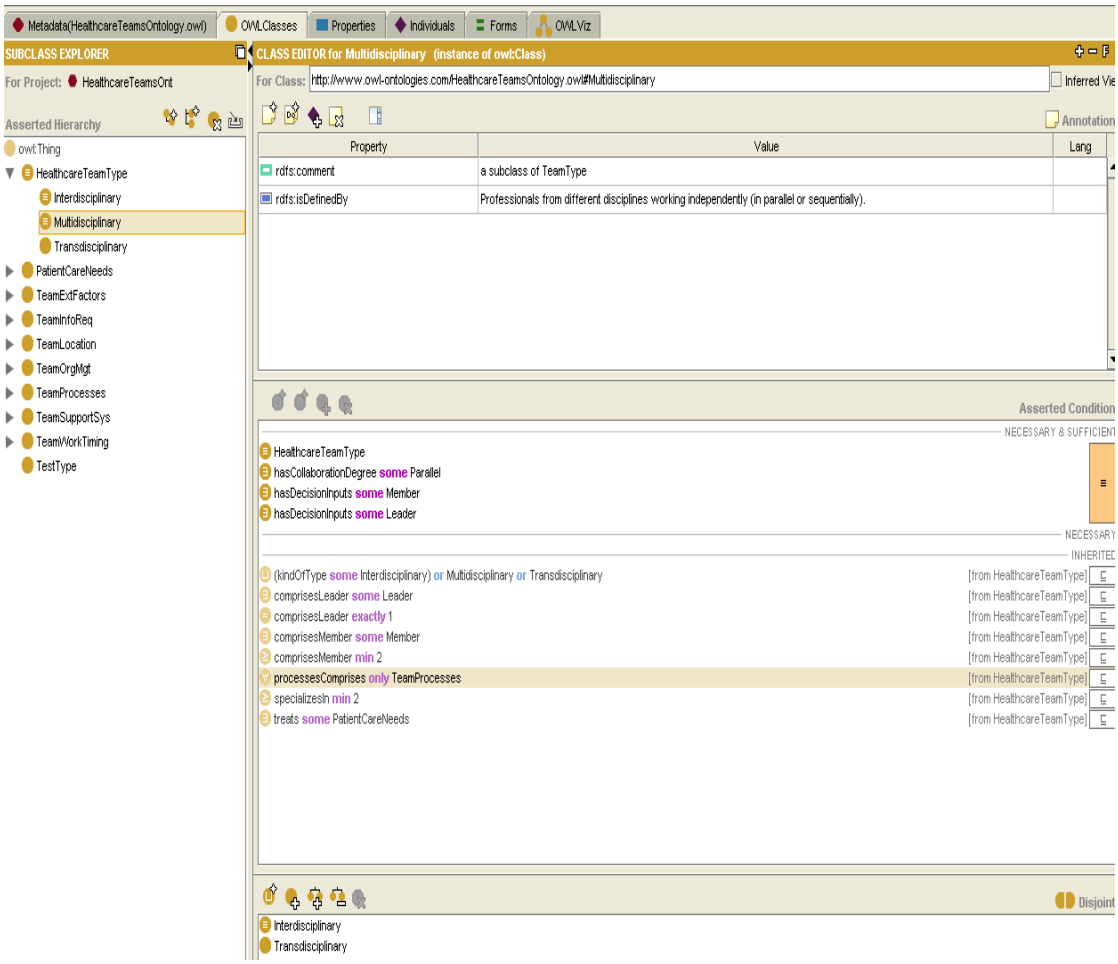

Figure 8. Conditions, dependencies and relationships for multidisciplinary team

For any of the patient's need and the recommended healthcare team setting, the most tangible differences would be based on organizational management factors, as processes such as 'meet', 'infer', 'treat' etc. will occur in the different team types (although might be in varying degrees and different levels). In addition, teams regardless of the type would also have information needs, require support systems, have same or different work locations and work synchronously or asynchronously. But goals, degree of collaboration, team makeup have the potential to vary greatly and these factors are not easily defined as they are mostly intangible. The figure below (figure 9) shows the some of the

dependencies, conditions and relationships of interdisciplinary team. When compared with that of multidisciplinary team, the major differences lies in the degree of collaboration as it is integrated in this case and decision making which is totally inclusive i.e. requiring inputs from leader and members of the team. While that of multidisciplinary team requires inputs for decision making only from 'some' members and leader.

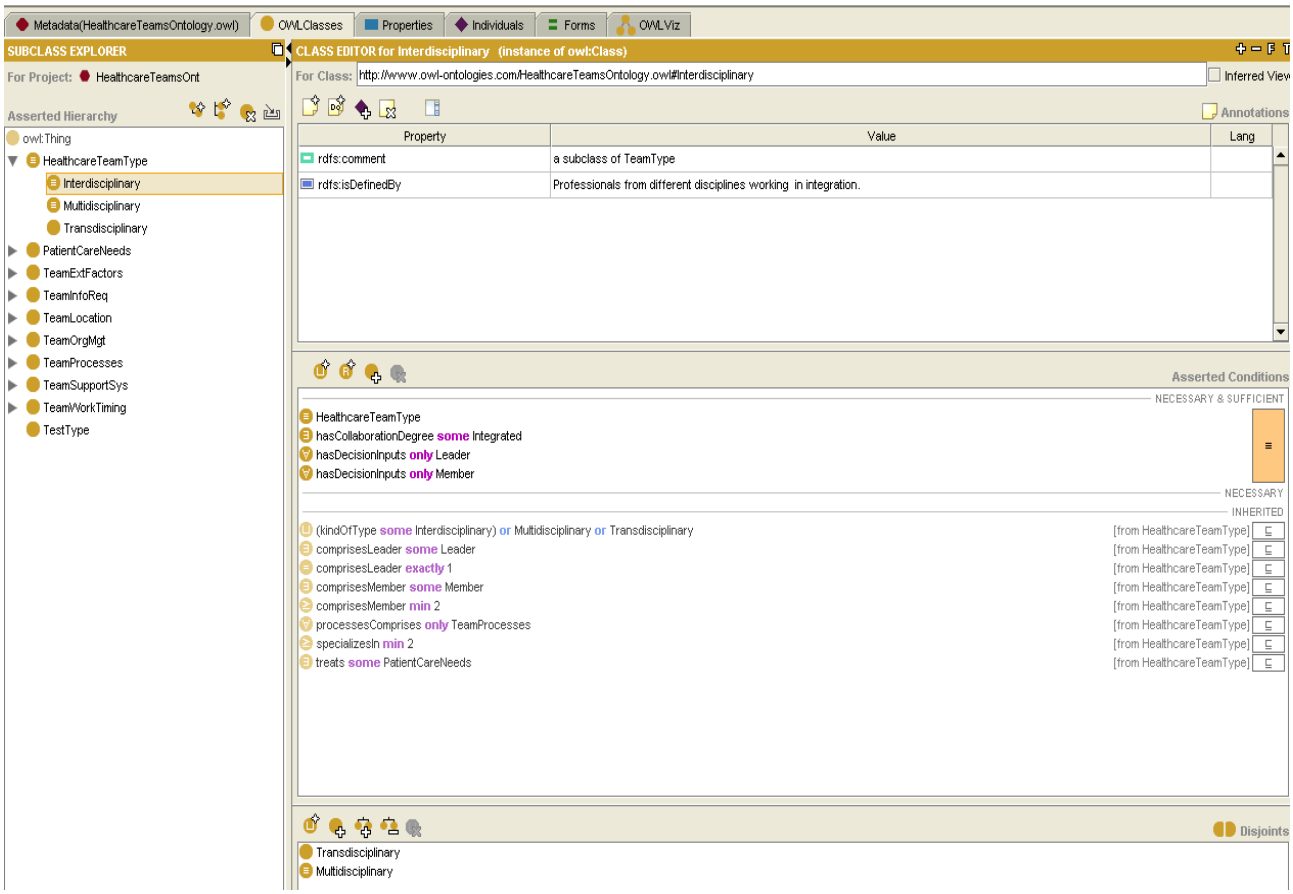

Figure 9. Conditions, dependencies and relationships for interdisciplinary team

We would attempt to emphasize on these points in the modeling of some scenarios by using BPMN to understand how much process modeling can model organizational management features or if human interactions are just too complex to be clearly modeled.

On the differing factors, the property `hasCollaborationDegree` was used as given in literature, it is depicted in table 4 below:

Table 4. Team type vs. level of collaboration

Team Type	Degree of collaboration
Multidisciplinary	Parallel
Interdisciplinary	Integrative
Transdisciplinary	Holistic

The models are presented and assessed in the next chapter.

Chapter 5: Assessment and Analysis of BPMN

In this chapter, we discuss the capability of BPMN to model teams in multi and interdisciplinary work settings.

While ontologies provide a good model for information systems, we go a step further by modeling some processes using BPMN. These models and their evaluation help to create a link between the methodology and its real applications. It also aids in recognizing how the features and aspects of the ontology are translated into modeling and system building as well as identifying what features may be inadequately represented in prototypes/developed systems and how such short-comings could be handled.

This modeling phase required some scenarios which we acquired from the literature. The scenarios featured healthcare professionals engaging in typical care delivery acts, but the models are developed based upon results derived from the ontology, i.e. the modeled activities are guided by output from the ontology.

We present six scenarios using concepts identified in the mind map and from the ontology. All the scenarios share some common characteristics but for the most part have been made to vary to emphasize different concepts in different team settings. Detailed explanations are given along with the individual models.

Scenario1

Process - Meet (multidisciplinary)

- This scenario comprise three participants:
  - Medical Doctor (MD)
  - Nurse
  - Pharmacist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

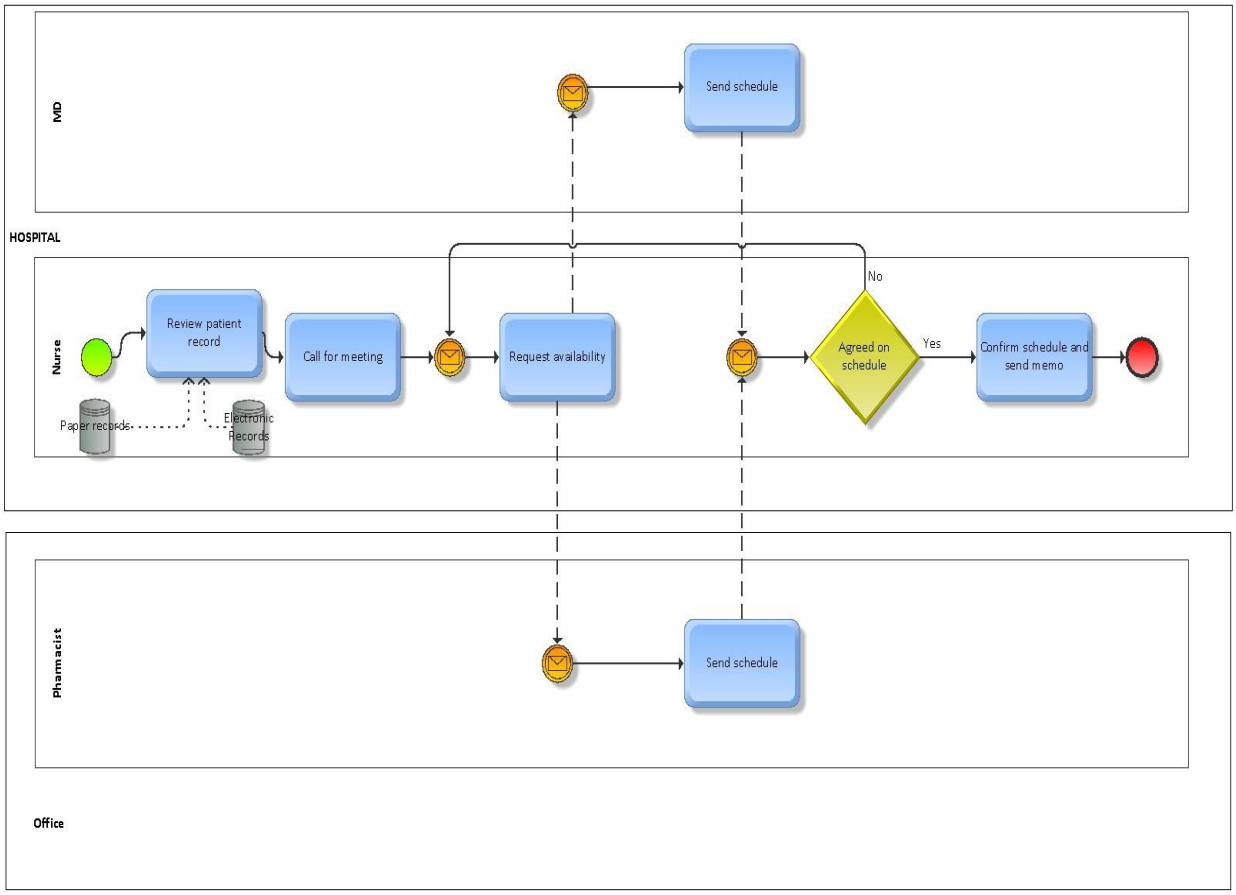

Figure 10. BPMN depicting the 'meet' process in a multidisciplinary setting

Model Information

- 3 actors
- 2 data objects
- 1 gateway
- multiple events, connecting objects and activities.

In the model above (figure 10), the professionals are getting on in the process of meeting and the team setting is multidisciplinary. The nurse as the team leader tries to schedule a meeting therefore send messages to the other participants, after confirmation of availabilities, the scheduling is done.

Some of the noteworthy characteristics of this model are;

- the different locations

- data requirements

- information exchange to multiple parties

Scenario 2

Process - Meet (interdisciplinary)

- This scenario comprise three participants:
    - Medical Doctor (MD)
    - Nurse
    - Pharmacist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

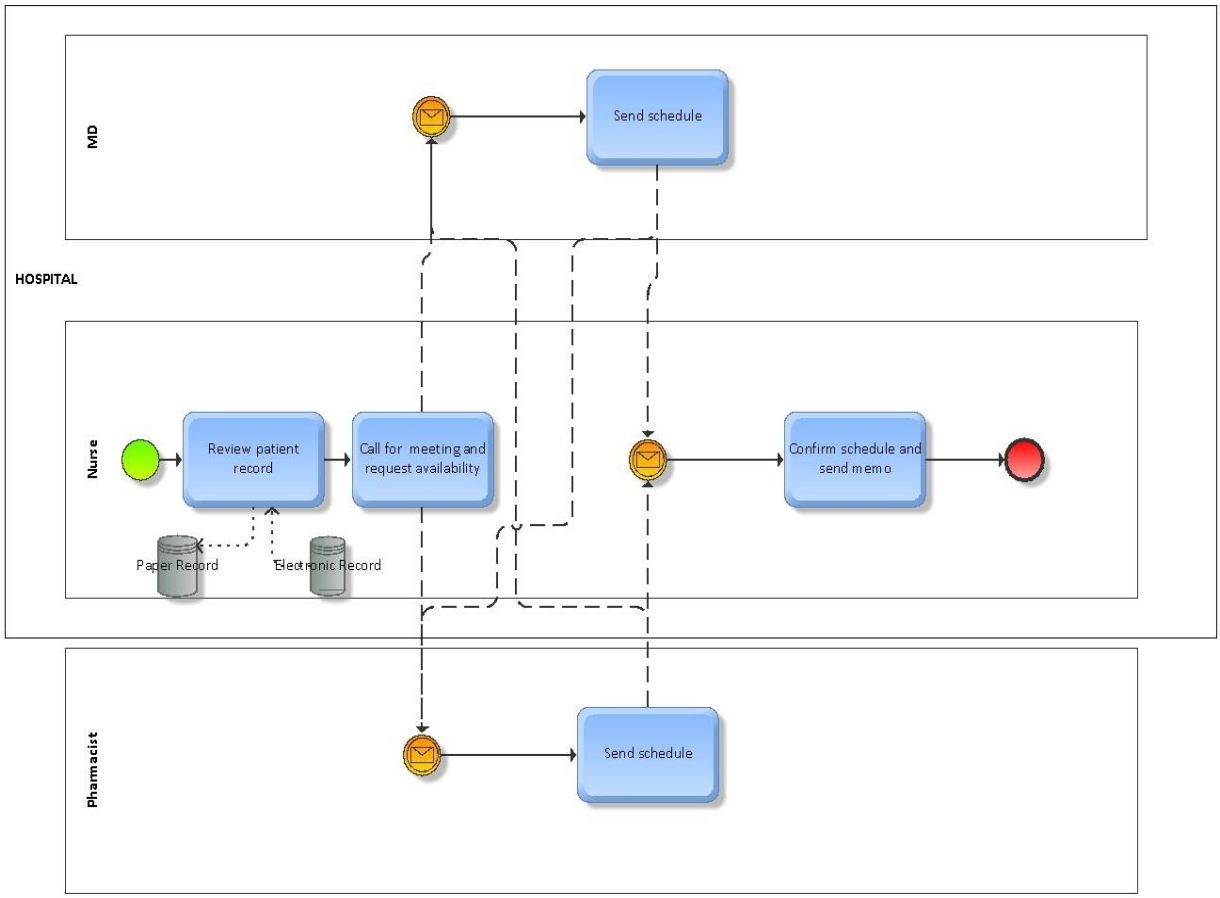

Figure 11.BPMN depicting the 'meet' process in an interdisciplinary setting

Model Information

- 3 actors
- 2 data objects

- multiple events, connecting objects and activities.

In the model above (figure 11), the professionals are getting on in the process of meeting and the team setting is interdisciplinary. The nurse as the team leader tries to schedule a meeting and informs the other participants, after confirmation of availabilities, the scheduling is done.

This model also depicts identification of different actors, different locations, data requirement, and multiple parties' information exchange amongst others.

For this process, there turns out to be no much difference in the modeling of the different team types particularly as regards size and expressiveness. In the former (multidisciplinary setting- figure 10), the team leader (nurse) calls for a meeting, requests availability and then sends a schedule to the other team members. The model allows for a continual iteration of sending schedules and availability until a consensus is reached. Whereas in the latter (interdisciplinary setting- figure 11), the nurse sends a schedule to both the MD and the pharmacist, they in turn confirm their availabilities and send the response back, but this time not only to the nurse but to the other two team members, possibly allowing for lesser iterations as all the parties involved are adequately informed through the process.

Scenario 3

Process - Infer (multidisciplinary)

- This scenario comprise three participants:
  - Medical Doctor (MD)
  - Nurse
  - Pharmacist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

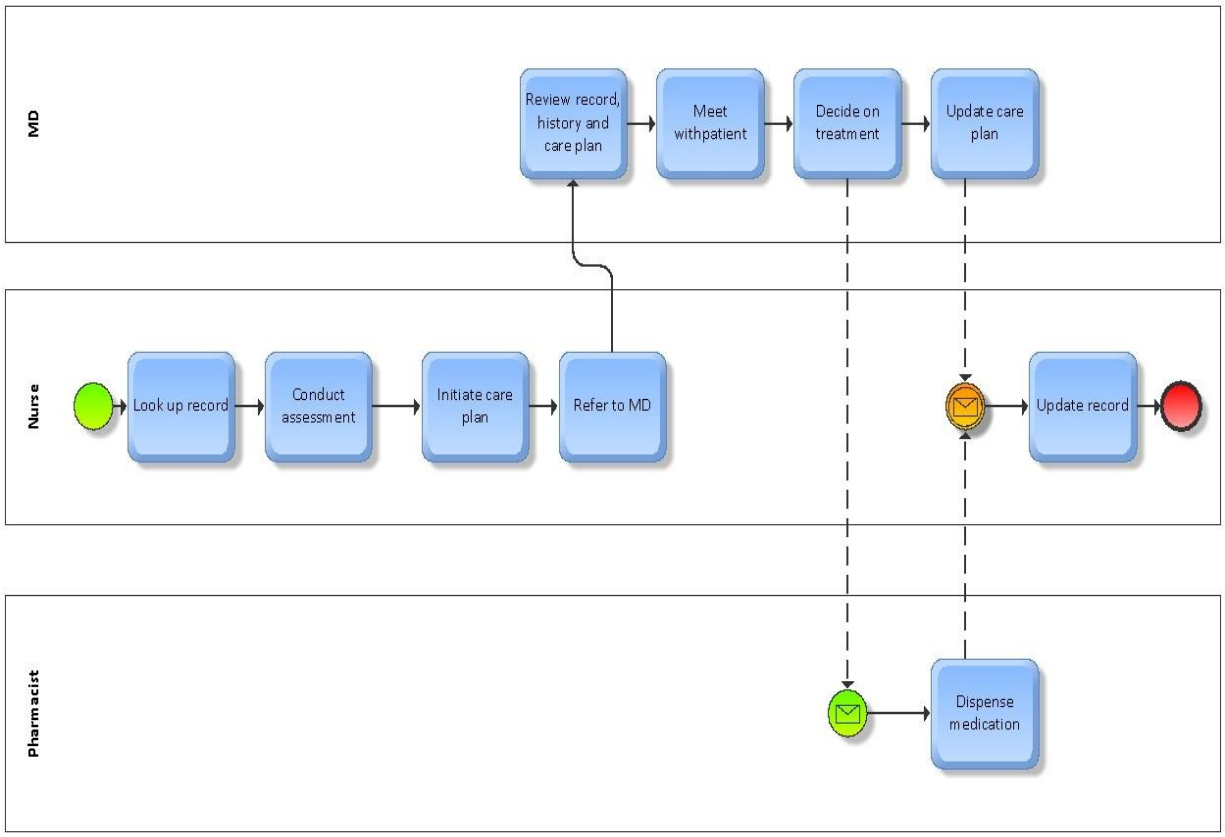

Figure 12.BPMN depicting the 'infer' process in a multidisciplinary setting

Model Information

- 3 actors
- multiple events, connecting objects and activities.

n this model (figure 12), the professionals are getting on in the process of 'inferring' and the team setting is multidisciplinary. The nurse (team leader) initiates the care plan and the process progresses.

The process starts by the nurse looking up the patient's medical record, conducting an assessment, initiating a care plan and then referring the patient to the MD. The MD reviews the patient's record, history, care plan and other relevant information, then meets with the patient, after that decides on treatment then goes further to update the care plan while informing the pharmacists of the prescribed medication. The pharmacist dispenses the medication and then updates the care plan as well, the nurse then goes ahead to update the patient's record.

Scenario 4

Process - Infer (interdisciplinary)

- This scenario comprise three participants:
  - Medical Doctor (MD)
  - Nurse
  - Pharmacist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

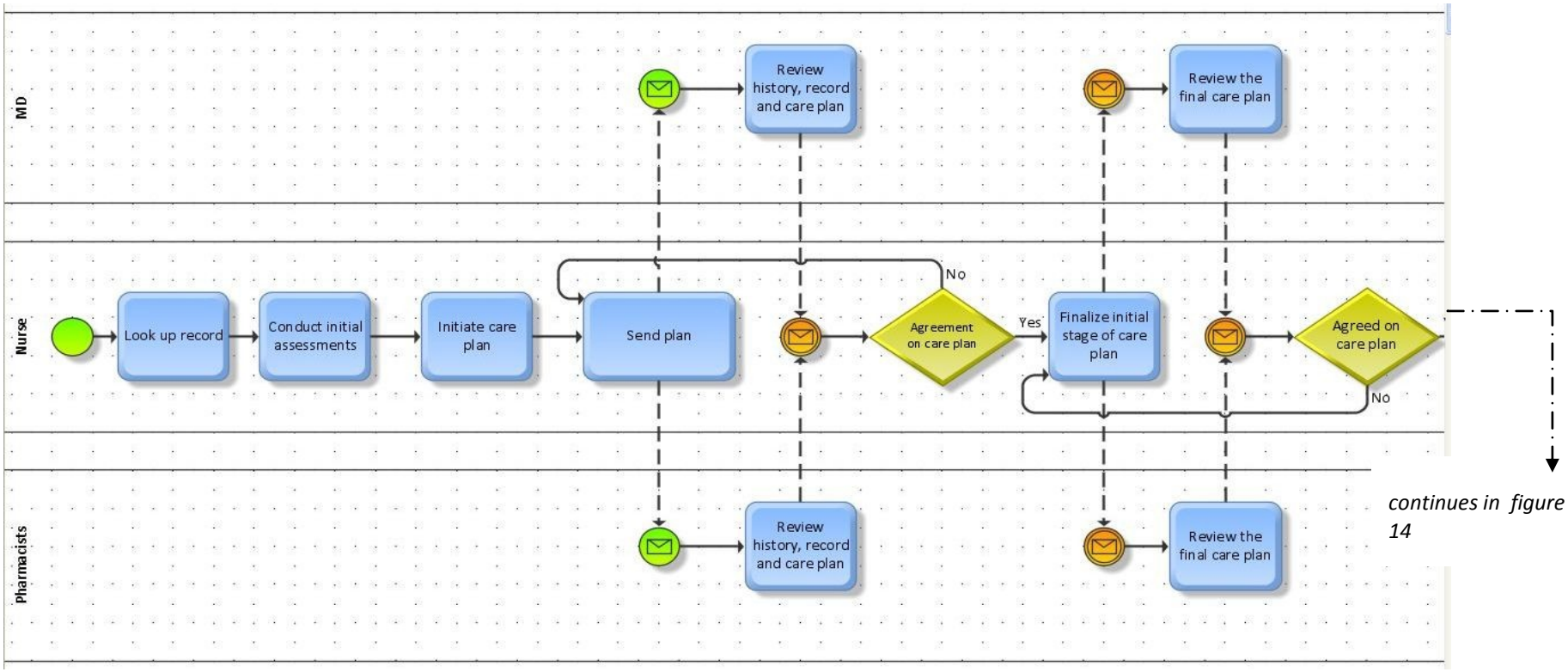

Figure 13. BPMN depicting the 'infer' process in an interdisciplinary setting (cont. in Fig 14)

continues from figure 13

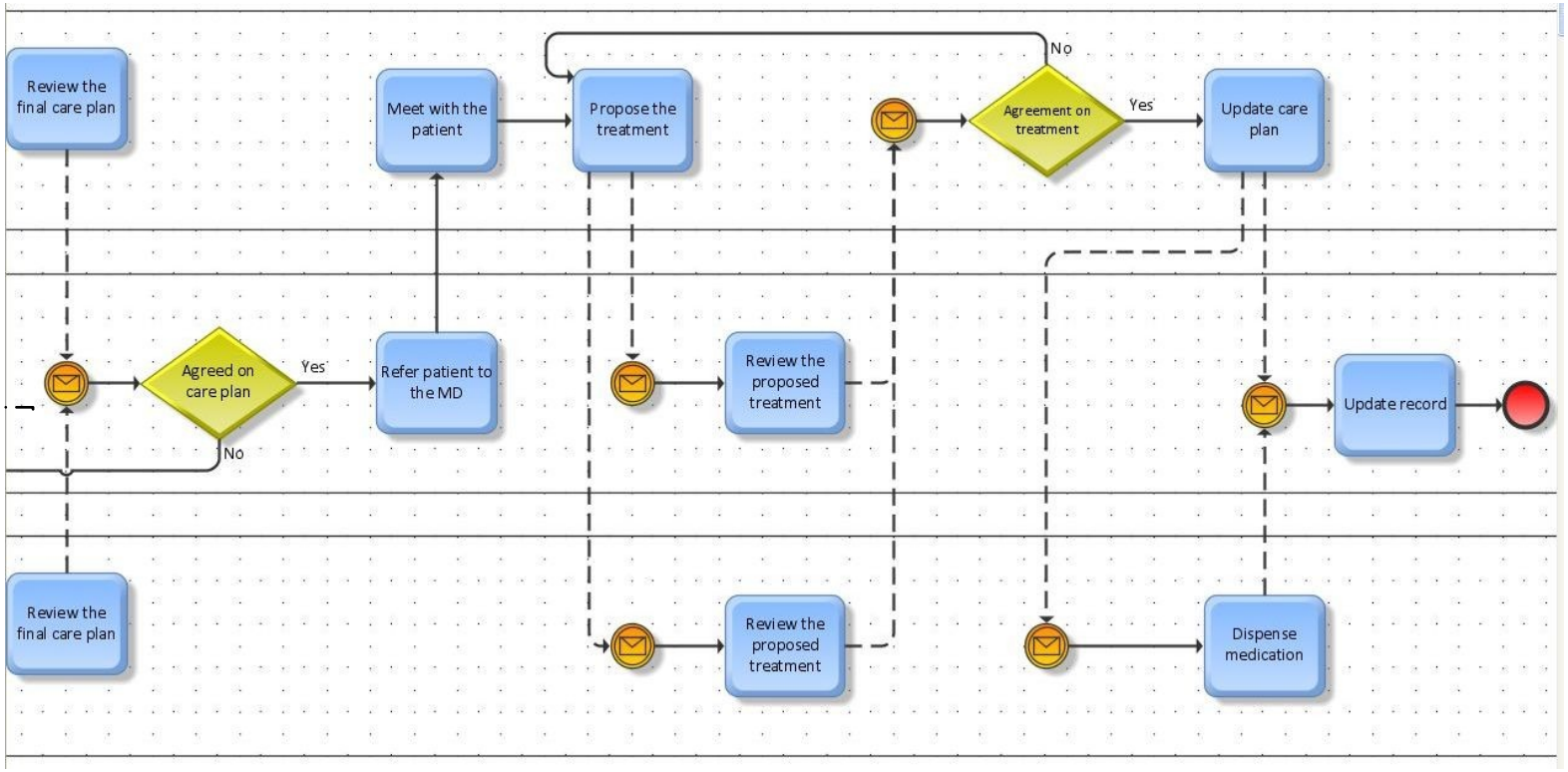

Figure 14. BPMN depicting the 'infer' process in an interdisciplinary setting (cont. from fig. 13)

Model Information

- 3 actors
- multiple events, connecting objects and activities.

Similar to the model depicted in figure 12, the professionals in the process of 'inferring' but the team setting here is interdisciplinary. The nurse (team leader) initiates the care plan and the process progresses.

This setting (interdisciplinary) is more complex than the former with a bigger model size as well (figures 13 and14), this stems from the explanation of such a team type as a closer knit is emphasized among team members. After the nurse initiates the care plan, it is sent to other team members to inform them of the patient's current status, changes are made to the plan if necessary and a final plan is made available after all concerned team members have arrived at an agreement (figure 13). The MD meets with the patient, proposes treatment and perhaps other alternatives and informs the other concerned team members of this decision. The team members go ahead to review the treatment plan leading to an update of the care plan by the MD after there had been an agreement, the pharmacist is then informed of the prescription after which medications are dispensed. The nurse is notified then goes ahead to update the patient's record (figure 14).

Scenario 5

- This scenario comprise three participants:
    - Medical Doctor (MD)
    - Nurse
    - Pathologist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

This scenario (and the next) is slightly different from the already described ones as emphasizes here is not based on type of process rather on other factors which would be explained shortly.

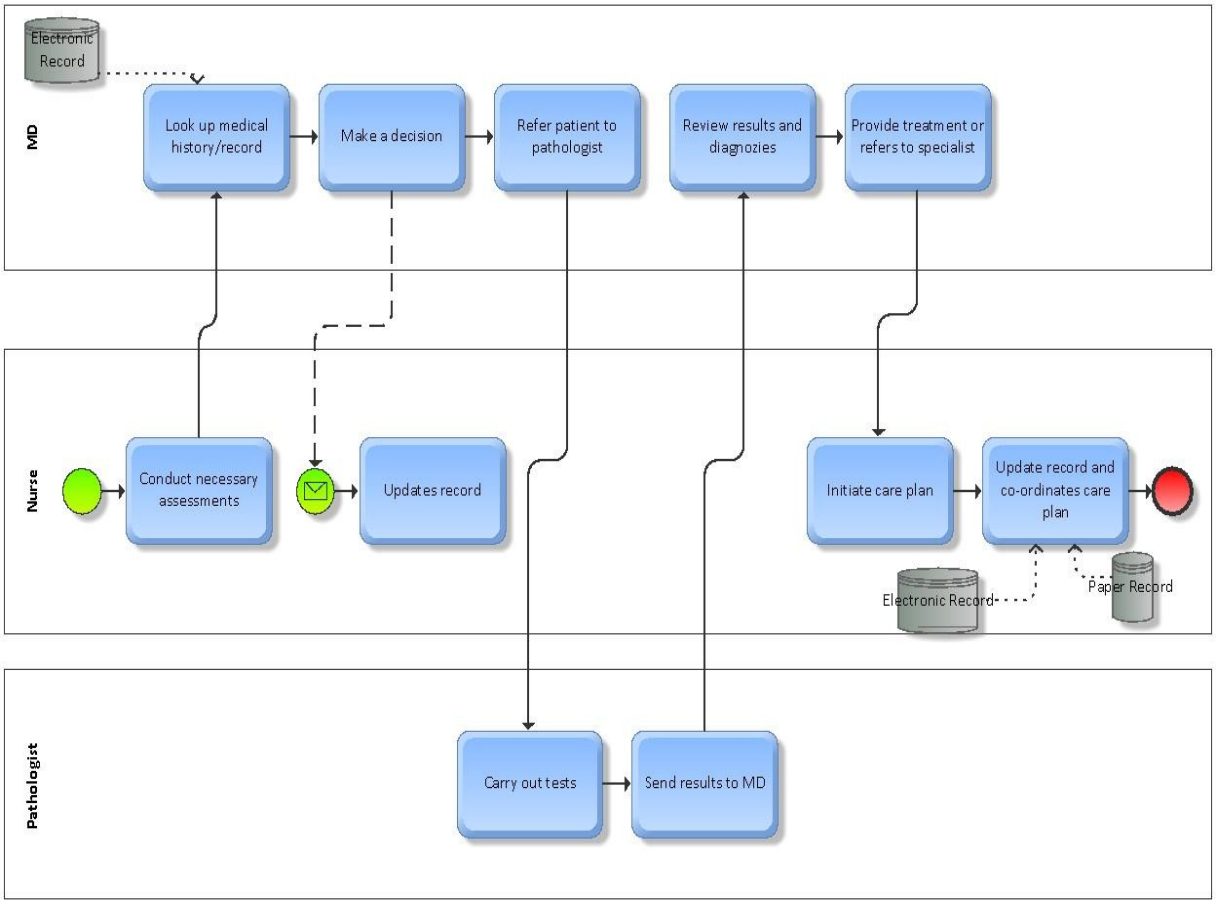

Figure 15. Multidisciplinary scenario

Model Information

- 3 actors

- 2 data objects
- multiple events, connecting objects and activities.

The model above depicts a multidisciplinary team setting (figure 15), the nurse conducts necessary assessments, the MD then looks up the medical history/record, makes a decision to refer the patient to the pathologist while informing the nurse who then updates the record. The pathologist carries out the test, sends the results to the MD who reviews it and makes a diagnosis, after which a referral to a specialist is made or treatment is given as the case may be. The nurse initiates the care plan then updates the patient's record.

A couple of the (multidisciplinary) factors could be highlighted in the model, some of which are 'members from different disciplines working independently', 'participants having separate but interrelated roles' and 'participants maintaining own disciplinary roles'.

Scenario 6

- This scenario comprise three participants:
    - Medical Doctor (MD)
    - Nurse
    - Pathologist

- The nurse is the patient's care coordinator in this instance as well as the team leader.

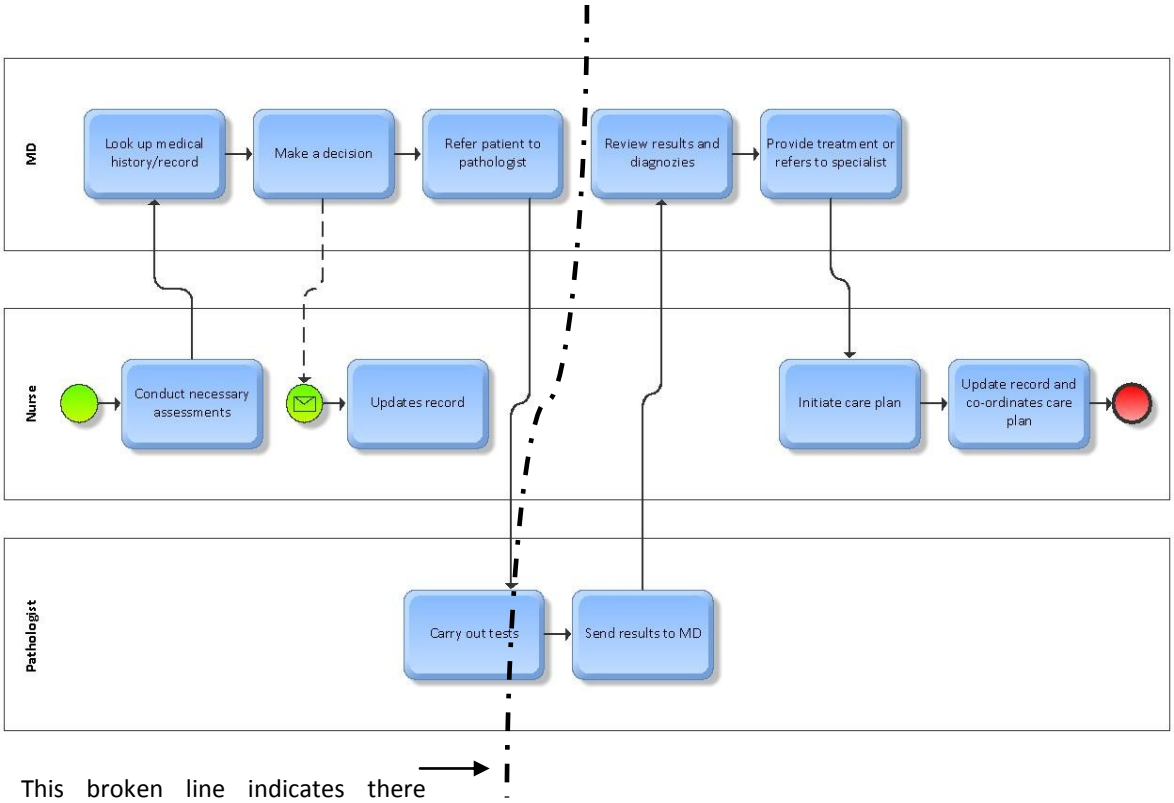

Figure 16. Interdisciplinary scenario

This model shares the same characteristics with the former (figure 15) but in an interdisciplinary setting. BPMN was not able to sufficiently model this process because the 'carry out test' activity would require a series of actions such as communicating the initial findings with the MD even before the final results are out. Such control/information flow is not supported for an on-going process in BPMN. The dashed line indicates how far such modeling would go.

The summary of our observations in this section of our research is presented in table 5 below and further elaborated upon in the following paragraphs.

As mentioned earlier, our modeling focused mainly on how organizational management features (particularly collaboration) influences team workings as this was the distinguishing factor among the team types as identified in our ontology. These features have an effect on all the processes involved in care delivery regardless of the team type. We therefore highlight some of these factors alongside some of the other concepts shown in the mind map.

Similar to the scoring/evaluating system in List and Korher B. (2006), where BPMN adequately modeled a factor, a sign (+) is assigned. If the factor cannot be presented by the language, we use the (-) sign. If the factor can be partially presented or adequately presented in some scenarios and otherwise in other scenarios, the sign (+/-) is used. Comments are also given alongside.

Table 5. Evaluation of BPMN to model highlighted features

Concepts/Features		**Aptness of BPMN to model**	**Comment**
Location	Same	+	This is depicted by using packages, contexts within the same location can be modeled in the same package as in figs. 10 and 11
	Different	+	
Process	Meet	+	These are the actual processes that were modeled (see figs. 10 and 12). Other factors define these processes.
	Infer	+	
Information storage	Required	+	BPMN allows use of data objects; this can be used to depict information storage (see figs. 10, 11 and 15). But in an instance of multiple data objects, no specifications can be made as to how much (what
	Produced	+	

			percentage) of data is retrieved or stored from each data object.
Information exchange	One-to-one	+	'Events' were used to represent information exchange as shown in all the models above. There are other ways to show this as well in BPMN such as using 'fork' for multiple participant info. exchange.
	multiple	+	
Information management	Security	-	BPMN does not provide such features. Extensions have been designed to cater to such needs (Rodriguez A. *et al.*, 2007)
	Access controls	-	
Team constituent	Role designation	-	Specific tasks cannot be assigned based on roles.
	Participant identification	+	Each actor can be named/identified as seen in all the models.

Team responsibilities/goals	Separate roles	+	Using swim lanes alongside participant identification allow for identification of boundaries as seen in the models above.
	Interrelated roles	-	Interrelated roles could not be modeled as boundaries could not be blurred.
Team properties	Synchronization (in between tasks)	-	As seen in fig. 16, tasks have to be completed before the process can progress
	Collaboration	+/-	This would vary depending on the type of process and the team type setting.

Other Comments

- BPMN does not cater to designation of positions such as leader or member within a team; since a leader cannot be identified in the model, some responsibilities or roles cannot be incorporated in the model. Although it allows for each participant to be identified (i.e. named).

- Modeling processes for teams in interdisciplinary settings is more challenging as there is a need for a lot of feedbacks which is needed for effective collaboration.
- Models for interdisciplinary team settings are much larger in size compared to their multidisciplinary counterpart.
- Concurrent synchronization of tasks is not possible.
- Modeling collaboration for the 'meet' sub-process was possible. Technology-enabled support systems provide a platform for this in reality also supporting asynchrony. Collaboration for ‘infer’ could only be partially modeled and collaboration in decision making could not be modeled.

In conclusion, modeling processes in either type of teams are inherently complicated just as healthcare delivery itself. One of the reasons is that care delivery is almost always customized to meet the largely varying need of patients. Also, since these processes involve several human interactions both in giving and receiving care, modeling could be intricate.

In the concluding chapter, discussions and suggested future works are suggested as well as some of the limitations of this study.

Chapter 6: Discussion and Future Works

While there have been several calls from many quarters for team-based care delivery, there still seems to be dearth in such type of care delivery for some reasons. An important one which this thesis focused on is the absence of technological models for information systems. Although, several research initiatives have focused on teamwork in healthcare, there is still an absence of a model.

This thesis presents our research on modeling teams in healthcare. We took into account the complexity and peculiar nature of the industry, the actors and needs. We aimed to develop a model that would support team-based design in complex domains such as healthcare.

The healthcare domain happens to be quite a challenging one with intention of team-based care delivery making both development and design more intricate. The complexity of healthcare processes, the diversity of the professionals, the tight government regulations, the varied needs of patients among others are the source of those challenges.

Although, the challenges have been identified by researchers and designers, there has been little effort to develop a model that would attempt to highlight these complexities as a technology is only as good as the model on which it is built.

For such a model to be developed, there needs to be a good understanding of teams (what they comprise of and how they function).

We identified team concepts associated with healthcare processes as a foundation to possibly designing a model.

We identified the types, dependencies and needs of healthcare teams, we then went ahead to depict this in a mind map. We then formalized the model of the teams in an ontology, creating instances and incorporating attributes of different team types as found in literature using one of the most used modeling language in healthcare- BPMN to evaluate the instances as well as.

With our design science methodology, we identified team concepts from literature review and case-studies. We found out that many of the similar works that have been done focused only on single settings, and there is little work that has been done in incorporating all the different aspect of multidisciplinary settings. It is worth to mention that that we also developed a reference model for team processes which came along while we identified team concepts.

Howbeit, our results show that BPMN does not satisfy all the requirements for modeling multiple-disciplinary team settings. In chapter four, the results of the ontology showed that the major difference in team types lies in their degree of collaboration, in the chapter five, we developed some models citing differences between multidisciplinary and interdisciplinary teams, and we found out that the language- BPMN does not have the capability to support all the attributes of each type of team. Also that processes in multidisciplinary settings may be easier modeled using BPMN compared to its counterpart- interdisciplinary teams. This however has to be addressed as literature has shown the needs and benefits of such team type.

As observed in the process modeling phase, BPMN does not sufficiently allow roles to be designated. This places a restriction as a leader (or any other role) cannot be defined, this does not allow for specific intervention by professionals playing a particular role. Participant identification is adequately modeled, this is crucial as it helps to define function (area of specialization).

Also, BPMN would need the ability to allow for synchronization between tasks to be modeled to successfully support multi-disciplinary team processes, as this is imperative to such teams.

Security and control features were not represented as they are not supported; however, extensions have been developed in this regard.

We suggest the idea of combining features in other similar modeling languages to provide a platform whereby models which are better suited to the team type can be developed. In addition, BPMN should be expanded to cater to synchronization between on-going task as well as role designation among others.

There are a few imitations related to our research and this thesis. Firstly, this thesis as an exploratory study focused on identifying team concepts, the concepts were not prioritized in any order throughout the stages of modeling. Also, only one ontology application and modeling language was used creating a possibility of a different outcome if some others were used. Lastly, the work-flows in the scenarios were based on make-believe instances rather than real-life occurrences.

Future works can be done in the area of developing an information system prototype, testing and expanding the ontology, trying real-life scenarios as well as using other languages for modeling.

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