Cognitive Work Analysis to Support Collaboration in Teamwork Environments

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Cognitive Work analysis (CWA) as an analytical approach for examining complex socio-technical systems has shown success in modeling the work of single operators. The CWA approach allows room for social and team interactions, but a more explicit analysis of team aspects can reveal more information for systems design. CWA techniques and models do not yet provide sufficient guidance on identifying shared constraints, team strategies, or social competencies of team players. In this thesis, I explore whether a team approach to CWA can yield more information than a typical CWA. Team CWA techniques and models emerge and extend from theories and models of teamwork, past attempts to model teams with CWA, and the results of two sets of observational studies. The potential benefits of using Team CWA models in domains with strong team collaboration are demonstrated through the results of a two-week observation at the Labour and Delivery Department of The Ottawa Hospital and a fifteen-week observation at the IBM Ottawa Software Group.

Acknowledgements

I am incredibly indebted to Dr. Catherine Burns (Professor at the University of Waterloo) for her continuous support, thoughtful advice and warm encouragement throughout my doctoral program. I acquired an invaluable wealth of knowledge under her supervision and learned how to approach a research problem effectively. I sincerely enjoyed the experience of working with her which trained me for my future career and life.

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The observational works of this thesis were conducted at the IBM Ottawa Software Lab and The Ottawa Hospital. I would like to thank all team members of the IBM Extreme Blue program who assisted in data collecting for my observational study. I wish to express my deep gratitude to Steve Gutz and Maria Smirnoff at the Business Analytics Group for their insightful comments and suggestions on my IBM experience. I am highly thankful to Kathy Momtahan and Barbara d'Entremont at the Nursing Professional Practice Department of The Ottawa Hospital who assisted in this work by providing access to the collaboration scenarios within the birthing units of the hospital.

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Dedications

To my beloved parents

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List of Acronyms

Acronym	Definition
AH	Abstraction Hierarchy
AW	Abstraction Wheel
AWT	Abstraction-Wheel Table
CAT	Contextual Activity Template
ConTA	Control Task Analysis
CT	Collaboration Table
CWA	Cognitive Work Analysis
DW	Decision Wheel
DWT	Decision-Wheel Table
EID	Ecological Interface Design
IFM	Information Flow Maps
OR	Operating Room
SA	Situation Awareness
SAD	Strategies Analysis Diagram
SOCA	Social organization and cooperation Analysis
SNA	Social Networking Analysis
SME	Subject Matter Expert
StA	Strategies Analysis
Team ConTA	Team Control Task Analysis
Team CWA	Team Cognitive Work Analysis
Team SA	Team Situation Awareness
Team StA	Team Strategies Analysis
Team WCA	Team Worker Competencies Analysis
Team WDA	Team Work Domain Analysis
WCA	Worker Competencies Analysis
WDA	Work Domain Analysis

Definitions

Term	Definition
Collaboration	*Collaboration occurs when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain* (Wood, Gray, 1991, p. 146).
Competence	*Competence is conceptualized in terms of knowledge, abilities, skills, and attributes displayed in the context of a carefully chosen set of realistic professional tasks, which are of an appropriate level of generality* (Hager & Gonczi, 1996, p. 15).
Coordination	*The act of managing interdependencies between activities performed to achieve a goal* (Malone & Crowston, 1990, p.6).
Strategy	*A category of cognitive task procedures that transform an initial state of knowledge into a final state of knowledge* (Vicente, 1999, p. 220).
Team	*A distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership* (Salas, Dickinson, Converse, & Tannenbaum, 1992, p.4).
Team role	*A pattern of behaviour characteristic of the way in which one team member interacts with another so as to facilitate the progress of the team as a whole* (Belbin 1981, p. 169)
Work domain	*The system being controlled, independent of any particular worker, automation, event, task, or Interface* (Vicente, 1999, p.10).

Chapter 1
Introduction

In teamwork environments, collaboration is critical; however, the requirements for such collaboration are not often considered in designing socio-technical systems to facilitate that collaboration. Designing for collaboration requires the consideration of participation, cooperation, social contact, and interaction factors present in a team environment. However, it is observed that teams often do not perform to their potential due to an inadequate awareness of team goals, conflicts between team members, mismatched individual goals, and breakdowns in process and coordination between team members. In this thesis, I focus on addressing these problems by creating a theoretical framework to reveal design requirements for technologies that support team collaboration. Much of the existing research literature focuses on evaluating team effectiveness, while there are relatively few design approaches for examining team design requirements. This work fills a gap by creating the theoretical basis for transforming knowledge about team effectiveness into team-supporting technologies that will improve team performance and collaboration.

In the sections that follow, the problem statement is reviewed, the research objective is identified, and the thesis structure is discussed.

1.1 Problem Statement

There have been several attempts at defining the term team, but the most recognized definition is the one by Salas, Dickinson, Converse, and Tannenbaum (1992). Salas et al. (1992) define a team as "a distinguishable set of two or more people who interact dynamically, interdependently and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership" (p.4). The highlight of this definition is the distinction between individuals' behaviours and the emergent behaviours as a team. While there are reasonably good measures in the literature for evaluating team efficiency (e.g., Brannick, Salas, & Prince, 1977; Cooke, 2005; Gorman, Cooke, & Winner, 2006; Guzzo, Salas, & Associates, 1995; Heinemann & Zeiss, 2002; Salas, Goodwin, & Burke, 2008; Swezey & Salas, 1992), very few approaches have focused on how to design proper technologies to improve team performance. Team Situation Awareness (Team SA) is one exception that has shown good results for differentiating the information requirements of individuals and teams (Endsley and Robertson, 2000 provide an example). A complementary approach to SA has been Cognitive Work Analysis (Vicente, 1999). While SA takes a cognitive information-processing approach to deriving requirements, CWA builds constraint-based models of a socio-technical system, seeking to reveal functional behaviour. CWA was developed explicitly for the purpose of analyzing complex systems where unanticipated events could occur (Vicente, 1999). While CWA has shown success in modeling the work of single operators (e.g., Bisantz & Mazaeva, 2009; Burns, Enomoto, & Momtahan, 2009; Effken et al., in press; Flach & Amelink, 2003; Groppe, Pagliari, & Harris, 2009; Ho & Burns, 2003; Naikar, 2009), relatively few attempts have been made to use CWA for modeling team situations (e.g., Ashoori & Burns, 2010; Burns, Torenvliet, Chalmers, & Scott, 2009; Burns & Vicente, 1995; Euerby & Burns, in press; Naikar, Moylan, & Pearce, 2006; Rasmussen, Pejtersen, & Schmidt, 1990). Through building constraint-based models of socio-technical systems, CWA has potential to be explicitly used to inform design specifications and extract design requirements for teamwork environments. However, CWA techniques and models do not yet provide sufficient guidance on identifying shared constraints, team strategies, or social competencies of team players. There has not been a concerted effort to study how CWA can be used for teams. The CWA approach allows room for social and team interactions, but a more explicit analysis of team aspects can reveal more information for systems design. The main question asked in this thesis is "Whether a team approach to CWA can yield more information than a typical CWA?" In the following sections, I will further refine this question to discuss the objective and the structure of the research performed in the thesis.

1.2 Research Objective

When designing collaborative systems for teamwork environments, a deep understanding of teamwork principles, such as shared processes and team strategies can considerably affect the design requirements and eventually the quality of the final product. Hence, the challenge in designing a teamwork solution is to study teamwork not only at a task level or a strategy level but also in a broader spectrum to include physical work-domain elements of the teamwork environment as well as the requirements for effective teamwork.

The fourth level of the CWA approach, social organizational analysis, allows room for social and team interactions. In recent work, as people have tried to develop social organizational analysis for their work domains; a plethora of different approaches have emerged. For example, Burns, Bryant, and Chalmers (2005) modeled the soft constraints that were introduced in work domains with strong intentional components; Hajdukiewicz et al. (2001) modeled work-domain regions to show where individuals needed to collaborate; and Naikar et al. (2006) modeled team activity. The existing approaches use models and ideas from many different phases to look at the social organization analysis. It became apparent in reviewing this work that social organizational analysis is in reality more than one phase and deserves a more in-depth treatment. Indeed, social organizational interactions have a complexity of their own, and result in a broad set of social and functional constraints influencing not only work-domain elements and control tasks, but also strategies, and worker competencies. Workers have social strategies as well as a range of social competencies that have not been adequately discussed in the previous attempts to use CWA for establishing collaborative work requirements. For this reason, I am proposing that it could be useful to modify the traditional five-level CWA approach to a 2x4 approach, where there is a parallel set of social or team models (Ashoori & Burns, 2010). While this new structure may not be needed in all cases, I suggest that such a framework could be useful in modeling socio-technical systems with a strong social component. In Team CWA, I look past individual work to identify teamwork constraints in four different levels: (1) Team Work Domain Analysis (Team WDA), (2) Team Control Task Analysis (Team ConTA), (3) Team Strategy Analysis (Team StA), and (4) Team Competencies Analysis (Team WCA). Figure 1 shows the connections between the original five-level CWA approach and the proposed Team CWA.

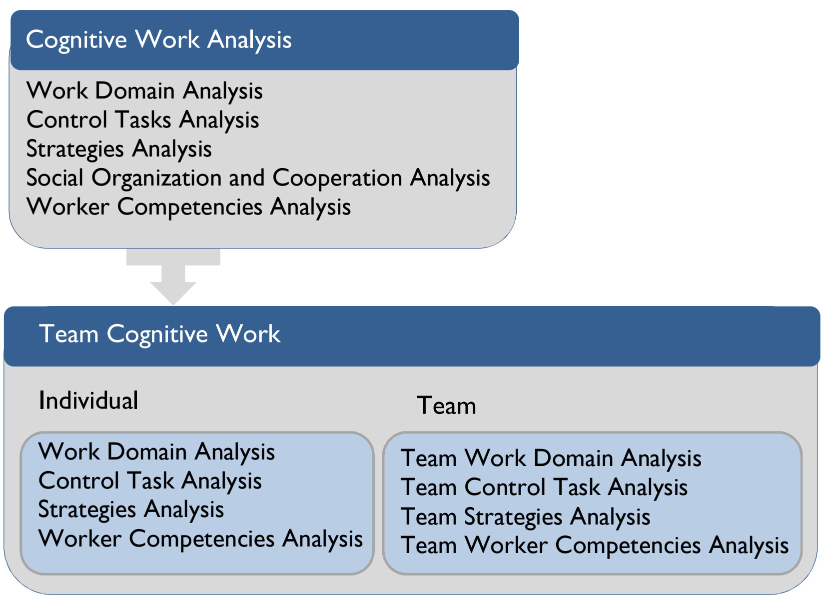


Figure 1. Team CWA as an Extension to CWA for Teamwork Environments. (Taken from Ashoori and Burns, 2012)

Team CWA suggests techniques and models that leverage the synergy between social organization analysis and the available guidelines of CWA for individual work analysis. Considering the social aspect of collaboration, Team CWA starts with a high-level analysis of teamwork within the work domain and drills down to shared tasks, teamwork strategies that accomplish those tasks, and qualifications that operators should exhibit for effective teamwork. The rest of this thesis is focused on the concepts, guidelines, and case studies for Team CWA.

Figure 2 shows the structure of this dissertation. Three research stages were completed, which are shown as the blue rectangles. The discussion part indicates the values, outcomes, and theoretical work underpinning each stage.

Stage 1: At the first stage, the theoretical basis for the extended models was explored. I reviewed the CWA framework as well as other key theories and models of teamwork, such as Team SA (Endsley, 1995), team development models (Tuckman & Jensen, 1977), and distributed cognition (Hutchins, 2000) that might lend more insight into how people collaborate and, thereby, could suggest ways in which CWA could be enhanced.

Stage 2: The second stage involved developing models and techniques of Team CWA phases. For each phase, I explored the values gained from the extended models in comparison to the commonly used basic CWA approaches. Team WDA was discussed in comparison to both the basic WDA (Rasmussen, Pejtersen, & Goodstein, 1994) and the existing WDA extensions for teamwork environments (e.g., Burns, Bryant, & Chalmers (2005) and Hajdukiewicz et al. (2001)). The second phase, Team ConTA, was compared to the basic ConTA (Rasmussen et al., 1994; Vicente, 1999) as well as the existing attempts on the use of ConTA for teamwork environments (e.g., Naikar, Moylan, & Pearce, 2006 and Jenkins et al., 2008b). The value gained from Team StA was evaluated in comparison to a basic StA for individual work (Vicente, 1999) and existing StA extensions for extracting collaborative requirements (e.g., Jenkins et al., 2008a). Finally the last phase, Team WCA, was evaluated in comparison to the basic WCA guidelines discussed by Rasmussen (1983), and Kilgore et al. (2006).

Stage 3: After developing the analytic models, I explored the applicability of the extended models for two different environments: (1) team interactions for an agile software development team at the IBM Ottawa Software Lab, (2) team interactions for a surgical team at the Labour and Delivery Department of The Ottawa Hospital.

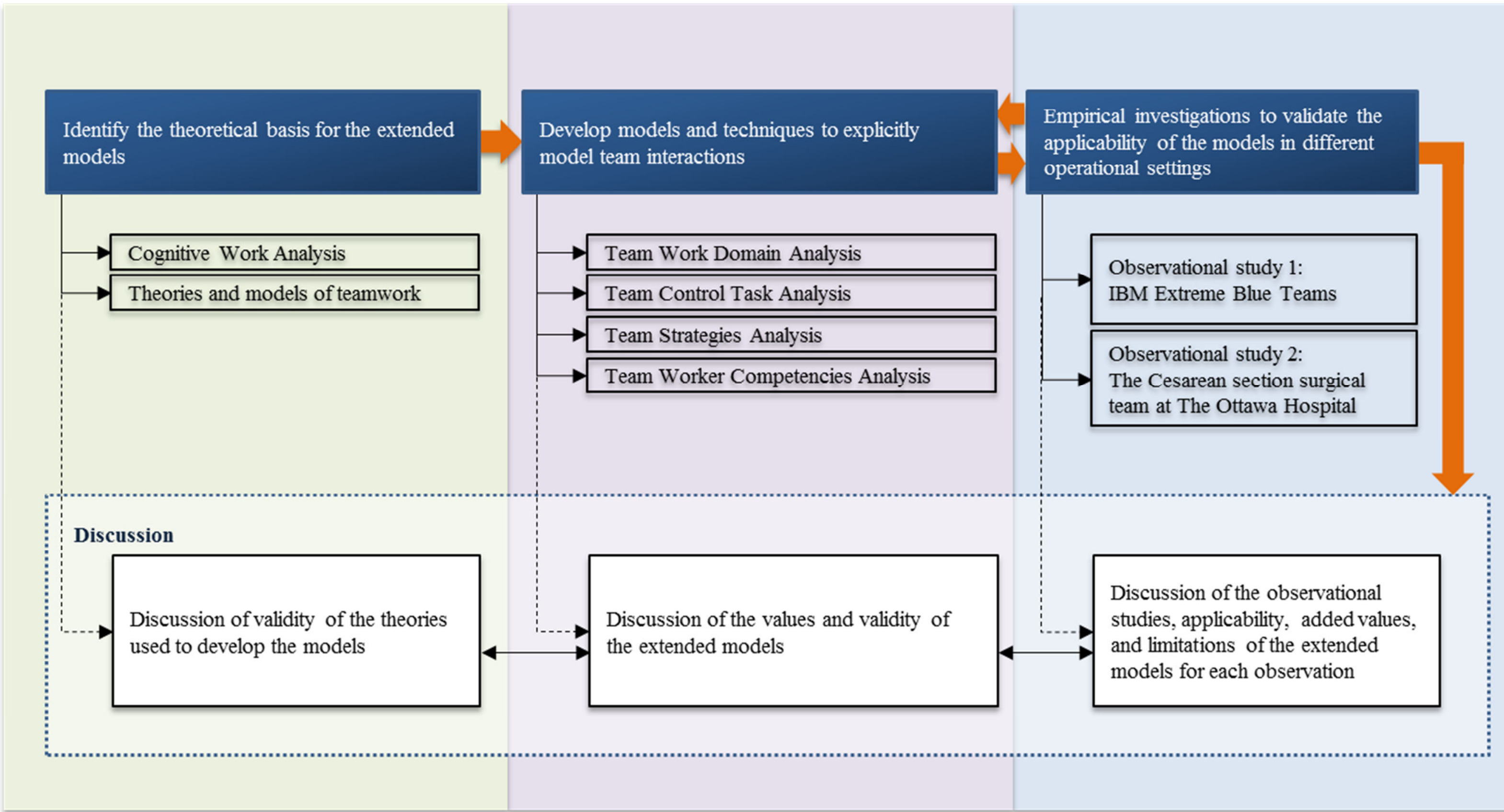


Figure 2. Structure of the Research Performed in the Thesis, Described as Three Stages.

In each section, the extended models were evaluated for suitability for use in operational settings. The values gained from each model were deliberated and the limitations for each approach were discussed in detail. In the chapters that follow, I will discuss the findings of each stage in more detail.

1.3 Thesis Overview

Figure 3 provides an overview of the structure thesis that will be used to introduce its themes at the start of each chapter to put the chapter material in context.

Chapter 1, the present chapter, provides an overview of the thesis. In Chapter 2, the literature on the use of CWA is presented and the techniques and models for each CWA phase are explored. Chapter 2 will show that CWA as a constraint-based method that has been successfully used for analysis of single operators has potential to be used for extracting collaborative requirements. Chapter 2 will also review some theories and models of teamwork that may lend insight in revamping CWA for teams.

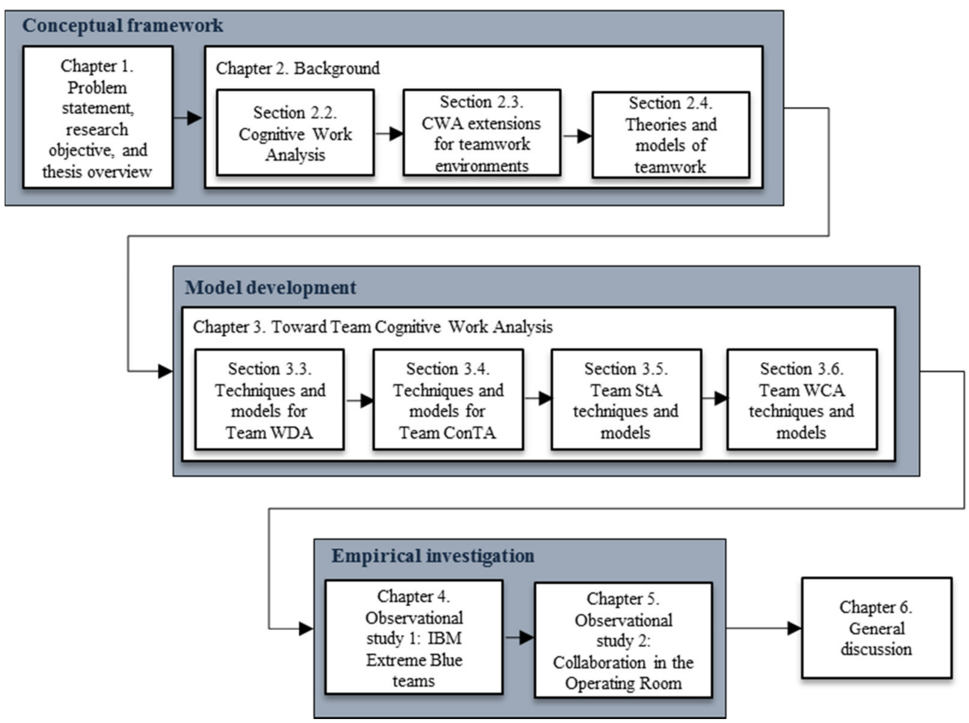


Figure 3. Thesis Overview.

In Chapter 3, the development of Team CWA models are described. The constraint-based models that are produced are responsibility maps, Collaboration Tables (CTs), Abstraction

Wheels (AWs), extended Contextual Activity Template (CAT) for teams, Decision Wheels (DWs), different categories of team strategies, and worker competencies.

In Chapter 4, the extended models are explored for a small software development team at the IBM Software group. During 15 weeks, I studied a team of four interns within the IBM Extreme Blue program. This observation provides an analysis of the whole team lifecycle for a small agile team with a hierarchical team structure. In Chapter 4, I will demonstrate how the extended Team CWA models fit within a hierarchal team structure.

The results of my second set of observations at the Labour and Delivery Department of The Ottawa Hospital are presented in Chapter 5. The surgical team provides a good example for the analysis of team requirements in various situations. The coordination structure, team strategies, responsibilities, and the expertise of the Operating Room (OR) crew would be different in an emergency situation versus a normal surgery. I will explore how my extended Team CWA models would fit within a highly dynamic critical environment.

In Chapter 6, a summary of the results is given, values and significant outcomes of this research are described, theoretical implications are stated, limitations of the current research are identified, and further avenues for research are presented.

Chapter 2
Background

Figure 4 provides an overview of thesis structure with the highlighted chapter material for Chapter 2. In this chapter, I will review the previous attempts to use CWA for extracting collaborative requirements as well as the theories and models of teamwork that may lend more insight into how people collaborate and, thereby, suggest ways in which CWA could be enhanced.

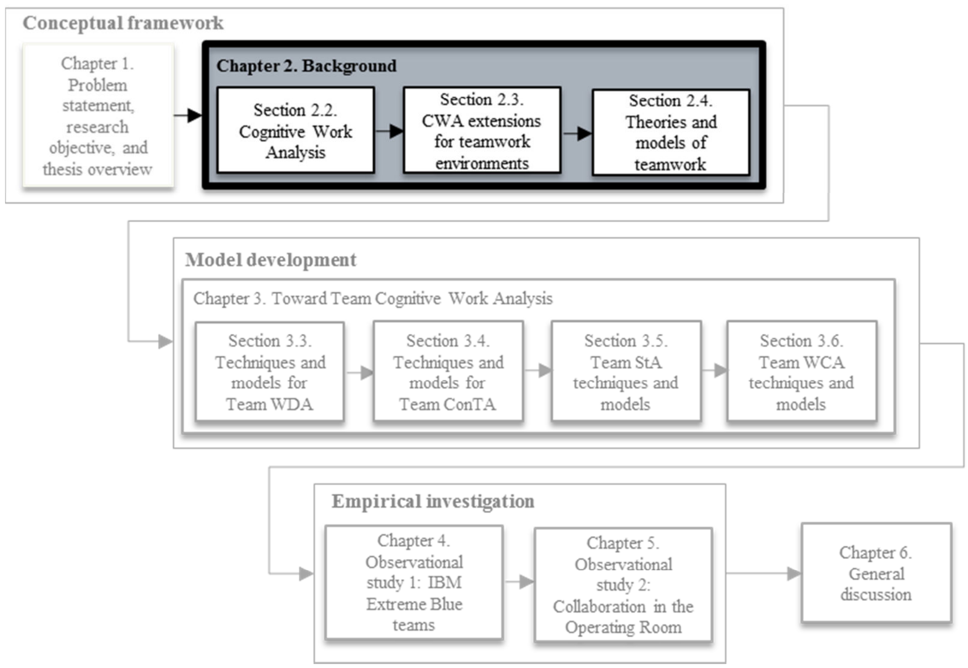


Figure 4. Chapter 2 Overview.

2.1 Introduction

Cognitive Work Analysis (CWA) is gaining momentum as a tool for analyzing complex socio-technical systems (Rasmussen, Pejtersen, and Goodstein, 1994; Vicente, 1999). CWA provides a set of five generic analyses that can be used to understand a field of work. In this section, I describe CWA phases and present the literature on techniques and models for each analysis. Much of the previous work on using CWA for designing socio-technical systems has not explicitly described the analysis of teamwork. There are several models of teamwork and coordination that may lend more insight into how people collaborate and, thereby, suggest ways in which CWA could be enhanced. In this chapter, I will also review some of these theories and models of teamwork and discuss their values to enhance my Team CWA models.

2.2 Cognitive Work Analysis

CWA emerged from the work of Jen Rasmussen and his group at the Risø National Laboratory in Denmark while they were completing a project to design a safe nuclear power plant for the Danish government (Vicente, 1997). Kim Vicente further developed this framework to introduce it as a framework for designing "safe, productive, and healthy computer-based work" (1999). CWA provides a comprehensive structure for extracting design constraints using five different analyses of (1) work-domain elements, (2) control tasks (3) strategies, (4) social and organizational constraints, and (5) worker competencies (Figure 5).

In the following sections, I will discuss these phases along with the techniques and models that I suggest for each phase.

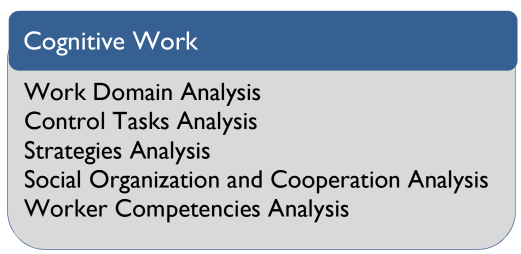


Figure 5. An Outline of the CWA Framework, Vicente's Notation (1999).

2.2.1 Phase I: Work Domain Analysis

Work Domain Analysis (WDA) examines the fundamental domain constraints that the user wants to control or to have information about. Stable behaviour-shaping constraints, such as purpose of the work, values, priorities, processes, and resources, are identified within this phase. Through the analysis of the field of possible actions, and a thorough understanding of the work-domain constraints, human factors practitioners may design displays that can help operators to reason effectively in unanticipated situations.

The Abstraction Hierarchy (AH) is a tool, introduced by Rasmussen et al. (1994), for analyzing work-domain constraints. A typical AH consists of five levels of work-domain constraints: (1) functional purpose, (2) abstract function, (3) generalized function, (4) physical function, and (5) physical form.

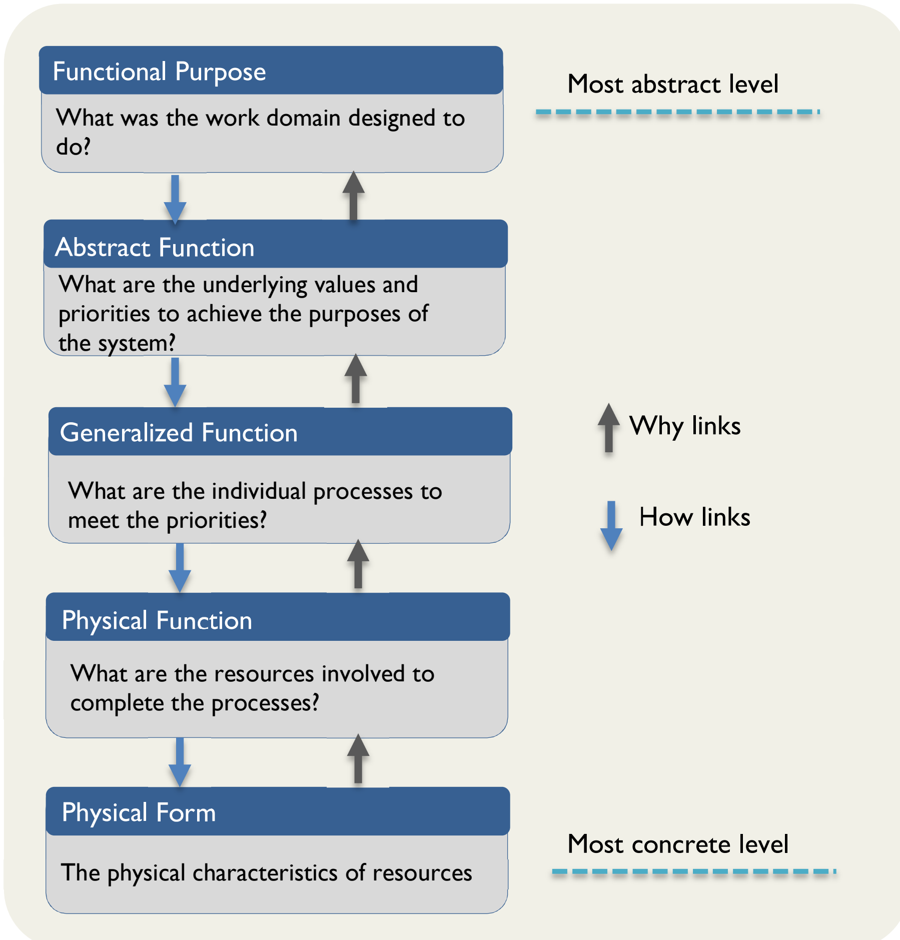


Figure 6. The Five Levels of the Abstraction Hierarchy. (Adapted from Burns and Hajdukiewicz, 2004)

As shown in Figure 6, the links between each level indicate how the higher element is achieved, or, in reverse, why the lower level is available. The AH provides a good mechanism to identify how constraints in one level affect the level below or above.

There has been several data collection approaches suggested for performing WDA. Field observations (Rasmussen, 1980), document analysis (Bisantz & Mazaeva, 2009), and pre-planned interviews with Subject Matter Experts (SMEs) (Naikar, Hopcroft, & Moylan, 2005) are examples.

2.2.2 Phase II: Control Task Analysis

Control Task Analysis (ConTA), the second phase of the CWA framework, examines the constraints on what needs to be done and allows identifying design requirements associated with control tasks. As discussed by Vicente (1999), the object of analysis in this phase changes from the thing being controlled (i.e., the work domain) to the requirements associated with effective control (i.e., control tasks). In this section, I explain how control-task constraints inherit and build on the work-domain constraints. Figure 7 shows the relation between control tasks and the work domain.

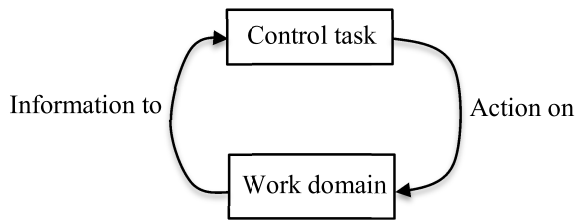


Figure 7. Simplified Diagram of the Relation between Control Tasks and Work Domain. (Taken from Vicente, 1999)

Rasmussen et al. (1994) describe ConTA as an analysis to assess what needs to be done, independently of how or by whom. They presented the decision ladder as a generic template for breaking down an operating mode into its constituent states of knowledge and information-processing activities. A typical decision ladder (shown in Figure 8) consists of a set of boxes to represent information-processing activities and ovals to represent the states of knowledge. In this model, various information-procession steps are involved in decision making, each one transforming one state of knowledge into another. Operators as the decision makers step by step evaluate what's going on, what lies behind that, what is the target goal, and how to achieve that. However, the expert operators might not follow a linear information-processing structure. Rasmussen et al. (1994) describe these shortcuts as shunts and leaps. Shunts connect information-processing activities to their output states of knowledge, and leaps associate states of knowledge.

As with the data collection techniques for WDA, researchers suggest several empirical approaches for performing ConTA. Interviews with SMEs using questionnaires, surveys, and walkthroughs (Naikar, Hopcroft, & Moylan, 2005); field observations (Rasmussen, 1980); and performing task analysis methods (e.g., Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003)) are examples.

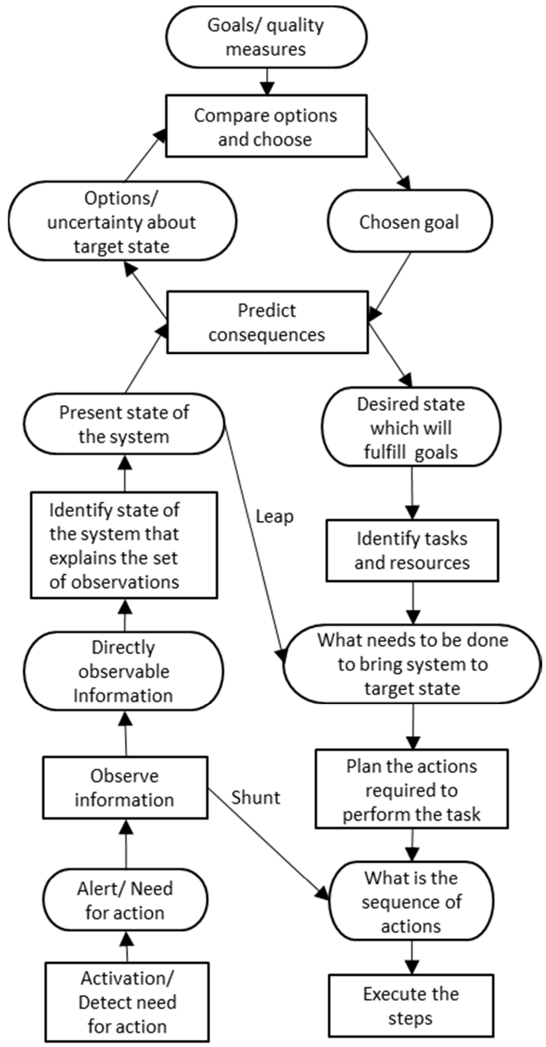


Figure 8. The Decision Ladder Template.
(Taken from Naikar, Moylan, and Pearce, 2006)

2.2.3 Phase III: Strategies Analysis

The value added by Strategies Analysis (StA) lies in understanding different ways to carry out the activities identified in a ConTA. StA allows designers to identify potential categories of generic strategies and identify design requirements associated with them. Vicente (1999) recommends an Information Flow Map (IFM) as a modeling tool for StA to represent cognitive procedures and different strategies to achieve a task goal. An IFM is application specific and often gets very complicated for complex tasks. Figure 9 shows an IFM that represents one state of knowledge transformed to another.

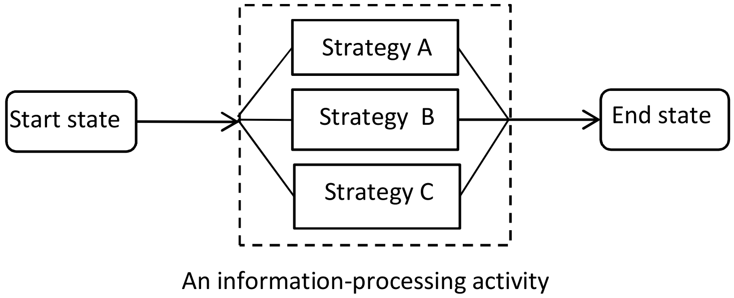


Figure 9. A typical Information Flow Map.
(Taken from Vicente, 1999)

Ahlstrom (2005) extends IFM to represent strategies as a sequence of actions. Figure 10 illustrates this approach.

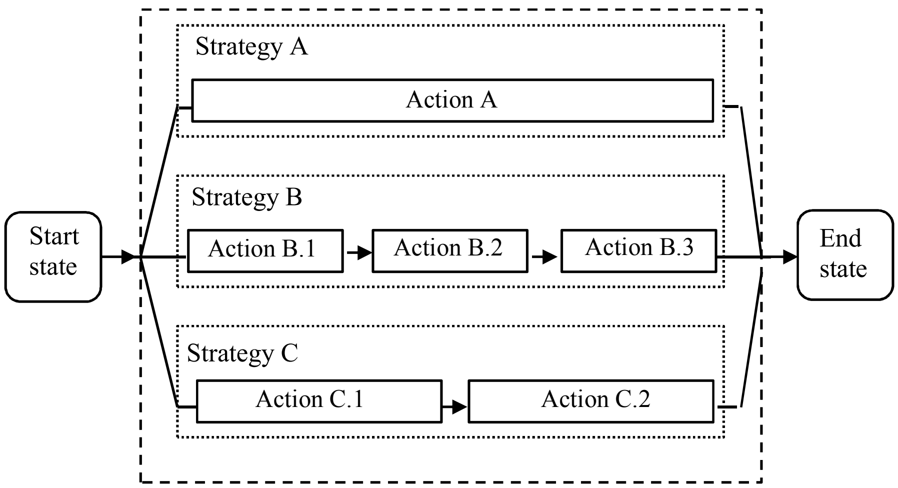


Figure 10. Strategies as a Sequence of Actions.

Although Naikar (2006) supports this adoption, she comments that StA is more concerned with an identification of categories of possible procedures rather than the detailed sequence of actions for each procedure. A formative analysis of strategies can result in specifications of strategies that are not compatible with the knowledge of actual domain-practitioners. In addition to a formative approach, the empirical methods, such as think-aloud analysis (Gray & Kirschenbaum, 2000) or Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003) are recommended to uncover practitioner knowledge and strategies.

2.2.4 Phase IV: Social Organization and Cooperation Analysis

While all other CWA phases focus on an examination of individuals' behaviours, Social Organization and Cooperation Analysis (SOCA) is used to study group behaviours and distribution of design requirements among individuals. Vicente (1999) recommends using the dominant modeling tools of the preceding CWA phases for this phase and brings up the discussion of mapping operators onto four different levels of

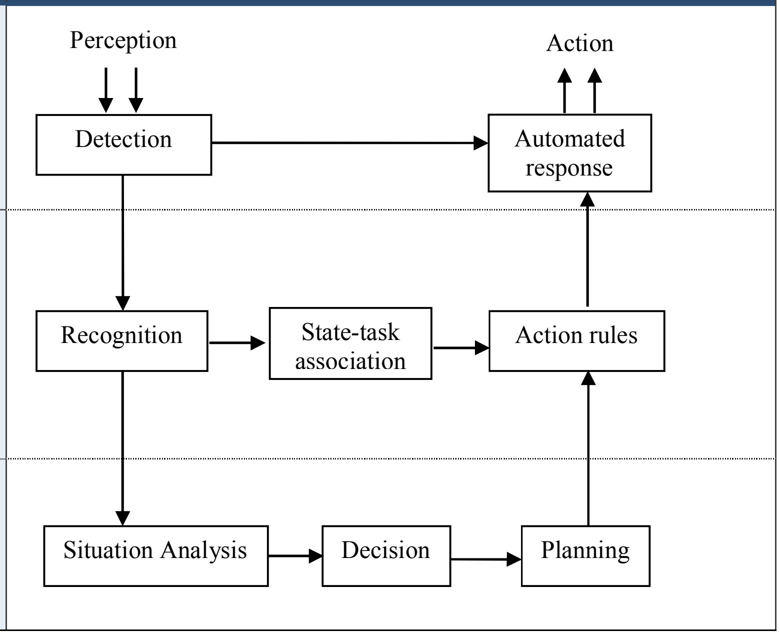
1. the work-domain model to identify which work-domain elements are shared and by which operators,
2. the decision ladder to study the allocation of control tasks to operators,
3. information flow maps to identify relationships between operators and how they contribute to executing the strategies, and
4. the structure of the organization to identify interaction patterns.

Much of the previous work on expanding techniques and models for SOCA has not considered worker competencies. In Chapter 3, I will discuss the functional and social competencies within the last phase of Team CWA, which is Team WCA. SOCA extensions and the literature on the use of the work-domain models, decision ladders, and information flow maps for modeling team interactions will be discussed in Chapter 3.

2.2.5 Phase V: Worker Competencies Analysis

Worker Competencies Analysis (WCA) consolidates all the requirements imposed by the preceding CWA phases for examining the implications of human characteristics in systems design. In this last phase, the focus is on psychological constraints to identify profiles of competencies that operators must possess in order to effectively perform control tasks. Much of the previous work on representing WCA constraints has used Rasmussen's (1983) Skills, Rules, and Knowledge (SRK) taxonomy. The SRK taxonomy defines three different categories of human behaviours: skill-based, rule-based, and knowledge-based. The first category, skill-based behaviours, occurs when there is no conscious behaviour control. An example is an experienced driver unconsciously driving within the lane. Table 1 shows the decision-making process for each for the SRK behaviours. For skill-based behaviours, perception is directly mapped to the actions. There is no major decision making involved here. The sensory input from the environments provides the signals for automated actions.

Table 1. Mapping of Human-Performance Model onto the SRK Taxonomy.

Rasmussen's SRK taxonomy (1983)	SRK schematic (adapted from Lintern, 2009a)
Skill-based behaviour	
Rule-based behaviour	
Knowledge-based behaviour	

Rule-based behaviours are guided through a pre-planned sequence of actions. For example, there is a rule for what to do when a traffic light is broken. Decision making for this category of behaviours involves recognition of the sensory input, comprehension of the state, and association of the sensory input to the output actions based on the stored rules for activities.

The last category, knowledge-based behaviours, involves decision making, situation analysis, planning, and reacting to contingencies. The sensory inputs are considered as the symbols to identify the situation, comprehend the consequences of an action, and plan for the possible set of actions.

Kilgore and St-Cyr (2006) present a SRK inventory, a matrix to describe potential operator behaviours for different information-processing activities identified in a ConTA. McIlroy and Stanton (2011) support this notation, but argue the need to consider the SRK discussion much earlier in the design lifecycle. They examine competencies based on general processes identified in a WDA, rather than a set of ConTA information-processing activities. This consideration of competencies at the work-domain level can create a direct link for examining how work-domain constraints influence the extraction of functional competencies. In Chapter 3, I will discuss functional competencies in more detail and will provide some examples of the SRK inventory for a healthcare scenario.

The SRK taxonomy can be used to adapt the interface to the capabilities and expertise of an operator in a specific task. Ecological Interface Design (EID) (Burns & Hajdukiewicz, 2004) is a well-known example of the applications of the SRK taxonomy in systems design.

In summary, CWA describes how a constraint-based analysis of a system may be performed and provides guidance to system analysts on techniques and models that are most appropriate for each CWA phase. While existing CWA techniques do not exclude the analysis of teamwork, they do not explicitly describe it adequately. In the following section, I will review the literature on using CWA for teamwork environments.

2.3 Cognitive Work Analysis for Teams

From a teamwork perspective, the goal of a WDA is to create a set of models for the team that describe the shared values, purposes, and priorities of teamwork. Some of the previous attempts to use WDA for establishing collaborative work requirements have examined joint work-domain models (Burns, Torenvliet, Chalmers, & Scott, 2009), work trajectories (Rasmussen, Pejtersen, & Schmidt, 1990; Burns & Vicente, 1995), responsibility maps (Hajdukiewicz et al., 2001), and the intentional WDA incorporating values or soft constraints (Burns, Bryant, & Chalmers, 2005).

Burns et al. (2005) suggest using the joint work-domain models to identify the shared work-domain elements between different team members. Figure 11 shows a "skeletal" model of the joint work-domain models for three team members. These parties interact with each other physically through the level of physical form and, then, depending on the work-domain constraints, they may share processes, principles, or purposes.

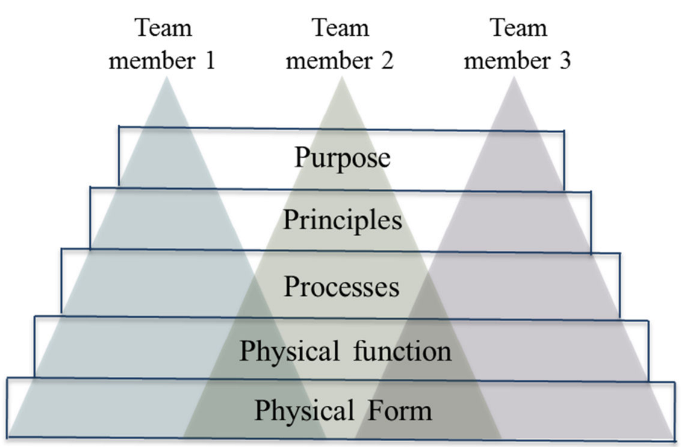


Figure 11. Joint Work-Domain Models.
(Adapted from Burns et al., 2005)

Joint work-domain models are appropriate when two or more team members share parts but not the entire same work domain.

Hajdukiewicz et al. (2001) recommend modeling the responsibility maps to show where individuals need to collaborate. They identify the work-domain regions that different team members act on. The overlap between the work-domain regions of team members may show how they work on a single work domain together. Figure 12 illustrates a hypothetical responsibility map for three team members. Responsibility maps can suffer from a scaling issue, being better suited to environments with only two or three clear team roles.

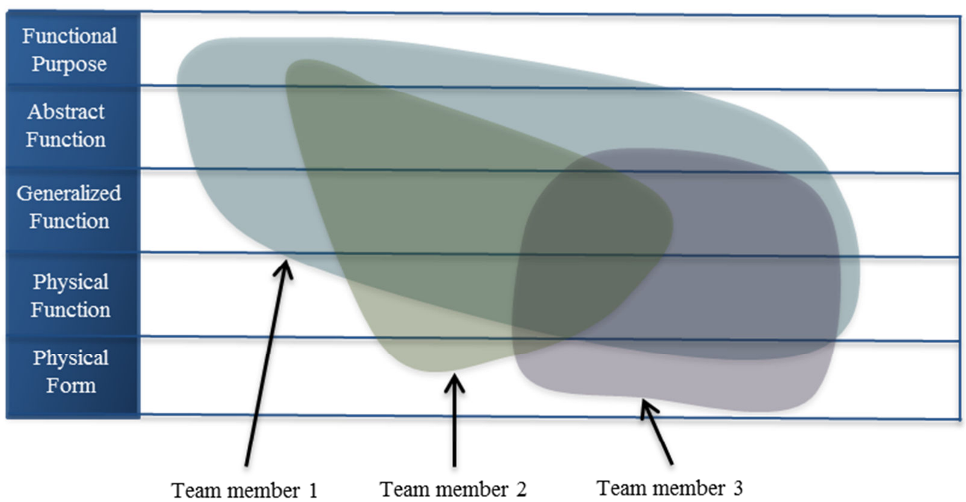


Figure 12. Responsibility Maps.
(Adapted from Burns and Hajdukiewicz, 2004)

The intentional WDA incorporating values or soft constraints (Burns et al., 2005) helps to identify the social constraints that affect decision-making. Values and priorities (also called *soft constraints*) are social organizational factors that constrain an action, but they are different from physical constraints. Burns et al. (2005) argue that physical constraints (also called *hard constraints*) cannot be violated; whereas, social organizational constraints can be broken, but probably will not be or should not be. Figure 13 shows the different regions of physical and social organizational constraints.

Figure 13. Different Regions of Physical and Social Organizational Constraint. (Taken from Burns et al., 2005)

Work trajectories (Rasmussen, Pejtersen, & Schmidt, 1990; Burns & Vicente, 1995) represent how various team members move through time through a work domain. While the work-domain model examines fundamental behaviour-shaping constraints for team members, the team members have freedom to plan their behaviour in response to various situations. Figure 14 represents the sample trajectories for three team members.

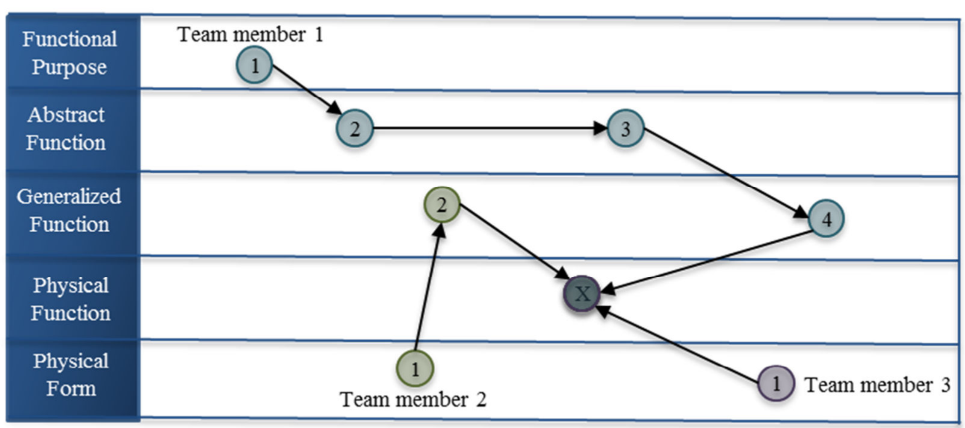


Figure 14. Work Trajectories.

Trajectories can vary depending on the situation, but the structure of the work domain is relatively constant. While joint work-domain models (Burns et al., 2005), responsibility maps (Hajdukiewicz et al., 2001), and work trajectories (Rasmussen et al., 1990) begin to show how the work-domain space can be used by teams, they can fall short of identifying in detail which WDA elements are used by which team members. Collaboration tables (Ashoori & Burns, 2012) may provide a representation of shared work-domain elements. Ashoori and Burns (2012) suggest an identification of each work-domain element separately, then, working out in detail the various team members influenced by that element. Quick schematics of the various team work-domain approaches are shown below in Figure 15.

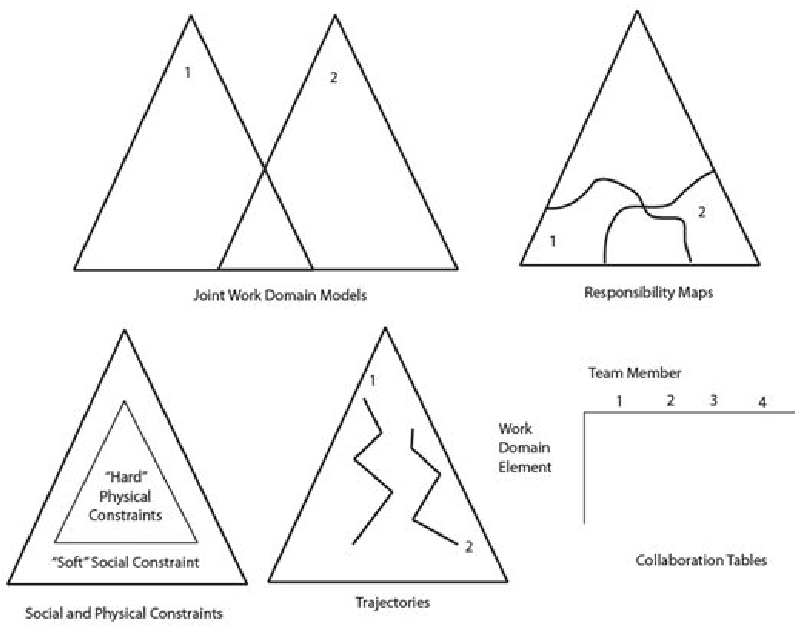


Figure 15.Various Approaches to Team Work Domain Analysis.

With respect to Team WDA, I propose that these methods continue to be used, but suggest the explicit mapping of work-domain collaboration be added when larger teams are being modeled or more detail is needed. In Chapter 3, I will review the key concepts of responsibility maps and collaboration tables using examples.

In a typical ConTA, Rasmussen et al. (1994) examine activities as a combination of work problems in various situations. However, this is different from Vicente's approach (1999) to activity analysis. For Vicente (1999), the analysis of activity involves analyzing operating modes and control tasks of a work system. Naikar, Moylan, and Pearce (2006) consolidate the approaches of Vicente and Rasmussen to ConTA and suggest decomposing activity into a set of recurring work situations to deal with and a set of work functions to perform. Then, they suggest further decomposing activity into the control tasks that are required for each work situation and work function. To support this representation, Naikar et al. (2006) recommends a new formative representation for ConTA, called the Contextual Activity Template (CAT). They argue that work functions for an individual can be different for various situations, which can lead to different interaction patterns in various collaboration situations. Figure 16 represents a CAT for three situations. Work situations are shown along the horizontal axis and work functions are shown along the vertical axis. The circles indicate the work functions and the horizontal lines connected to the circles indicate all of the work situations in which a work function can happen.

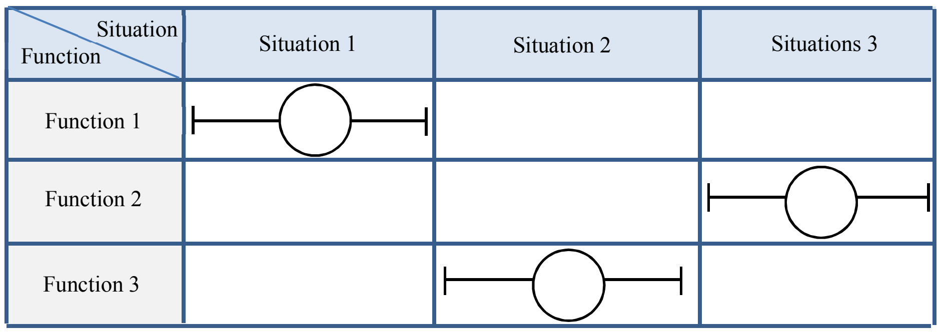


Figure 16. Typical Contextual Activity Template.

The CAT is a helpful tool when work functions change over different situations (e.g., a typical care giving process versus an emergency situation). Variations of the CAT include the colour-coded CAT of Jenkins et al. (2008a) and the team-view CAT of Ashoori and Burns (2011). Figure 17 represent one colour-coded CAT for three team members. Different team members are represented with different colours.

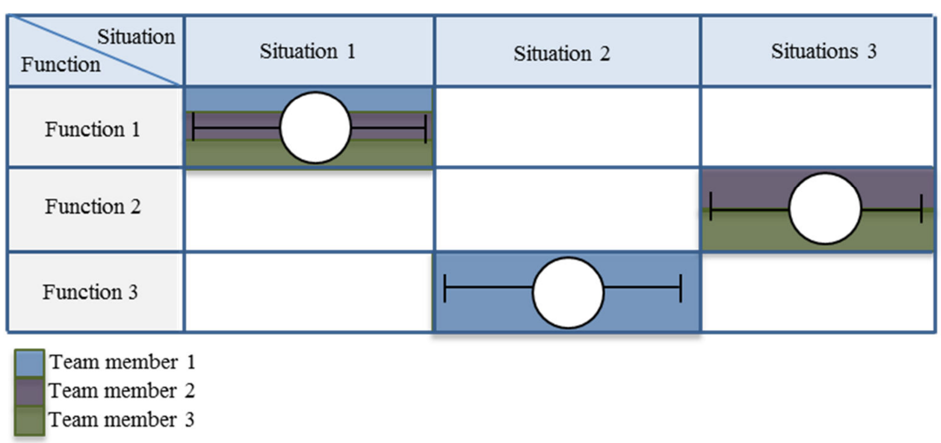


Figure 17. Colour-Coded Contextual Activity Template.
(Adapted from Jenkins et al., 2008a)

Figure 18 shows a simple team-view CAT (Ashoori & Burns, 2011). Work situations are shown along the horizontal axis and roles and responsibilities are shown along the vertical axis. The ovals indicate the teamwork functions and the horizontal lines connected to the circles indicate all of the work situations in which a work function can happen. The small solid circles attached to the teamwork functions indicate the team members that collaborate on completing that function. By using this representation, one can identify what needs to be done in various situations and examine the interaction patterns over time.

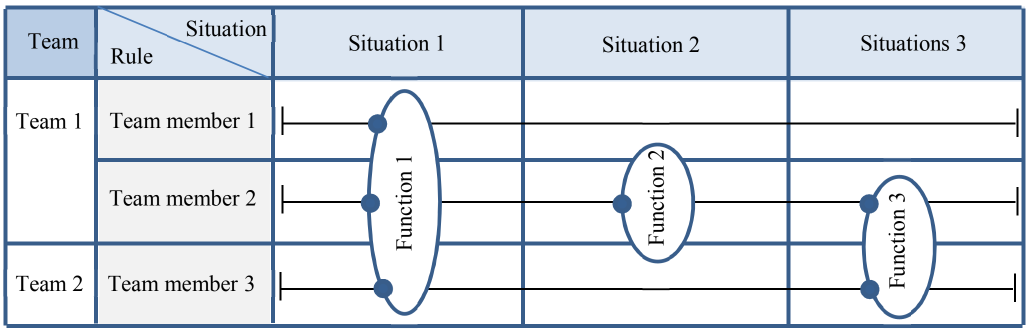


Figure 18. Modified Contextual Activity Template for Teams.
(Adapted from Ashoori and Burns, 2011)

While the CAT is a good representation to show how individuals are involved in multiple activities in various situations, the chained ladders (Rasmussen et al., 1994) are a good representation to show how different parties interact on a single control task. Figure 19 shows a chained ladder for three team members.

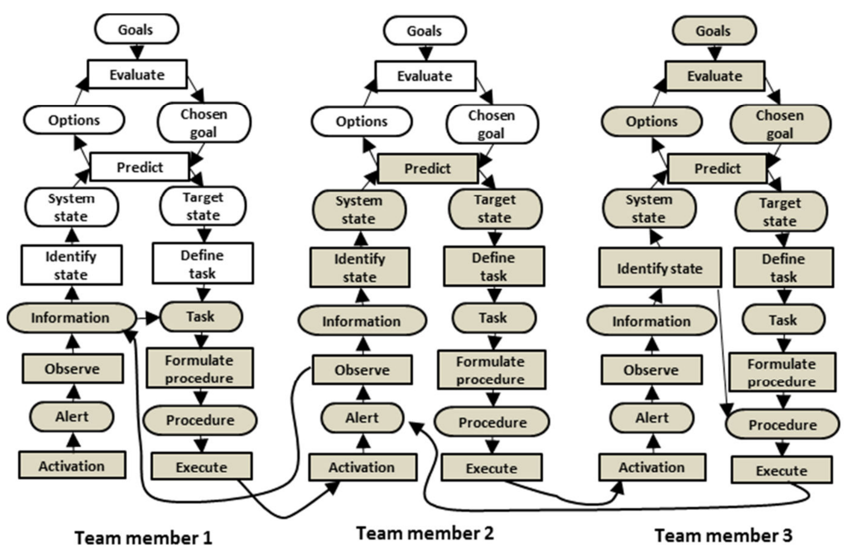


Figure 19. Hypothetical Chained Ladder for Three Team Members.

Rasmussen et al. (1994) suggest the use of a chain ladder to represent a distribution of decision activities in a team. There is one decision ladder for each operator where the links between the ladders can be used to demonstrate the workflow. For example, in Figure 19, three team members work together to accomplish a control task. The links between the ladders of the first two members indicate that the activity of the first team member triggers an action for the second team member and results in a better understanding of the current situation. In Chapter 3, I will review the key concepts for the CAT and the chained ladders and will explore them in a healthcare scenario.

There have been very few studies that explore StA techniques and models for teamwork environments. Jenkins, Stanton, Salmon, and Walker (2009) suggest a colour-coded IFM to represent how operators work together to accomplish control tasks. They extend this idea to map the colour-coded IFMs to the cells of a CAT to represent strategies in various situations. I support this approach, but argue that a description of strategies might not be sufficient to serve as the sole basis for design. The StA should be concerned with identification of general categories of possible cognitive procedures and also the detailed sequence of actions for each procedure. Cornelissen et al. (2011) introduce a Strategies Analysis Diagram (SAD) as an extension to the AH for generating strategy pathways over the work domain. They suggest adding a supplementary layer to the AH and associate the physical work-domain resources with a list of actionable verbs that describes strategies at a physical work-domain level. For each CWA analysis, Table 2 summarizes the primary sources of knowledge acquisition, knowledge representation, and existing team extensions. In Chapter 3, I will come back to these models to discuss them in detail along with examples.

The majority of previous attempts at using CWA for an examination of collaborative requirements have used models and ideas from many different phases to look at social organizational analysis. This suggests that SOCA is in reality more than one phase and deserves a more in-depth treatment. Indeed, social organizational interactions have a complexity of their own, and create a broader set of constraints involved in control tasks, coordination structure, team strategies, and the social competencies expected from a strong team player. For this reason, I propose that it may be useful to modify the traditional CWA approach and more explicitly examine the social components of a team. However, this explicit discussion of the social components requires a thorough understanding of the psychological constructs of effective teamwork as well as the design considerations for effective socio-technical systems. In the following sections, I will discuss three prominent teamwork frameworks that can lead to a better understanding of social components of a team.

Table 2. Summary of the CWA Tools.

Phase	**Tools**		
	Knowledge acquisition tools	Commonly used knowledge representation tools	Team extensions
WDA	- Interviews with SMEs using questionnaires, surveys, and walkthroughs (Naikar et al, 2005; Bisantz & Mazaeva, 2009) - Field observations (Naikar et al, 2006; Rasmussen, 1980) - Document analysis (Bisantz & Mazaeva, 2009)	- Abstraction Hierarchy (Rasmussen, Pejtersen, & Goodstein, 1994)	- Joint work-domain models (Burns, Torenvliet, Chalmers, & Scott, 2009) - Trajectories (Rasmussen, Pejtersen, & Schmidt, 1990; Burns & Vicente, 1995) - Responsibility maps (Hajdukiewicz et al., 2001) - Intentional WDA incorporating values or soft constraints (Burns, Bryant, & Chalmers, 2005)
ConTA	- Field observations (Naikar et al, 2005; Rasmussen, 1980) - Interviews with SMEs using questionnaires, surveys, and walkthroughs (Naikar et al, 2005; Rasmussen, 1980) - Task analysis methods, such as Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003)	- Decision Ladder (Rasmussen, Pejtersen, & Goodstein, 1994; Naikar, Moylan, & Pearce, 2006) - Contextual Activity Template (Naikar et al., 2003)	- Chained ladders (Rasmussen, Pejtersen, & Goodstein, 1994) - Colour-coded CAT (Jenkins et al., 2008a) - CAT for designing new teams (Naikar, N., Pearce, B., Drumm, D., & Sanderson, M. P. (2003) - Team-view CAT (Ashoori & Burns, 2011) - Decision Wheels (Ashoori & Burns, 2010)
StA	- Document analysis, interviews (Rasmussen, 1981) - Empirical methods, such as think-aloud analysis (Gray & Kirschenbaum, 2000), Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003), or Contextual Design (Beyer & Holtzblatt, 1998)	- Information Flow Map (Vicente , 1999) - StA plotted on the CAT (Jenkins et al., 2009) - Strategies Analysis Diagram (Cornelissen et al., 2011)	- Colour-coded IFM (Jenkins et al, 2009)
SOCA	Same methods as used for the first three phases	- Abstraction Hierarchy - Decision Ladder - Contextual Activity Template - Information Flow Map	All of the above tools are conducted as part of SOCA. Much of the previous work on using CWA for teamwork environments has focused on SOCA as the single phase for social organizational analysis
WCA	No constraint-based data collection method is specifically discussed for this phase (Crone, 2011)	- SRK taxonomy (Rasmussen, 1983) - SRK inventory for decision ladders (Kilgore & St-Cyr, 2006) - SRK inventory for the AH (McIlroy & Statnton, 2011)	There has not been much attempt to use WCA for analyzing social competencies

2.4 Theories and Models of Teamwork

An examination of the commonly used theories and models of teamwork for the purpose of systems design may lend insight into a better understanding of the social components of teamwork. Much of the previous work on an examination of effective teamwork has focused on understanding the psychological constructs of the team (e.g., Cooke, 2005; Gorman, Cooke, & Winner, 2006; Ingram, Teare, Scheuing, & Armistead, 1997) rather than designing socio-technical systems to support and facilitate interoperation. To scope this work, I have decided not to explore models of team cognition. Although they certainly describe how well a team works together, these models focus on internal macro-cognitive processes. The focus of this work is to develop CWA models that describe team coordination and collaboration, primarily the external processes of how teams work together and interact with their work domain. As well, there is a wealth of information on community building models. While this is also relevant for social organizational analysis, this level of analysis is beyond the team level. It should be noted, however, that Euerby and Burns (in press) have applied the Communities of Practice framework to CWA. The methods examined in this thesis are those that explicitly look at the coordination activities of teams and how teams collaborate. Distribution cognition (Hutchins, 2000) is one of the methods that may provide a theoretical foundation for understanding human-computer interactions. Distributed cognition provides an integrated framework for research that combines ethnographic observation and controlled experimentation as a basis for design of collaborative systems.

The second method that I explored is Team SA. As discussed earlier in Chapter 1, Team SA has shown good results for differentiating the information requirements of individuals and teams. Team SA can be a complementary approach to CWA for an identification of information requirements. It provides the shared SA requirements and the degree to which the operators know which information needs to be shared. I explored the Team SA requirements to understand team activities in a variety of situations, analyze the information requirements of effective interactions, and identify the SA processes that serve to share a common understanding of what is happening on the shared elements.

Team development models are the third method that I explored to analyze behaviour changes during the team lifecycle. Team development models, such as Tuckman's five stage model (Tuckman & Jensen, 1977), examine the change of team's behaviours and teamwork requirements over different stages of the team lifecycle. I explored the team development models specifically to identify various strategies that a team adopts at different stages of its lifecycle.

In the following sections, I will briefly review the key concepts of distributed cognition, Team SA, team development models, and computer-based cooperative work.

2.4.1 Distributed Cognition

Hutchins (2000) argues that when the work that is distributed is the cognitive work, teamwork involves the distribution of two different cognitive tasks: the cognition that deals with the work that the team is performing, and the cognition that governs the coordination of the elements of the team's work. Distributed cognition emphasizes on the importance of observation of human activity "in the wild" and analysis of distributions of cognitive processes across members of a team. Hutchins (2000) describes that knowledge lies not only within the individual but in the individual's social and physical environment.

Distributed cognition provides an integrated framework for research that combines ethnographic observation and controlled experimentation as a basis for design of collaborative systems (Hollan, Hutchins, & Kirsh, 2000). Hutchins (2000) suggests the use of ethnographic observation to generate rich descriptions of how team works, self-organize, develop, and use cognitive artifacts. Distributed cognition helped me to plan for my observational studies and focus to study individuals in action and examine what people know as well as how they go about using what they know to do what they do.

2.4.2 Team Situation Awareness

Endsley (1988) explains SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (p.789). For example when crossing an intersection, the first level of SA examines the driver's perception of the traffic light, the car speed, and the distance from the intersection. The second level of SA focuses on the comprehension of the current situation and the driver's decision of whether to cross the intersection or stop at the light. Finally, the third level of SA projects the possibility of getting stuck when crossing a yellow light.

While each team member possesses the SA required for his or her responsibility, they share a common understanding of what is happening on the shared SA elements. Team SA is often seen as individual SA plus a number of processes that serve to share that part of SA with team members (Rousseau, Trembly, Brenton, 2004). Team SA discusses the shared SA requirements and the degree to which the operators know which information needs to be shared. For example, in a poor Team SA, a team member needs a given piece of information for his or her job requirements, but cannot obtain that.

Endsley, Bolte, and Jones (2003) describe a model of Team SA to conceptualize how team develops high level of shared SA. Figure 20 illustrates this model.

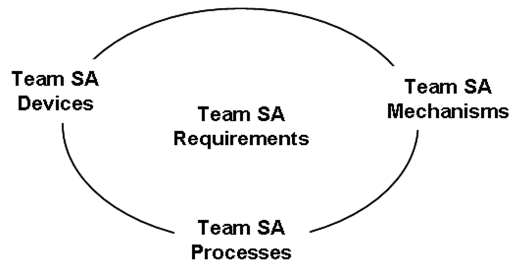


Figure 20. Model of Team Situation Awareness.
(Adapted from Endsley, Bolte, and Jones, 2003)

Endsley et al. (2003) discuss the shared devices that are available for information sharing as well as the shared mental models and the shared SA processes required to achieve, acquire, or maintain SA. Each of these factors acts to help build team and shared SA. While a design built from CWA should support SA (Hauland, 2002), a design built from Team CWA should support Team SA. Team SA emphasizes the need for individual SA, as well as shared SA across the team. Individual SA is largely handled through the normal CWA requirements. With respect to shared SA, I explored how the normal CWA models could be extended to understand the requirements, devices, mechanisms, and processes of Team SA.

Team SA requirements concerns with the degree to which team members need to know which information needs to be shared. This includes the awareness about the shared and individual goals and information. For example, two team members that work together on performing a shared task should have information on each other's progress. A Team CWA approach should identify these SA requirements. I will demonstrate in Chapter 3 that Team WDA has the potential to be used for an identification of Team SA requirements.

Team SA devices include discussion of available devices for information sharing. I will come back to this discussion in Team ConTA and will demonstrate that how the Team ConTA tools can be used to better understand Team SA devices.

With respect to Team SA mechanisms, I will explore that how the Team ConTA models can be used to show when teams must collaborate on knowledge-based tasks together, where shared mental models might be most needed. However, I should mention that the main focus on this research is not to evaluate mental models and team cognition.

Team SA Processes concerns the processes required to achieve, obtain, or maintain SA. The Team CWA models can provide support to analyse Team SA processes at the strategies and also worker competencies level. I will come back to this discussion in Chapter 3, when I explore coordination strategies and social competencies in a team.

2.4.3 Team Development Models

Team development models, such as Tuckman's five-stage model (Tuckman & Jensen, 1977), examine the change of team behaviours and teamwork requirements over different stages of the team lifecycle. Team development models can lend insight into identifying team strategies as well as design requirements for an adaptive system to operator-behaviours over time. I will come back to this discussion in Chapter 3, when I discuss different formative categories of strategies for teams.

Several attempts have been made to examine how teams change during their lifecycle (e.g., Morgan, Salas, & Glickman, 1993). The most recognized model is Tuckman's five-stage development model (Tuckman & Jensen, 1977). Tuckman and Jensen introduce an elegant explanation of team development called *Forming-Storming-Norming-Performing-Adjourning* model. A schematic of the model is shown in Figure 21 and explained in detail in Table 3.

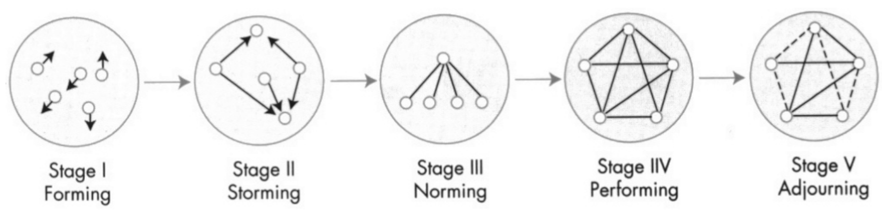


Figure 21. Stages of Group Development.
(Adapted from Robbins and Langton, 2005)

There has been some other work complementary to the Tuckman's team development model, such as the discussion of transitions between these stages (Gersick, 1988), or prediction of team behaviour in various situations (Morgan, Salas, & Glickman, 1993). The Tuckman's five-stage model can be used as a basis to study behaviour changes during the team lifecycle and examine how these behaviour changes can affect design requirements at each stage. There could be different design requirements at different stages of the Tuckman's team development model.

Table 3. Tuckman Team-Development Model.

Development stage	Highlights	Description
Forming	Awareness	Team members try to determine their positions in the team, and identify acceptable behaviours and procedures to follow.
Storming	Intragroup conflicts	Operators accept the existence of the team, but conflict arises as they resist the constraints that the team imposes on individuality.
Norming	Cooperation	In this stage, close relationships develop and the team demonstrates cohesiveness and sets norms for appropriate behaviours.
Performing	Productivity	The structure at this point is fully functional and accepted. Team energy has moved from getting to know and understand each other to performing the task at hand.
Adjourning	Wrap up	Adjourning is the last stage when the team prepares to split up. High task performance is no longer the team's top priority. Instead, attention is directed toward wrapping up activities.

At the forming stage, operators seek to identify the purpose of teamwork, understand the overall team composition, and explore the resources available to support teamwork. Design requirements for this stage may include team size, team structure, and the expertise of the end-users, a list of result-oriented tasks, and purpose of teamwork. A sample socio-technical system, at the forming stage, may run and share the results of different personality tests for the team members to give them a better understanding of who is onboard and how their personality may change when conflict arises.

The storming stage is the stage when team members are most likely to resist the constraints. The team members allocate different roles and decide on the management style. Coordination structure is set and the team members choose the team leaders. A complementary socio-technical system, at the storming stage, may facilitate role allocation, conflict management, and leadership strategies.

The norming stage defines a period when close relationships develop and the team demonstrates cohesiveness and sets norms for appropriate behaviours. A socio-technical system, at the norming stage, may be used to support norms and policies, conflict resolution, and effective coordination.

The last stage, the performing stage, is the stage when socio-technical systems are most helpful. Design requirements, at the performing stage, may involve task analysis, strategy analysis, and an analysis of team competencies.

A good understanding of team development models may result in a better understanding of operators' behaviours and, consequently, designing an adaptive solution to changing behaviours. I explored team development models specifically to identify various strategies that a team adopts at different stages of its lifecycle. For example, teams mostly adopt coordination strategies during the storming or norming stage for examining management styles, conflict resolution strategies, and leadership models. However, during a performing stage, team members may mostly leverage operational strategies to explore different ways of accomplishing control tasks. In Chapter 3, I will come back to the Tuckman's (1965) team development model and discuss the implications of that model on designing strategies for teams.

2.4.4 Computer-Supported Cooperative Work

Computer-Supported Cooperative Work (CSCW) refers to operators working together with help from computers. Wilson (1991) describes CSCW as "a generic term which combines the understanding of the way people work in groups with the enabling technology of computer networking and associated hardware, software, services, and technologies" (p.6). With respect to this definition, CSCW recommends an analysis of how operators work together prior to designing computer support for them.

In Team CWA, I focus more on understanding collaborative requirements of work domain rather than technologies to support it. While CSCW aims to support group effectiveness in terms of working processes and technologies that might be used to support that, it may offer insights to fill the gap between an analysis of work processes in Team CWA and the technology concerns.

Schmidth and Bannon (1992) argue the need for understanding the nature of cooperative work as a foundation to designing information systems to support the work. They discuss that the CSCW needs to address three specific requirements of cooperative work: (1) articulating cooperative work; (2) sharing an information space; and (3) adapting the technology to the organization, and vice versa. They argue that a CSCW should support management of work flows and common information spaces. Bannon and Schmidt (1989) define information space as a shared 'space' comprising data, such as personal beliefs, or shared concepts.

With respect to this definition, Team CWA should identify how people in a distributed setting can work cooperatively in a common information space. At the work-domain level, Team CWA could be used for an identification of the shared elements of the information space (i.e., boundary objects). A *boundary object* is a concept from Activity Theory (Bodker, 1991) that shows how various artifacts pass between different activity-systems (Star & Griesemer, 1989). When two parties collaborate, a boundary object is either a shared physical or conceptual object. Boundary objects often present unique design challenges in that they must be designed to be compatible in different activity systems and in collaborative work environments, for different team members, or for different teams entirely. Boundary object is a critical, but understudied theoretical construct in CSCW (Lutters & Ackerman, 2002). Bannon and Bødker (1997) discuss the importance of an analysis of boundary objects for constructing common information space for CSCW. At the work-domain level, Team WDA could be able to identify the boundary objects and the shared elements of the information space. At the control-task level, Team ConTA could be used to identify shared workflows and discuss the distribution of workflow to different team members. At the strategies level, Team CWA could provide a description of strategies as a sequence of actions, and identify the information requirements for each action.

Much of previous works on the analysis of CSCW system requirements has focused on the use of the CSCW taxonomy (Reinhard et al, 1994) to understand the workflows and the shared information space. The CSCW taxonomy analyzes the functional requirements of the system in terms of (1) interaction requirements, (2) coordination requirements, (3) distribution requirements, (4) user-specific reactions, (5) visualization, and (6) data hiding. Interaction requirements evaluate the synchronicity of the interaction. Coordination of interactions deals with communication within the group. Distribution requirements examine the need to interact from remote places. User-specific reactions identify the desire specific reactions that a user expects from the system. Visualization identifies the requirements for visualizing shared information facilities. Data hiding explores information access requirements. In Team ConTA, I used the CSCW taxonomy to identify a set of criteria for examining team interactions.

2.5 Summary

While there are reasonably good measures in the literature for evaluating team effectiveness, very few approaches have focused on how to design proper technologies to improve team performance. There are some relevant works on the applicability of distributed cognition to learning and systems design. Hutchins' ethnographic approach (2000) generates rich descriptions to improve understanding of how team works, self-organize, develop, and use cognitive artifacts. CSCW (Schmidth & Bannon, 1992) can be used as a foundation for designing information systems to support cooperative work. CSCW recommends an analysis of how operators work together prior to designing computer support for them and, therefore, can serve as a basis for defining system requirements. Team SA (Endsley & Robertson, 2000) has shown good results for differentiating information requirements of individuals and teams. While SA takes a cognitive information-processing approach to deriving requirements, CWA builds constraint-based models of socio-technical systems, seeking to reveal functional behaviours. Thereby, CWA has potential to be used for establishing collaborative works. However, much of previous work on using CWA for extracting design requirements for teamwork environments has focused on SOCA as the single phase for social organizational analysis. It became apparent in reviewing this work that a single phase model for social organizational analysis may not exist or may not be appropriate. I propose that it can be useful to modify the traditional CWA approach and more explicitly examine the social components of a team.

Chapter 3
Toward a Team Cognitive Work Analysis

Figure 22 provides an overview of thesis structure with the highlighted chapter material for Chapter 3. In this chapter, I will review the key concepts and the extended models of different Team CWA phases.

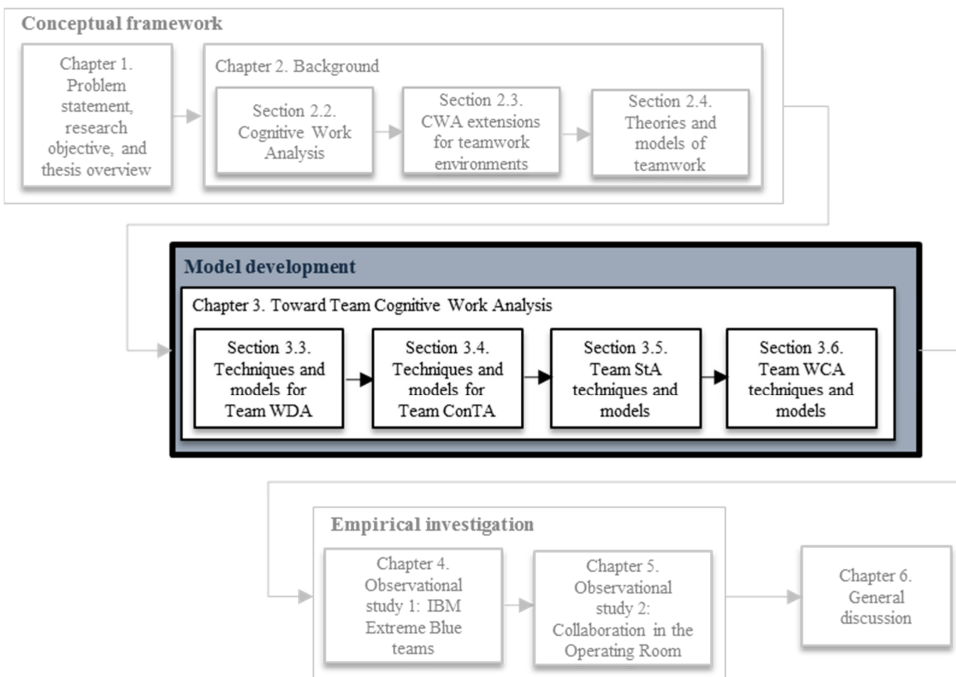


Figure 22. Chapter 3 Overview.

3.1 Introduction

CWA has been used successfully for deriving design requirements to support single operators and has potential to be used for extracting collaborative requirements. Team CWA suggests techniques and models that leverage the synergy between social organization analysis and the available guidelines of CWA for individual work analysis. In this chapter, I mainly adopt Vicente's terminology (1999) for CWA because it is the more recent formulation of CWA and more commonly used in the latest literature. The opportunities for a team-oriented approach to CWA are outlined in the following paragraphs, according to the five phases of CWA.

At the work-domain level, WDA examines fundamental work-domain constraints including purpose of the work domain; values, priorities, and principles; general work processes; and physical elements of the work domain. However, WDA does not provide sufficient guidance on extracting which work-domain elements are shared and by whom. Team WDA could address this challenge and provide models and techniques for analyzing shared work-domain elements. Later in Section 3.3., I will demonstrate how Team WDA models may contribute to an identification of shared work-domain elements. The constraint-based models that are produced for Team WDA are responsibility maps, collaboration tables, and abstraction wheels. In the following sections, I will examine the key concepts of each of these models with examples from a familiar system.

At the control-task level, ConTA has been successfully used to extract control task requirements and examine changing demands in various situations. However, ConTA falls short in explaining team interactions and shared workflows. Team ConTA expands chained ladders (Rasmussen et al., 1994) into decision wheels (Ashoori & Burns, 2011) and provide suggestions to revamp the CAT for team environments (Ashoori & Burns, 2012). Team ConTA provides models for an analysis of team structures, inter-team, and intra-team interactions at the control-task level. The discussion of inter-team interactions in Team ConTA should result in a better understanding of interdependencies between teams, which has not been addressed in ConTA. This understanding can also be used for designing new teams and identifying poor team-structures. By organizing along inter-team interactions, more effective team structures may be built. In Section 3.4, I will explain Team ConTA models and demonstrate the value of its models using examples.

At the strategy level, much of the previous attempts to use StA for strategies analysis have focused on the examination of IFMs for modeling a descriptive characterization of strategies for single operators (e.g., Vicente, 1999; Ahlstrom, 2005). Naikar (2006) supports this descriptive approach, but she comments that StA is more concerned with an identification of categories of possible cognitive procedures rather than a detailed sequence of actions for each procedure. In Team StA, I focus on both a descriptive characterization of strategies to reveal how an experienced operator accomplishes a task and a broader discussion of team strategies to analyze different categories of team strategies. In Section 3.5, I will examine team strategies within four different categories of strategies: (1) operational, (2) coordination, (3) team development, and (4) structural. The first category, operational strategies, focuses on different ways of accomplishing control tasks. The second category, coordination strategies, is used for examining coordination structures and the processes underlying coordination. Team development strategies, the third category, arise from the Tuckman's team development model (Tuckman & Jensen, 1977) and examine how team strategies change at different stages of the team lifecycle. The last category, structural strategies, inherits and builds on the work-domain constraints. Structural strategies examine how various categories of work-domain constraints may result in different team strategies. In Section 3.5, I will further explain these four categories by using examples.

At the worker competency level, much of the relevant existing work has focused on the use of the SRK taxonomy (Rasmussen, 1983) for an analysis of individuals' behaviours and the job-specific competencies. However, social competencies and implications of social characteristics should be also considered in systems design. Team WCA examines worker competencies in two different categories of (1) functional competencies and (2) social competencies. Functional competencies define the job-specific competencies in terms of the knowledge, abilities, and skills that operators must possess in order to effectively carry out control tasks. In Team WCA, the SRK taxonomy is used as the primary tool to analyze functional competencies of team members. While functional competencies describe the skill-set required for operators to take over their functional roles, social competencies can indicate the desired behaviours that operators should exhibit for effective interactions with each other (Belbin, 1981). Effective social problem solving, direct constructive communication, and a good relationship with other teammates are examples of social competencies. Team WCA models and techniques are explained in Section 3.6.

In the following section, a typical, but complex, collaboration scenario (Ashoori & Burns, 2012) is described, revealing how Team CWA could be used in a broad range of teamwork-like scenarios. I will continue to use this sample scenario throughout the next sections to explain the Team CWA models and demonstrate the applicability of the extended models in familiar application domains. Using the same scenario for each example makes it easy to follow the various techniques I modified.

3.2 Scenario

A subject matter expert, who was a birthing unit coordinator at The Ottawa Hospital, developed this sample scenario. The scenario exemplifies different levels of interactions among the healthcare professionals working at the Labour and Delivery Department of this hospital. Following the scenario, I have shown the overall workflow of the scenario so it can be understood more clearly.

This scenario involves a patient, Mrs. X, who has entered the hospital to deliver a baby and develops a fairly straightforward complication, a headache. She is assigned a staff nurse to manage her care. The staff nurse assesses the patient and determines that the patient needs to be assessed by a physician. The nurse talks to the obstetrical resident available about Mrs. X. The obstetrical resident comes to the Mother-Baby Unit (MBU) to assess the patient and decides that the patient could benefit from an epidural blood patch (a simple surgical procedure that injects a *sample of the patient's blood into her epidural space). He contacts the anesthesiologist to double check the prescription with the anesthesiologist. The anesthesiologist obtains patient's consent for the blood patch and calls the care facilitator in the MBU to arrange for transferring the patient to the Birthing Unit (BU) for the blood-patch procedure. This care facilitator contacts the care facilitator in the BU to arrange a time for the blood patch. The care facilitator in the BU identifies a primary nurse to do the blood patch for Mrs. X and calls the care facilitator at the MBU to discuss a time for the procedure. The patient is transferred to the BU. The anesthesiologist is present to do the procedure. Afterwards, the patient is ready to transfer back to the MBU. The primary nurse reports the situation to the staff nurse before transferring the patient to the MBU.*

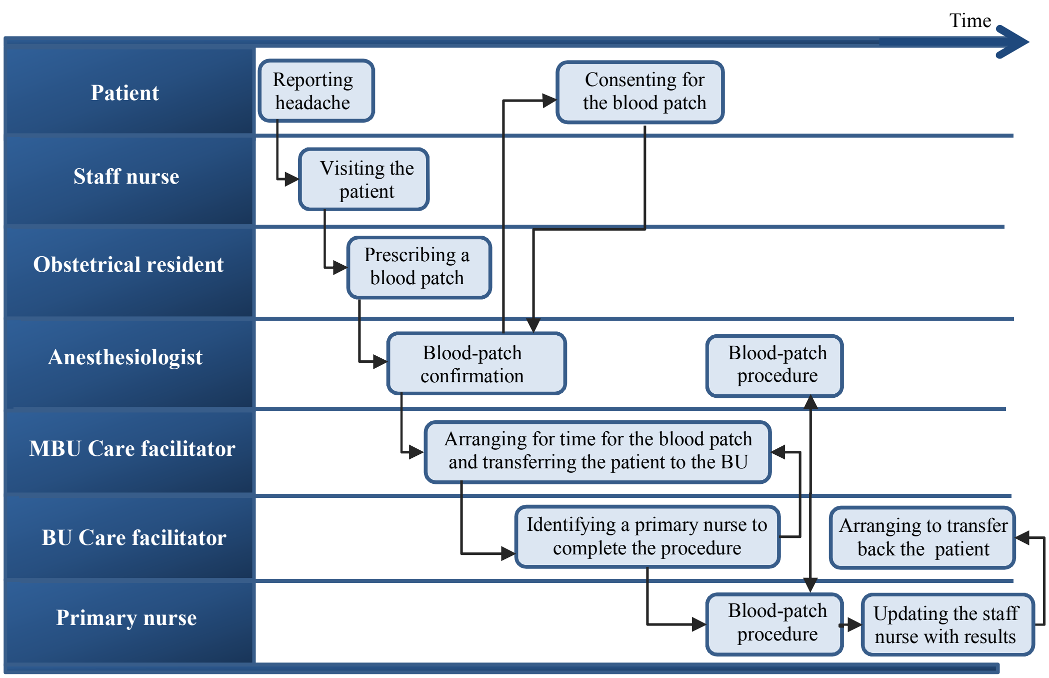


Figure 23. Workflow of the Healthcare Scenario.
(Adapted from Ashoori and Burns, 2012)

Figure 23 shows the workflow diagram of this scenario. Different roles and responsibilities are shown along the vertical axis. The horizontal axis shows the work progress over time. In this scenario, I am mostly interested in workflow, team structure, inter-team and intra-team interactions, shared work-domain elements, and the expertise of people involved. In the rest of this chapter, I will use this scenario to explain the extended models and demonstrate their value.

3.3 Phase I: Team Work Domain Analysis

From a teamwork perspective, the goal in using a WDA is to create a set of models for the team that describe the shared values, purposes, and priorities of teamwork. Team WDA could address this challenge and provide models and techniques for analyzing shared and individual purposes; values, priorities, and principles; processes; and boundary objects. Discussion of shared work-domain elements in Team WDA may support identification of Team SA requirements. Team SA requirements remark the degree to which the team members know which information needs to be shared. Since Team WDA provides models and techniques for analyzing shared or individual work-domain elements, it can be used to identify the Team SA requirements at different levels of purposes, values, processes, and physical work-domain resources. Team WDA models also have potential for designing new teams or identifying poor team structures.

Bannon and Bødker (1997) discuss the importance of analyzing boundary objects in order to construct common information space for CSCW. At the work-domain level, Team WDA should be able to identify boundary objects and shared elements of the information space.

Team WDA methods could supplement traditional WDA by showing various aspects of teamwork or team requirements. A regular WDA should be still conducted as the foundation for these models in order to understand the functional characteristics of the work domain. Then, depending on the nature of the team situation to be analyzed, the base WDA can be re-examined for team aspects. Since the traditional WDA methods have been described in other publications, I focus, in the next section, on explaining the key concepts of the extended WDA models with examples from the sample scenario.

3.3.1 Basic Work Domain Analysis

A typical WDA examines the fundamental behaviour-shaping constraints, such as purpose of the work domain, values, priorities, processes, and resources. Figure 24 shows the basic work-domain model for the healthcare scenario. The AH consists of five levels of abstraction that were described earlier: functional purpose, abstract function, generalized function, physical function, and physical form.

At the functional-purpose level, the AH corresponds to work-domain purposes. There are three purposes identified for the healthcare scenario: (1) maintaining patient's health, (2) pain management for the patient, and (3) effective administration to facilitate the care giving process.

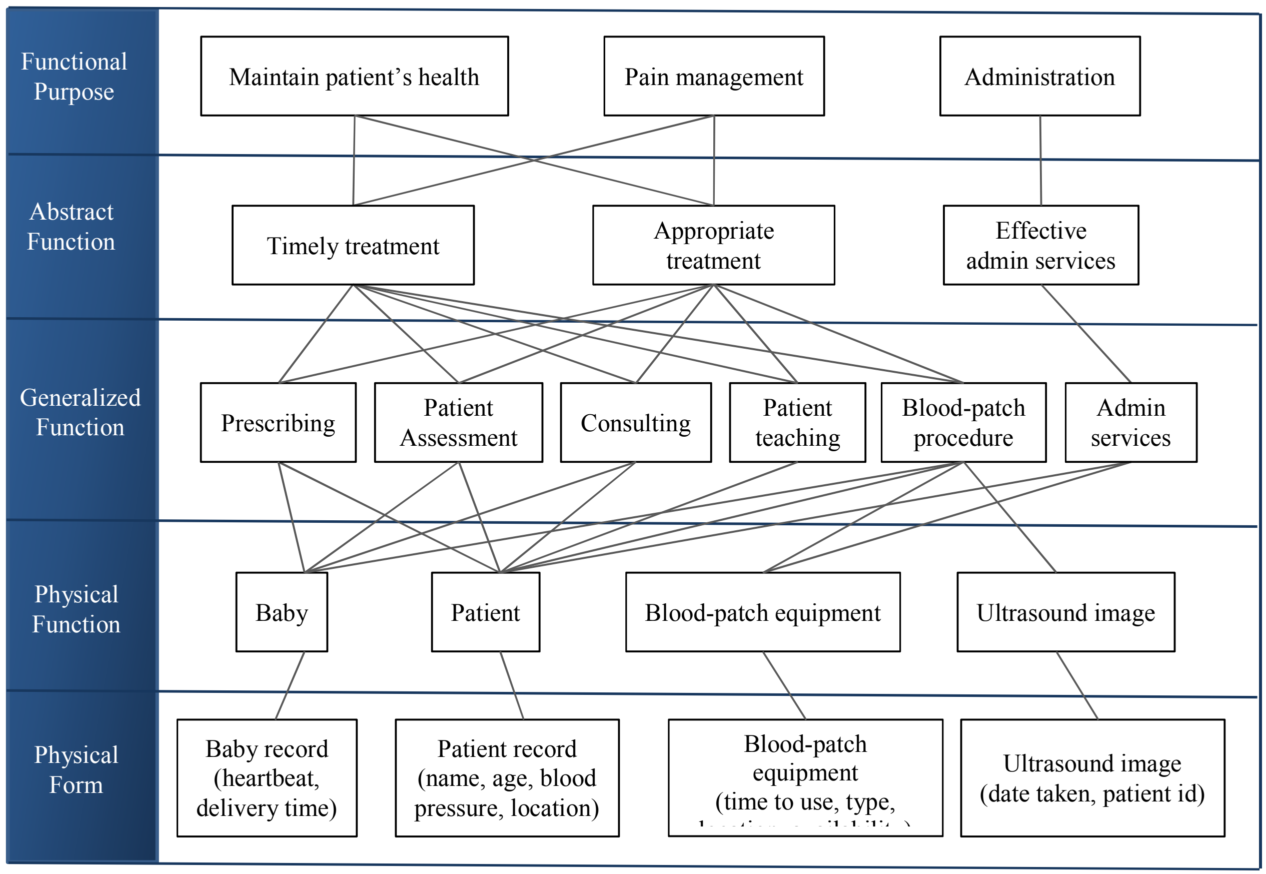


Figure 24. Work Domain Model of the Labour and Delivery Department.

The AH at the abstract-function level corresponds to values, priorities, and principles. As shown in Figure 24, there are three values in the healthcare scenario: (1) timely treatment, (2) appropriate treatment, and (3) providing effective administrative services. The structural links of the AH going from the abstract-function level to the level above correspond to the why-how relation between the purposes of the work domain and the values and priorities.

The main processes in the healthcare scenario are described at the generalized-function level. There are six processes identified in the healthcare scenario: patient teaching, patient assessment, consulting, prescribing, completing blood-patch procedure, and facilitating administrative services. The structural links of the AH going from the process level to the level above, shown in Figure 24, indicate the work-domain processes to meet the priorities.

At the physical-function level, the physical work-domain resources are identified. Patient, baby, blood-patch equipment, and the ultrasound image are examples of the work-domain resources in the healthcare scenario. The structural connections at this level indicate the physical resources involved to complete the processes.

At the final level of the AH, the physical-form level, the physical characteristics of work-domain resources are identified. For example, for the blood-patch equipment, the type, location, availability, and time of the procedure are identified. The structural links of the AH going from the physical-function level to the level above correspond to the attributes of work-domain resources.

Although the basic work-domain model indicates the work-domain purpose and values, it does not provide guidance on identifying which work-domain purposes are shared and by whom. Similarly, the abstract-function level of the AH provides a list of values, but falls short in an examination of shared values. The basic WDA has been successfully used for an examination of individual work processes and physical elements of the work domain (e.g., Ahlstrom, 2005; Bisantz & Mazaeva, 2009; Burns, Enomoto, & Momtahan, 2009; Naikar, Hopcroft, & Moylan, 2005). However, the discussion of shared processes and boundary objects has not yet been considered in the existing applications of regular WDA.

In the following section, I explain how collaboration tables can provide an extension to the AH to identify the shared and individual purpose, values, and processes, as well as boundary objects.

3.3.2 Collaboration Tables

As discussed earlier, a plethora of different approaches were employed as practitioners tried to develop social organizational analyses for their work domain. For example, Burns et al. (2009) examined joint work domain models to identify the shared work-domain elements and Hajdukiewicz et al. (2001) modeled responsibility maps as work-domain regions to show where individuals needed to collaborate. Joint work domain models are appropriate when two or more team members share parts, but not the entire same work domain. Figure 25 shows the responsibility map for the sample scenario.

The overlap between the decision spaces of each team member shows how they work on a single work domain together. For larger teams with more complex interactions, it gets very complicated to graphically illustrate the overlaps between the decision spaces. Responsibility maps are appropriate for two or three team members, but the maps do not scale up well for large teams.

The goal of WDA from a teamwork perspective is to identify which work-domain elements are shared, and by whom, and which elements only influence individuals. While this information can be derived from joint work-domain models or responsibility maps, with larger teams and more complex interactions, a table format can be clearer (Ashoori & Burns, 2012). Collaboration Tables (CTs) provide a table format for examining the overlaps between the decision spaces of team members.

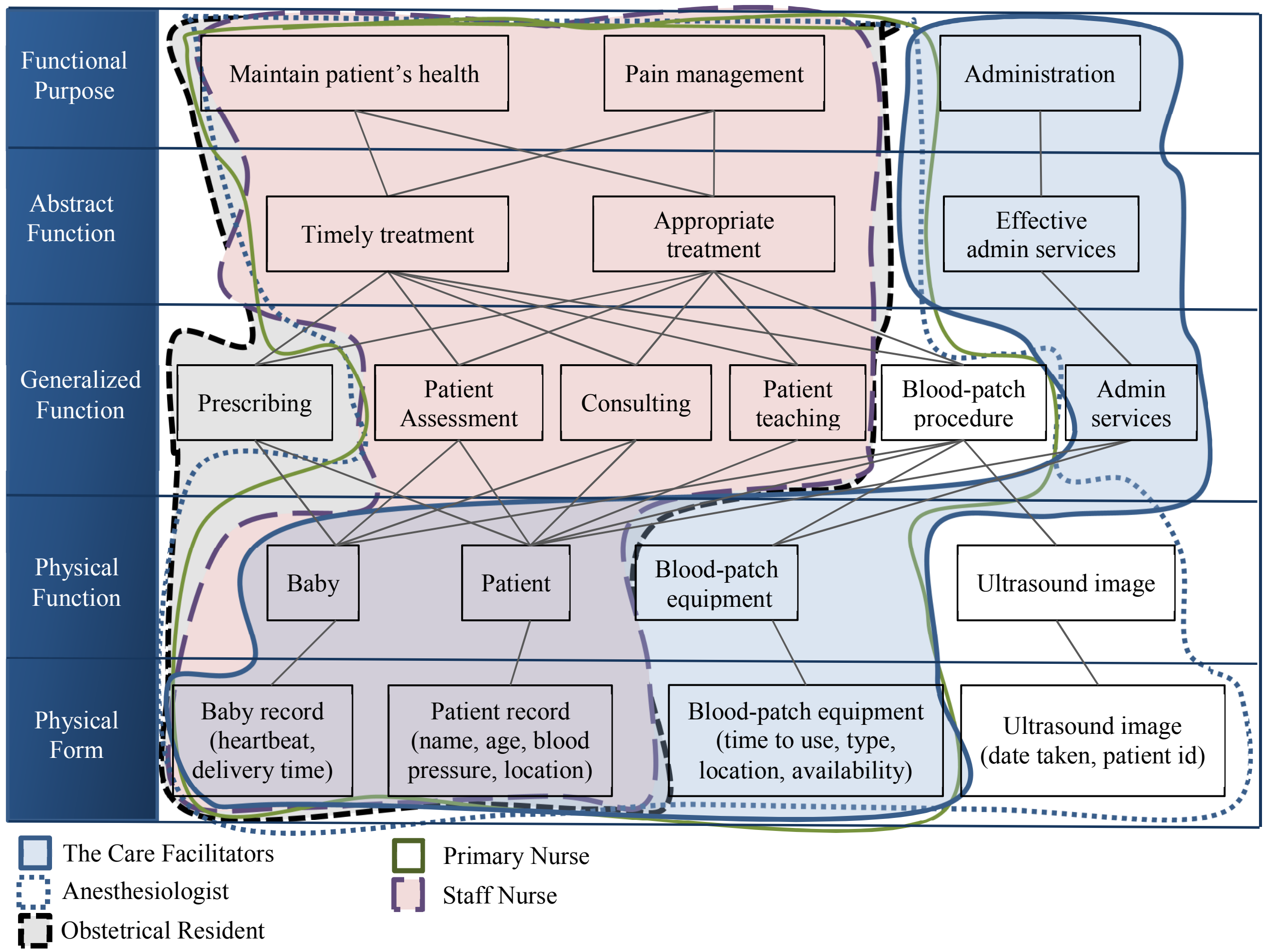


Figure 25. Responsibility Maps for the Labour and Delivery Department.

As in the AH, a typical CT (Ashoori & Burns, 2012) is divided into five different levels: (1) functional purpose, (2) abstract function, (3) generalized function, (4) physical function, and (5) physical form. At the functional-purpose level, the CT indicates roles and responsibilities that contribute to a work-domain purpose. For example, all the healthcare professionals in the healthcare scenario collaborate to provide pain management for the patient, but only the care facilitators perform administrative duties, such as operating telephones, keeping track of equipment, and other clerical functions (Table 4).

Table 4: Collaboration Table at the Functional-Purpose Level.

Functional purpose	Staff nurse	Obstetrical resident	Anesthesiologist	BU Care facilitator	MBU Care facilitator	Primary nurse
Pain management	X	X	X			X
Administration				X	X	
Maintaining patient health	X	X	X			X

At the abstract-function level, a CT identifies shared or not shared values, principles, and priorities. In the sample scenario, Table 5 shows three shared values of (1) timely treatment, (2) appropriate treatment, and (3) effective administration. While the healthcare professionals contribute to provide an appropriate, timely treatment for the patient, the care facilitators smooth the care giving process by facilitating administration.

Table 5: Collaboration Table at the Abstract-Function Level.

Abstract function	Staff nurse	Obstetrical resident	Anesthesiologist	BU Care facilitator	MBU Care facilitator	Primary nurse
Timely treatment	X	X	X			X
Appropriate treatment	X	X	X			X
Effective administration				X	X	

At the generalized-function level, a CT describes the overlap between the processes that each team member is responsible for. When designing a new system to facilitate a collaborative process, it is important to clearly examine to what extent a team member contributes to complete that process. For example, as shown in Table 6, all team members contribute to patient assessment, consulting, and patient teaching, but only the primary nurse and the anesthesiologist are responsible for the blood-patch procedure.

Table 6: Collaboration Table at the Generalized-Function Level.

Generalized function	Staff nurse	Obstetrical resident	Anesthesiologist	BU Care facilitator	MBU Care facilitator	Primary nurse
Patient assessment	X	X	X			X
Prescribing		X				
Consulting	X	X	X			X
Patient teaching	X	X	X			X
Blood-patch procedure			X			X
Admin services				X	X	

When an individual process is not shared in a team, an information system to automate that process facilitates the work of the individual responsible for that process, but not necessarily team interactions.

Table 7: Collaboration Table at the Physical-Function Level.

Physical function	Staff nurse	Obstetrical resident	Anesthesiologist	BU Care facilitator	MBU Care facilitator	Primary nurse
Patient	X	X	X	X	X	X
Baby	X	X	X	X	X	X
Blood-patch equipment			X			X
Ultrasound image			X			

When the staff nurse reports the patient status to the obstetrical resident, the boundary objects shared between these two parties are the patient and baby information. As another example, the blood-patch equipment is a boundary object shared between the primary nurse and the anesthesiologist during the blood-patch procedure. Therefore, an information system that is designed to facilitate collaboration between the primary nurse and the anesthesiologist should support information access to the patient and baby records as well as the blood-patch equipment, but not necessarily to the ultrasound image which is solely used by the anesthesiologist.

Collaboration tables may support Team SA requirements with an identification of which work-domain elements are shared and by whom. Team SA requirements remark the degree to which team members know which information needs to be shared. At the functional-purpose level, the CT can be used to identify the shared or individual purposes in a team. At the abstraction-function level, shared values and priorities are identified. At the generalized-function level, the CT helps to identify a distribution of work-domain processes to team members. For example, when two team members work together on a same task, not only they need to have their individual SA about the task they perform, but also they need to share awareness about each other's task status and their progress on performing their parts. The CT, at the generalized-function level, identifies the shared processes and, at the physical-function level, provides an examination of boundary objects.

3.3.3 Abstraction Wheels

Although the AH provides a basic tool to model dependencies between work-domain elements, it falls short in analysing team structures and inter-team interactions. An Abstraction Wheel (AW) is a complementary tool to the CTs that provides a visualization of the shared work-domain elements. In a typical AW, each team is represented by a wheel and each team member is represented by a portion of the wheel. Figure 26 shows a mapping of a typical AH to a slice of the AW.

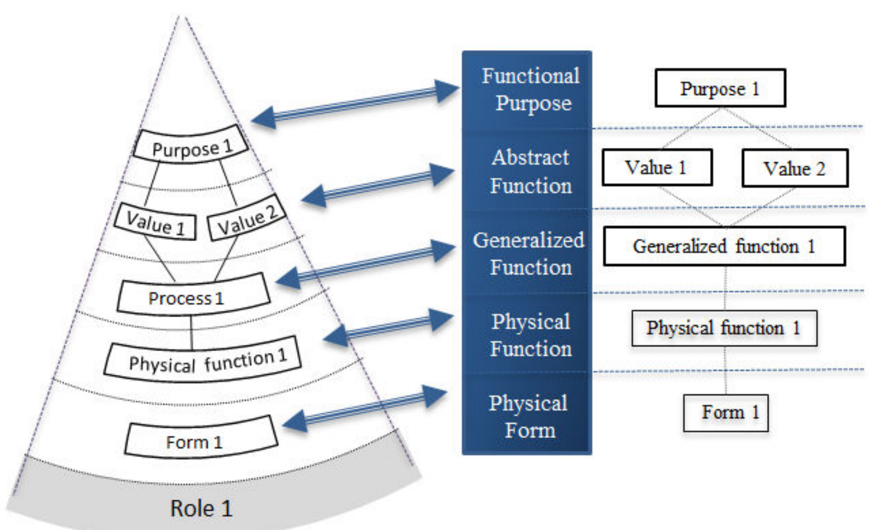


Figure 26. Mapping of an Abstraction Hierarchy to a Slice of the Abstraction Wheel.

The inner circles of each wheel represent the corresponding AH level in a WDA. The most inner circle represents the functional-purpose level and the outer circle represents the physical-form level. As discussed in Chapter 2, the structural links between different levels of an AH indicate how the higher element is achieved, or in reverse, why the lower level is available. Similarly, the structural links between the levels here indicate the how-why connections in a WDA.

The AW can be used as a graphical illustration of the work-domain elements shared within a team or across multiple teams. By illustrating inter-team and intra-team interactions, the AW can be also used for an examination of team structures. The AW for the sample scenario is shown in Figure 27. As shown in the figure, two teams of the Labour and Delivery Department involve in this scenario: MBU, and BU. The AW can be used for analyzing team structure as well as different roles and responsibilities in a team. The connections between two wheels represent the shared work-domain elements between the corresponding teams. Consequently, the AW may provide a graphical illustration of inter-team interactions at the work-domain level.

The Abstraction-Wheel Table (AWT), as a complementary table format to the visual diagrams, provides a description of each interaction and examines the scope (i.e., inter-team or intra-team), the AH level, and the type of the shared work-domain elements (i.e., shared purpose, value, process, or boundary object). Table 8 shows the AWT for the wheels in Figure 27. Connections are numbered (and correspond to the numbers in Figure 27) for simplification. For example, the most inner circle shows that administration (Link #1) is the shared purpose between the care facilitators; whereas, pain management (Link #2) and maintaining patient health (Link #3) represent the shared purposes between the rest of the healthcare team.

Not only does the AW provide a graphical illustration of shared work-domain elements, but it also offers a graphical representation of team structures and also inter-team interactions between multiple teams. This is a view that is not discussed in a typical CT. Although the AW can be built without building the CT first, I recommend building the CT before developing the AW. The CT provides a clear table format of shared work-domain elements that can be used to support a graphical illustration of shared elements in the AW.

Table 8: Abstraction-Wheel Table for the Healthcare Scenario.

	Team members involved	AH level	Shared element	Scope	Type
1	- Care facilitator at BU - Care facilitator at MBU	Functional purpose	-Administration	BU-MBU	Shared purpose
2	- Obstetrical resident - Anesthesiologist - Staff nurse - Primary nurse	Functional purpose	-Pain management	BU-MBU	Shared purpose
3	- Obstetrical resident - Anesthesiologist - Staff nurse - Primary nurse	Abstract function	-Timely treatment -Appropriate treatment	BU-MBU	Shared value
4	- Care facilitator at BU - Care facilitator at MBU	Abstract function	-Effective administration	BU-MBU	Shared value
5	- Anesthesiologist - Primary nurse	Generalized function	-Blood patch	BU-MBU	Shared process
6	- Care facilitator at BU - Care facilitator at MBU	Generalized function	-Admin services	BU-MBU	Shared process
7	- Obstetrical resident - Anesthesiologist - Staff nurse - Primary nurse	Generalized function	-Consulting -Teaching -Assessment	BU-MBU	Shared process
8	- Obstetrical resident - Anesthesiologist - Staff nurse - Primary nurse - Care facilitator at BU - Care facilitator at MBU	Physical function	-Patient record -Baby record	BU-MBU	Boundary object
9	- Anesthesiologist - Primary nurse	Physical function	-Blood-patch equipment	BU-MBU	Boundary object

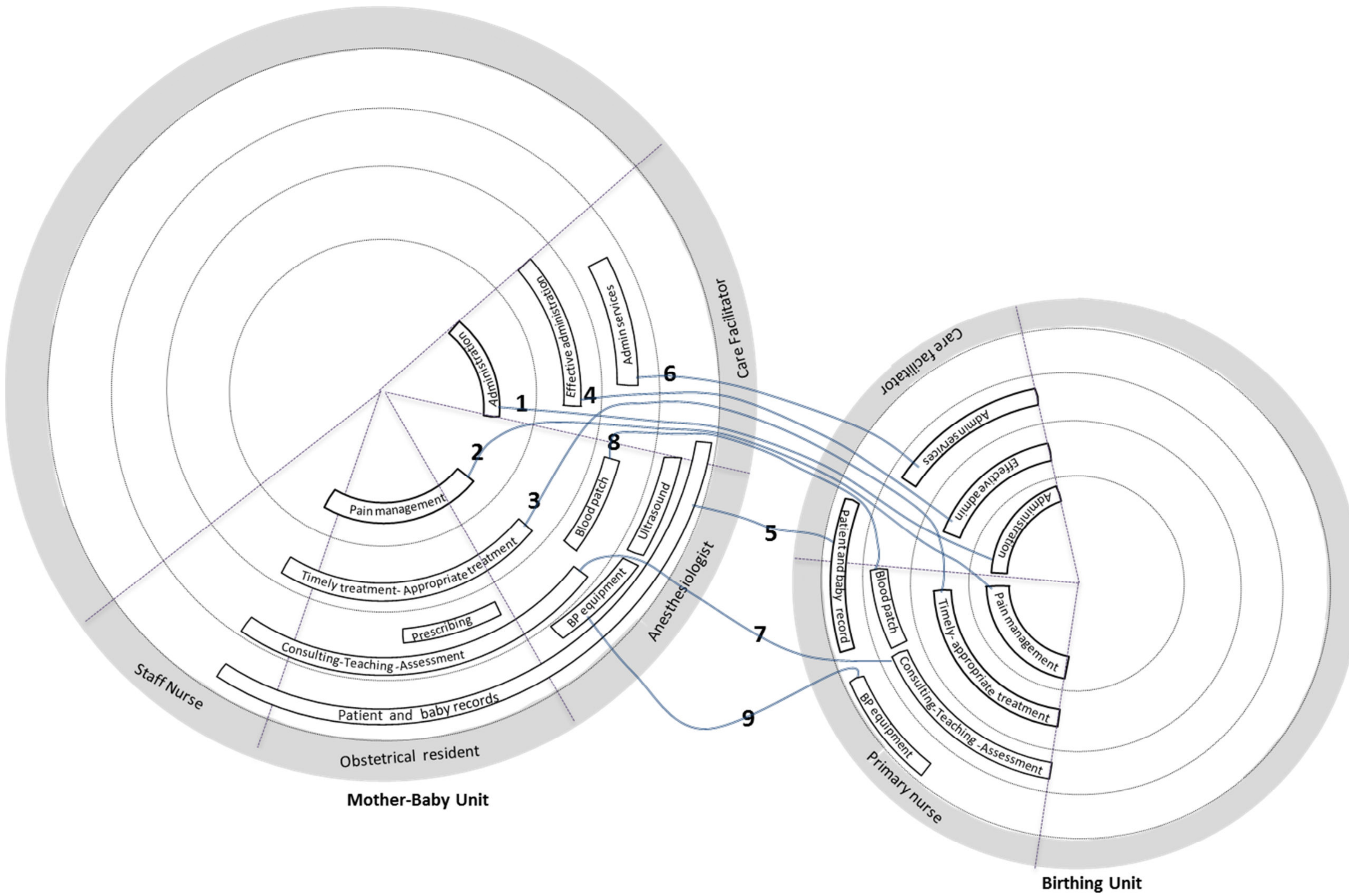


Figure 27. Abstraction Wheels for the Healthcare Scenario.

In large organizations, with a hierarchy of multiple teams, it often gets very complicated to complete a traditional WDA for the organization, as the regular AH does not provide guidance for modeling team structures and inter-team interactions. As a rule of thumb, for organizations with small-sized teams, it is suggested that a single is used for the whole organization instead of separating into multiple teams. However, with large organizations with more teams and roles, it can be easier to look at the separate work domains for various teams, in order to see the details of what work-domain elements are shared and by which teams. Since the AW provides a graphical illustration of team structures, and inter-team interactions at the work-domain level, it can be used for an examination of work-domain constraints in larger teams.

As in the CT, the AW provides a method for examining shared or not shared purpose and values, shared or not shared processes, and boundary objects. Since the AW reveals complementary information about the team structures and also inter-team interactions, it has potential to be used for designing new teams and identifying poor team structures.

3.3.4 Value from Team Work Domain Analysis

Team WDA may supplement traditional WDA with methods to analyze various aspects of teamwork or team requirements. A regular WDA is still conducted as the base for these models, then, depending on the nature of the team situation to be analyzed, the base WDA can be re-examined for team aspects. Several key requirements are identified by Team WDA:

1. Shared or not shared purposes, values, priorities or principles. While the CT may provide a representation of shared purpose and values, the AW may offer a model to visualize those shared elements. When higher-level aspects of work domain are shared, one can expect various team members to be collaborative and likely to work well together. By identifying areas where higher-level elements are not shared, one may be able to identify where conflicts or counterproductive actions could occur.
2. Shared or not shared processes. While the CT may provide a representation of shared processes, the AW may provide a graphical illustration of shared processes within a team and across different teams. Shared processes require tight coordination between team members; whereas, the processes that are not shared can often be tailored to individuals.

3. Boundary objects. Boundary objects need to be carefully designed to be compatible with needs and purposes of multiple operators. Boundary object is a critical, but understudied, theoretical construct in CSCW (Lutters & Ackerman, 2002). At the work-domain level, the collaboration tables and the abstraction wheels can be used to identify boundary objects in a cooperative work.

4. Support Team SA requirements. Collaboration tables may support Team SA requirements with identification of which work-domain elements are shared and by whom. Team SA requirements remark the degree to which the team members know which information needs to be shared. The CT can be used to identify the Team SA requirements at different levels of purposes, values, processes, and physical work-domain resources.

5. Team structure. In a typical AW, a wheel represents each team with each team member comprising a portion of the wheel. By examining the shared work-domain elements within a team and across different teams, one can identify poor team structures and use the abstraction wheels to redesign new teams.

6. Inter-team interactions. The AW provides a model to visualize inter-team interaction at the work-domain level. As a complementary table format to the visual diagrams, the abstraction-wheel tables can be used for examining the scope of each team-interaction and identifying the work-domain elements shared across multiple teams.

7. Potential for designing new teams or identifying poor team structures. Organizing along shared purpose and values, or shared process and objects, allows more effective team structures to be built.

In this section, I explained different models and methods of Team WDA, as the first phase of Team CWA. In the following section, I will explain Team ConTA models and demonstrate the value of the extended models using examples.

3.4 Phase II: Team Control Task Analysis

The collaborative nature of control tasks in a team considerably affects the control tasks for individuals and the role each individual plays in a team. ConTA has been successfully used for examining the control tasks for single operators (e.g., Burns, Enomoto, Momtahan, 2009; Naikar, Moylan, & Pearce, 2006). The objective of Team ConTA is to re-examine the regular ConTA for team aspects. Team ConTA could provide tools and methods for better understanding team structures, team interactions, shared workflows, and boundary objects. Team ConTA models expand decision ladders (Rasmussen et al., 1994) into decision wheels (Ashoori & Burns, 2010) and provide suggestions to revamp the CAT for teams (Ashoori & Burns, 2011). In the following section, I will introduce the extended models for Team ConTA and will explore them for the sample scenario.

3.4.1 Chained Ladders

Rasmussen et al. (1994) suggest the use of a chain of ladders to represent the distribution of decision activities in a team. There is one decision ladder represented for each operator and the links between the ladders can be used to demonstrate the workflow. Figure 28 shows a chain of the decision ladders for the sample scenario.

Links are numbered for simplification. Beginning at the lower left of the patient's ladder, a headache for the patient is a signal to make a decision about contacting the staff nurse (Link #1). The shaded boxes in the lower left of the decision ladder of the staff nurse represent the decision-making process about the reason for the pain and the need to consult with an obstetrician. The staff nurse visits the patient looking for other evidence (Link #2) and decides to consult with the obstetrical resident available in the unit (Link #3). The shaded boxes of the decision ladder of the obstetrical resident show his or her evaluation of the patient record and the decision-making process for reasoning about the pain and possible prescriptions to relieve that (Link #4). Once the obstetrical resident decides that the patient might benefit from a blood patch, he or she is aware that the decision must be approved by the anesthesiologist and he or she is expected to contact the anesthesiologist for approval. This shortcut is shown as a shunt in the decision ladder of the obstetrical resident. Afterwards, the obstetrical resident shares the decision with the anesthesiologist to get the approval for the procedure (Link #5).

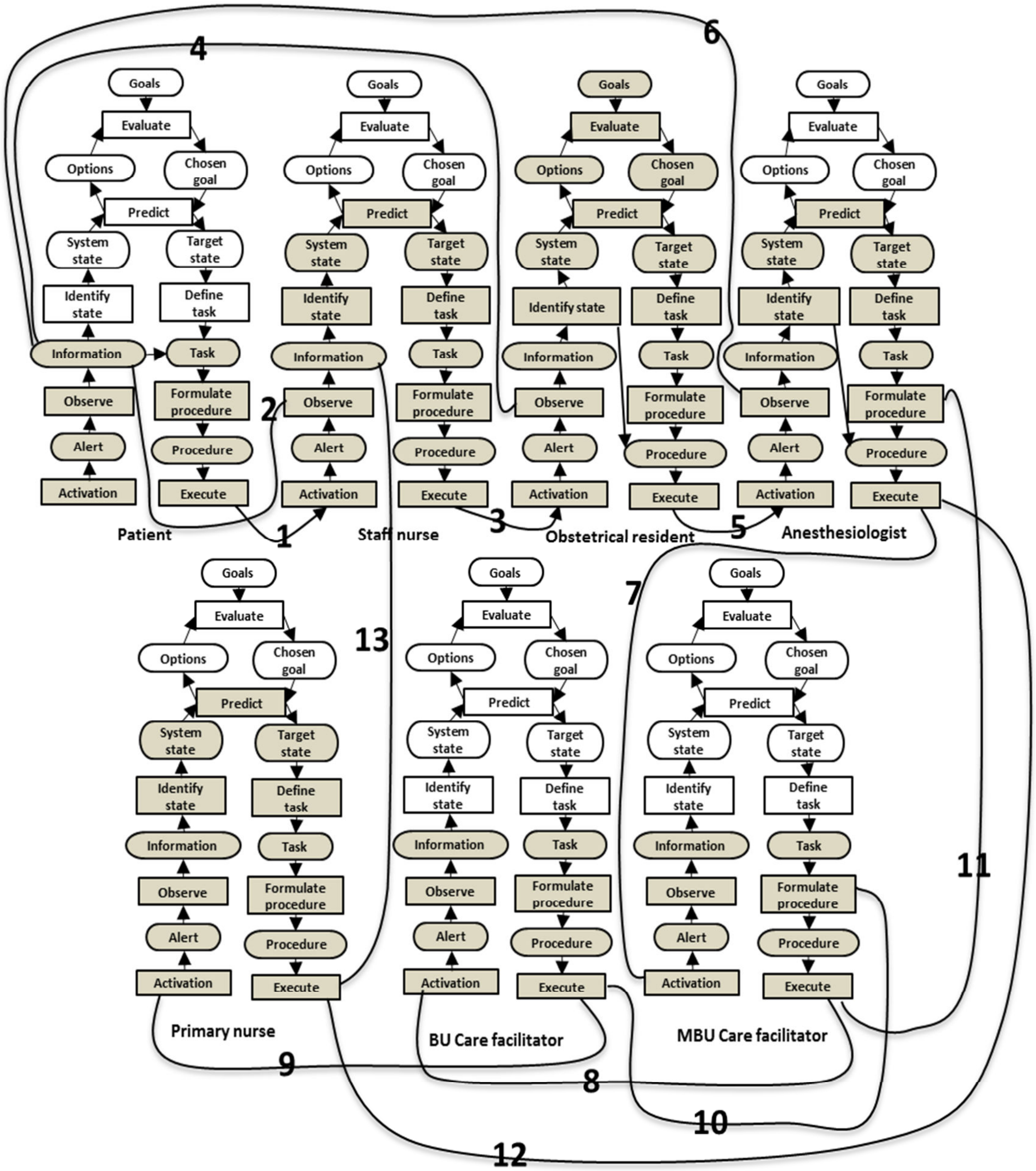


Figure 28. Chain of Decision Ladders for the Healthcare Scenario. (Adapted from Ashoori and Burns, 2012)

The shaded boxes in the anesthesiologist's ladder indicate his or her evaluation of the patient record as well as the decision-making process for prescription verification (Link #6). Based on the results of the obstetrical resident's analysis and the patient record, the anesthesiologist would draw a conclusion whether to approve the prescription or not. The anesthesiologist is aware that the first step in completing a blood-patch procedure is to contact the MBU care facilitator to arrange the procedure with the BU. The shortcut is shown as a shunt in the decision ladder of the anesthesiologist. Right after the anesthesiologist's request for the blood-patch arrangement (Link #7), the care facilitator in the MBU contacts the care facilitator at the BU to request for an available nurse and arrange to transfer the patient (Link #8). Afterwards, the care facilitator in the BU assigns a nurse to complete the procedure (Link #9) and confirms the arrangement with the care facilitator at the other unit (Link #10). The MBU care facilitator updates the anesthesiologist with the details of the arrangement (Link #11). Once the patient is transferred, the primary nurse and the anesthesiologists are available to complete the procedure (Link #12). After the procedure, the patient is transferred back to the MBU and the primary nurse updates the staff nurse with the results of the blood patch (Link #13). I have to acknowledge that some of the tasks discussed here are not a control task as they do not directly act on the physical resources of the work domain. My sample scenario is limited in this regard, but it is still a good example to demonstrate the use of the ideas.

As shown in the figure, the chained ladder gets chaotic for larger teams. Although this approach provides a model to represent shared workflows in a team, it may suffer from a scaling issue, being better suited to environments with two or three clear team roles. While the chained ladder does not support modeling team structures, one may be able to manage complexity of workflows by adding an additional layer to the chained ladders for modeling team structures. The decision wheel (Ashoori & Burns, 2011) is introduced to analyze team structures at the control-task level. In the following section, I will explain the concept of the decision wheel and demonstrate the value of the model using examples.

3.4.2 Decision Wheels

The chained ladder is a good representation to show how different parties interact on a single activity, but they may not provide sufficient guidance on modeling team structures. The decision wheel (Ashoori & Burns, 2010) as an extension to the decision ladder could provide a model for examining synchronous or asynchronous team interactions. The basic ladder does not support explicitly an examination of the synchronicity of communication, though there is no reason that they could not. However, in a Team ConTA analysis, the synchronicity of communication should be identified. As discussed in Chapter 2, the CSCW taxonomy suggests a set of criteria for defining CSCW system requirements. With respect to the interaction requirements, CSCW taxonomy recommends and examination of synchronicity, communication channels, and a system distribution for each interaction, such as the need to interact from remote places (Reinhard et al., 1994). In this section, I use the CSCW criteria as a basis for the analysis of interactions.

In a typical decision wheel, the wheel represents a team with each team member comprising a portion of the wheel. The decision ladders of the team members are represented within the slices and the connections between the ladders represent team interactions. Figure 29 illustrates the mapping between a standard decision ladder and a slice of the wheel. Information-processing activities are represented by small circles while ovals depict the cognitive states of knowledge resulting from the information-processing activities. There is a colour code to distinguish synchronous from asynchronous information-processing activities. The legend in Figure 30 shows this colour code.

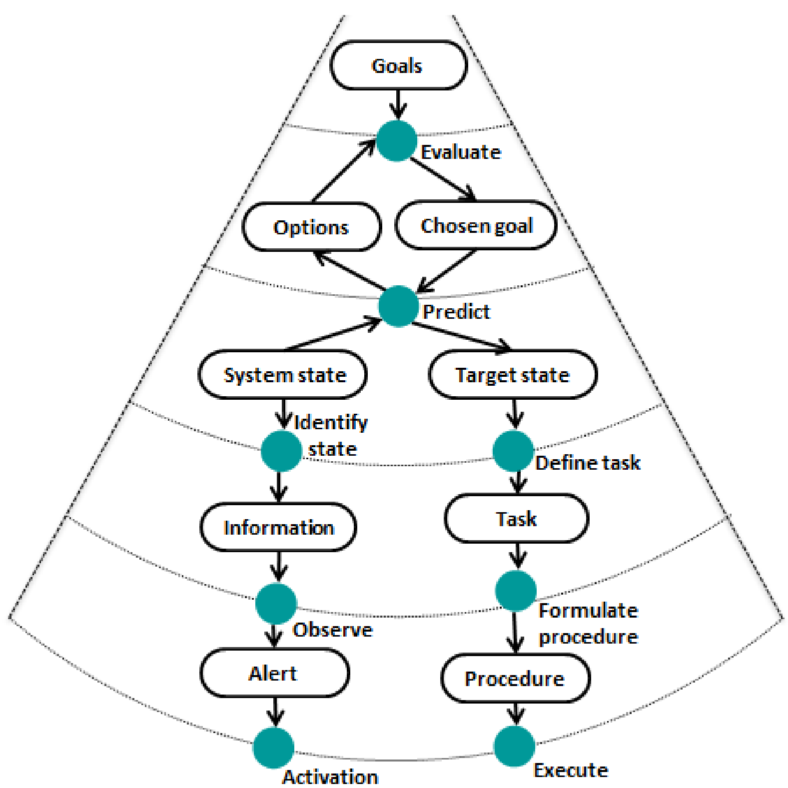


Figure 29. How to Map a Decision Ladder to a Slice of the Decision Wheel. (Taken from Ashoori and Burns, 2012)

Figure 30 shows the decision wheel for the sample scenario. Each wheel in the figure represents one of the teams in the Labour and Delivery Department. Connections between the wheels represent inter-team interactions between the MBU and the BU teams. In the figure, the MBU decision wheel consists of five slices representing the patient, staff nurse, obstetrical resident, anesthesiologist, and care facilitator. The BU team requires two slices, one for the primary nurse and one for the care facilitator. The connections between the slices of a team represent intra-team interactions and the connections between the wheels represent inter-team interactions. Further characteristics of each interaction are described in a Decision-Wheel Table (DWT), shown in Table 9.

Each row of the table represents a single collaborative link between operators. Links are numbered in the table and correspond to the numbers in Figure 30. For each collaboration link, type of interaction (synchronous/asynchronous), scope of interaction (between teams or intra-team), corresponding control task, and boundary objects (the object shared within the link) are listed in the table. These factors were chosen since they could be relevant to the design and development of a support tool for teams (Ashoori & Burns, 2010). As shown in Figure 30, the patient's headache is the signal to initiate the workflow. She calls the assigned staff nurse to discuss her headache (Link #1). Afterwards, the staff nurse visits the patient (Link #2) and calls the obstetrical resident to discuss the severity of the patient's headache (Link #3). The obstetrical resident comes to the ward to visit the patient (Link #4) and decides the patient may benefit from a blood patch. The obstetrical resident contacts the anesthesiologists to verify the procedure (Link #5). The anesthesiologist visits the patient to assess if the patient would benefit from an epidural blood-patch injection (Link #6). After verifying the blood patch, the anesthesiologist contacts the care facilitator in the MBU to arrange for the procedure (Link #7). The care facilitator at each unit is responsible for arranging inter-team procedures (Link #8). The care facilitator at the BU assigns a primary nurse for the procedure (Link #9) and updates the care facilitator at the MBU with the time for the procedure (Link#10). The care facilitator at the MBU confirms the arrangement with the anesthesiologist (Link #11). The patient is transferred to the BU, where both the anesthesiologist and the primary nurse are present to complete the procedure (Link #12). Afterwards, the patient would be ready to transfer back to the MBU. The primary nurse reports the progress of the procedure to the staff nurse before the patient is transferred back to the MBU (Link #13).

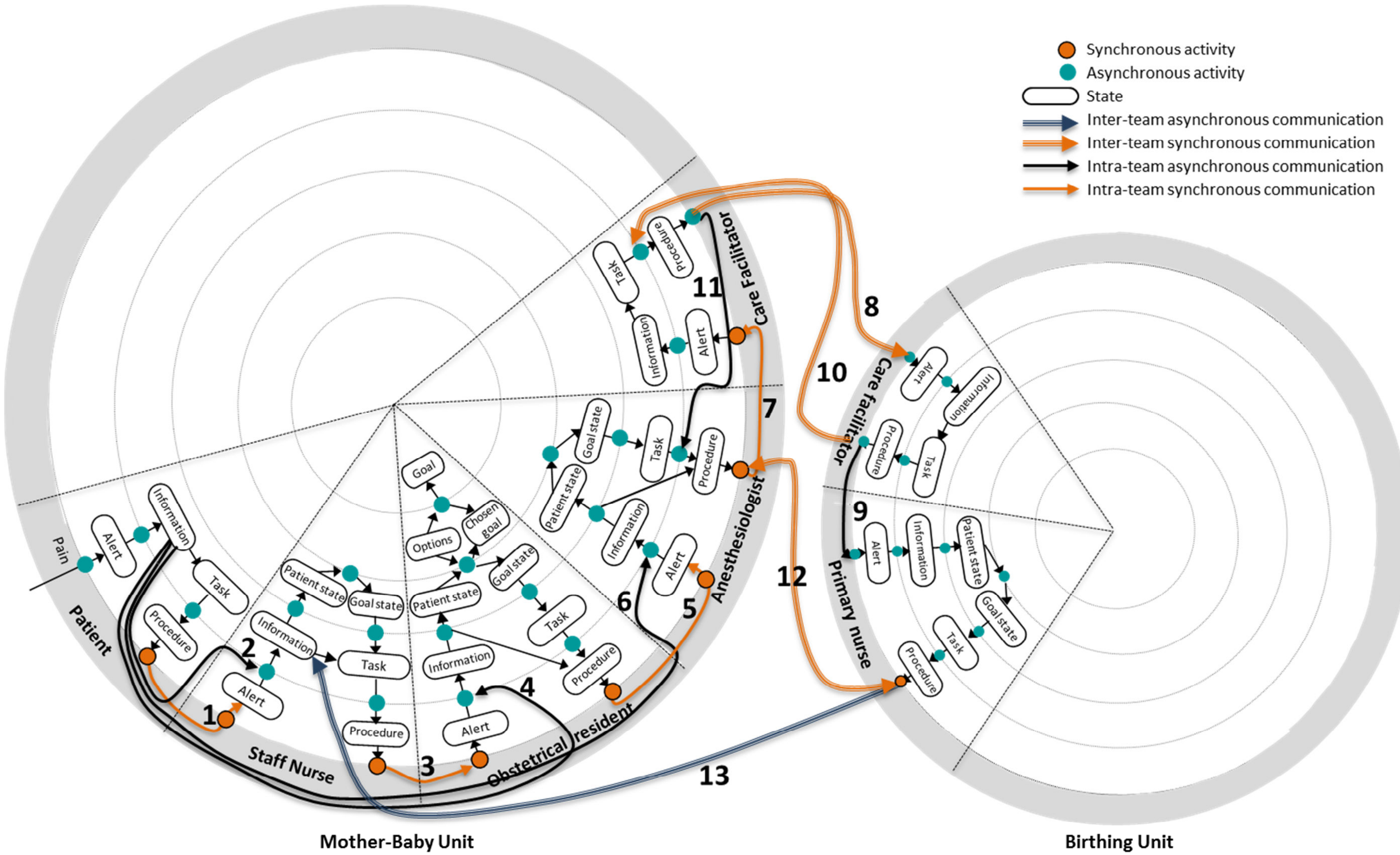


Figure 30. The Decision Wheel for the Healthcare Scenario.

Table 9: The Decision-Wheel Table for the Healthcare Scenario.

	Team members involved	Task	Boundary Objects (Star & Griesemer, 1989)	CSCW criteria (Reinhard et al, 1994): Synchronicity	Distribution
1	-Patient -Staff nurse	-Patient teaching -Patient assessment	-Patient record -Baby record	Synchronous	MBU
2	-Patient -Staff nurse	-Patient assessment	-Patient record -Baby record	Asynchronous	MBU
3	-Staff nurse -Obstetrical resident	-Consulting	-Patient record -Baby record	Synchronous	MBU
4	-Patient -Obstetrical resident	-Patient teaching -Patient assessment	-Patient record -Baby record	Asynchronous	MBU
5	-Obstetrical resident -Anesthesiologist	-Consulting	-Patient record -Baby record	Synchronous	MBU
6	-Patient -Anesthesiologist	-Patient teaching -Patient assessment	-Patient record -Baby record	Asynchronous	MBU
7	-Anesthesiologist -MBU Care facilitator	-Administrative arrangements for the blood patch	-Patient record -Baby record	Synchronous	MBU
8	-MBU Care facilitator -BU Care facilitator	-Administrative arrangements for the blood patch	-Patient record -Baby record	Synchronous	MBU-BU
9	-BU Care facilitator -Primary nurse	-Assigning a nurse	-Patient record -Baby record	Asynchronous	BU
10	-BU Care facilitator -MBU Care facilitator	-Administrative arrangements for the blood patch	-Patient record -Baby record	Synchronous	MBU-BU
11	-MBU Care facilitator -Anesthesiologist	-Administrative arrangements for the blood patch	-Patient record -Baby record	Asynchronous	MBU
12	-Anesthesiologist -Primary nurse	-Consulting -Blood-patch procedure	-Patient record -Baby record -BP equipment	Synchronous	MBU-BU
13	-Primary nurse -Staff nurse	-Consulting	-Patient record -Baby record	Asynchronous	MBU-BU

The decision wheel along with the corresponding table may be used to extract the collaborative work requirements and gain insight into the behaviour of one team member in relation to another. A serendipitous feature of this structure is that high-level cognitive tasks become focused in the centre “bulls-eye” of the wheel. While the decision-making activities are mapped to the inner circles, observations and actions tend to filter to the outside of the wheel, making it easier to examine team interactions at different levels. With respect to Team SA mechanisms and mental models, the decision wheels show when teams must collaborate on knowledge-based tasks together (the centre of the wheel), where shared mental models might be most needed.

The decision wheel could also support an extraction of Team SA devices by examining the distribution and synchronicity of interactions. Surely, knowing when people are collocated, collaborating synchronously or asynchronously would be important in building a design that can support Team SA.

In the following section, I will explain the key concepts of the extended CATs for teams with examples from the healthcare scenario.

3.4.3 Team Contextual Activity Template

While the decision wheels are a good representation to show how different parties interact on a single control task, the CAT is a good representation to show how individuals are involved in multiple control tasks in various situations. However, the basic CAT does not convey information about team structures, team interactions, or boundary objects. Figure 31 shows the basic CAT for the sample scenario.

Naikar, Moylan, and Pearce (2006) consolidate the approaches of Vicente (1999) and Rasmussen (1994) to ConTA and suggest decomposing activity into a set of recurring work situations to deal with and a set of work functions to perform. In a basic CAT, work situations are shown along the horizontal axis and work functions are shown along the vertical axis. The circles with their horizontal lines indicate all work situations in which a work function can happen. As shown in the figure, three main work situations are identified for the sample scenario: (1) patient assessment, when the healthcare team assesses the patient to figure out the reason for headache and decides on the proper pain killers; (2) arranging for the blood patch procedure, and (3) completing the procedure to relieve pain. The primary work functions identified here are (1) patient assessment, (2) consulting, (3) patient teaching, (4) prescribing, (5) administration to arrange for the blood patch, and (5) completing the procedure. While the basic CAT provides a good illustration of work functions in various situations, it does not represent the distribution of shared work functions to different team members.

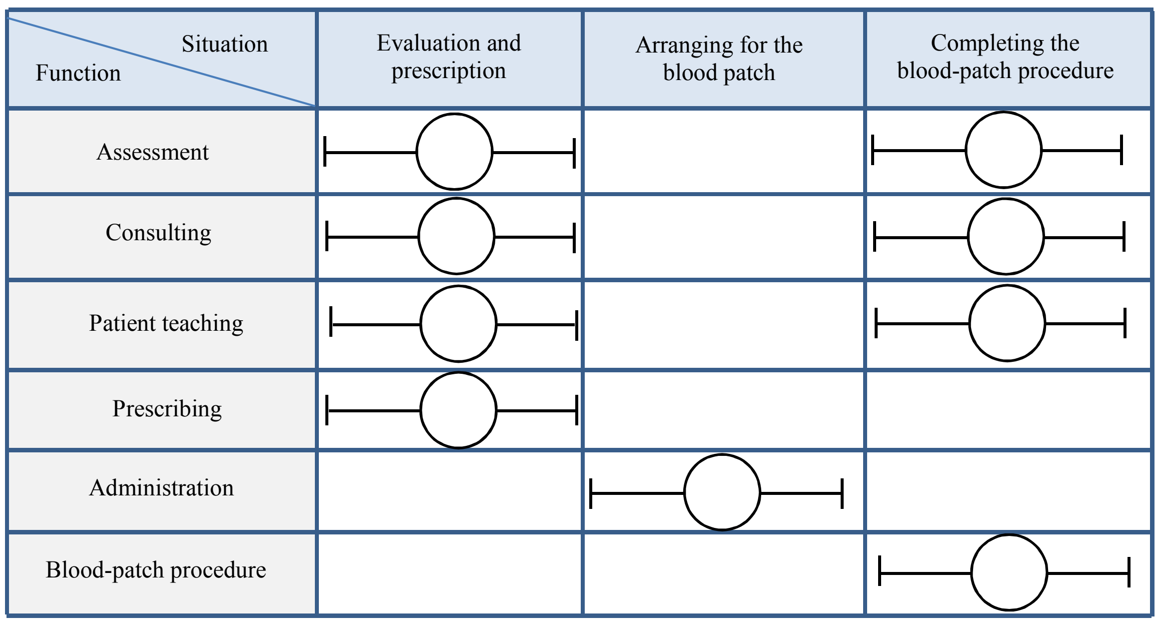


Figure 31. The Contextual Activity Template for the Healthcare Scenario.

Naikar et al (2003) argue that the basic CAT can be extended to identify poor team structures. They suggest mapping workflow to the CAT to represent a distribution of work problems to the team members. Figure 32 shows this representation for the sample scenario. Roles and responsibilities of team members are described in rows (e.g., obstetrical resident, anesthesiologist) and the work problems allocated to the team members are illustrated with circles (e.g., patient assessment, prescribing). Communication and coordination associated with reallocation of work problems are shown with arrows.

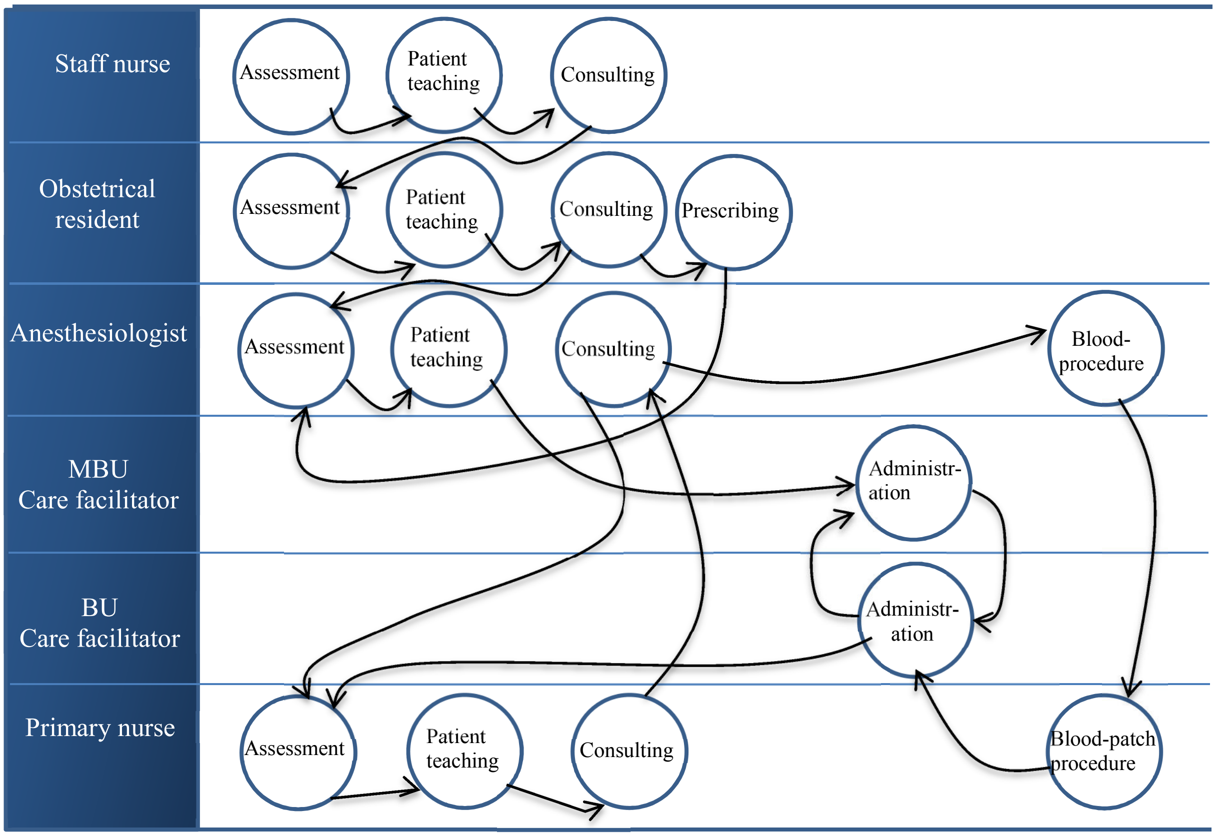


Figure 32. The Contextual Activity Template Modified to Represent the Distribution of Work functions to Team Members.

Naikar et al (2000) suggest the use of this representation to explore feasibility of alternative team designs. They argue that by summarizing patterns of activity and workload of team members, a spare capacity for future roles and responsibilities can be estimated. This process can differentiate between various team arrangements and lead to recommendations for a potentially effective team design. Figure 33 shows three main groups of team activities extracted from the healthcare scenario at the control-task level. In order to minimize inter-team connections, each activity group can be assigned to a team.

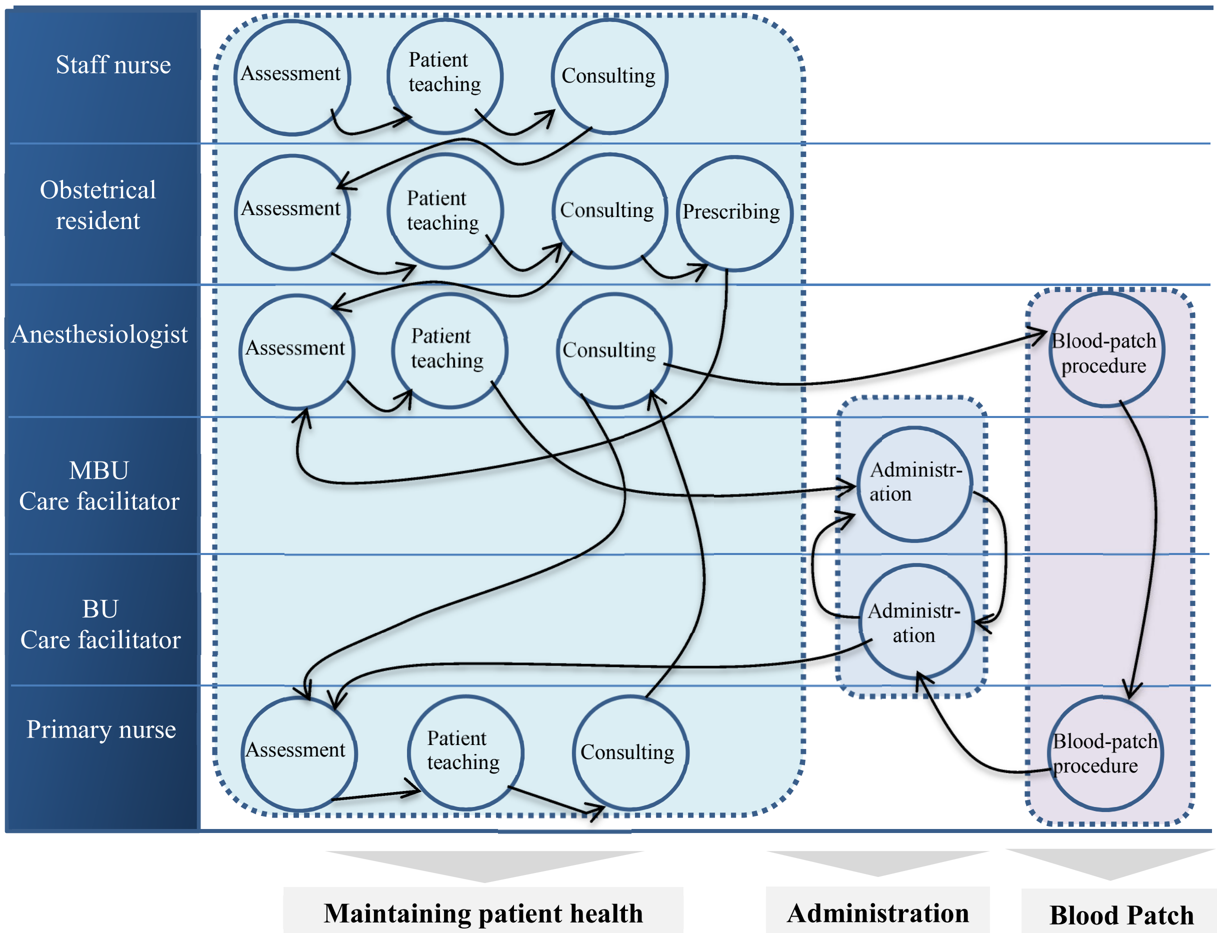


Figure 33. Representation of Activity for the Healthcare Scenario.

The challenge in designing a new team is to study teamwork not only at the task level (Naikar et al., 2000), but in a broader spectrum to include physical work-domain elements as well as values, and priorities of a team. Organizing along shared purposes and values, or shared processes and objects, may result in building more effective team structures. In the healthcare scenario, three groups of activities can be extracted from the CAT (Figure 34). Although the blood-patch procedure can be seen as a different group, it shares the purpose and values with maintaining patient health. The blood-patch team can be a good candidate to be part of the healthcare team at the MBU. Redesigning the MBU team to include the primary nurse can reduce considerable amount of inter-team arrangements and result in a more effective team structure.

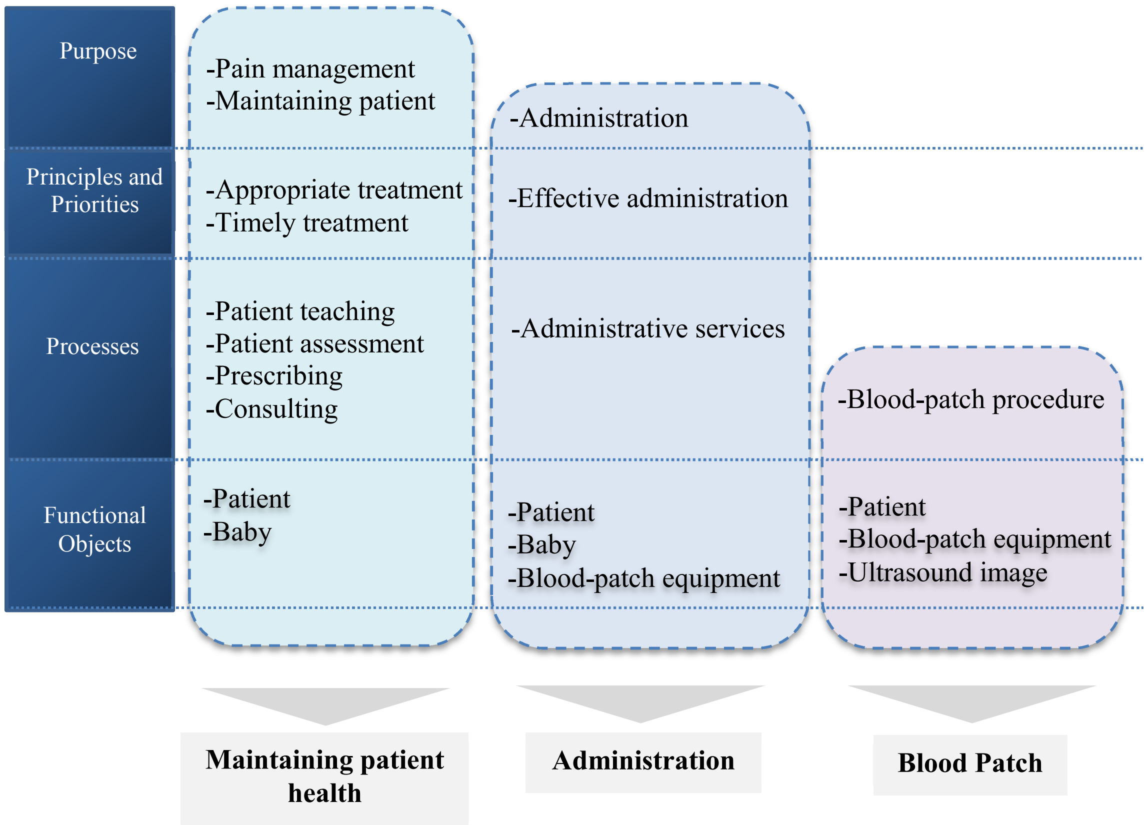


Figure 34. Collaboration Maps for the Healthcare Scenario.

Figure 35 shows the decision wheel for the new healthcare team. In comparison with the decision wheels in Figure 30, this new design saves unnecessary information exchange between the units and can result in a less complex caregiving process.

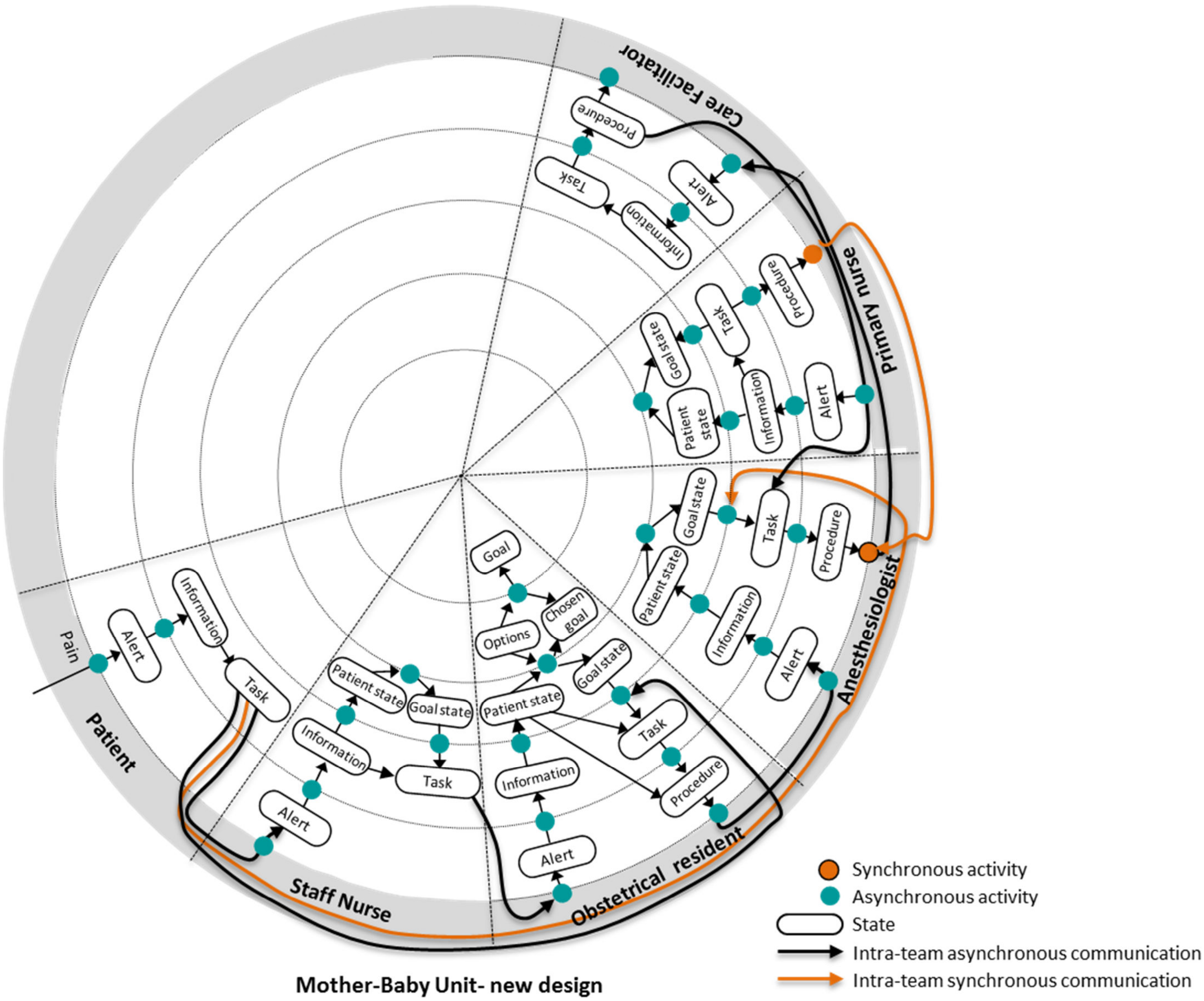


Figure 35. The Decision Wheel for the New MBU Team.

Besides the potential for designing new teams, the basic CAT can also be used for exploring responsibilities of team members in a variety of situations. Figure 36 shows a modification of the basic CAT to represents team interactions in various situations. Work situations are shown along the horizontal axis and roles and responsibilities are shown along the vertical axis. The ovals indicate the teamwork functions and the small solid circles attached to the teamwork functions indicate team members that collaborate on that function. By using this representation, one can identify what needs to be done in various situations and examine interaction patterns over time.

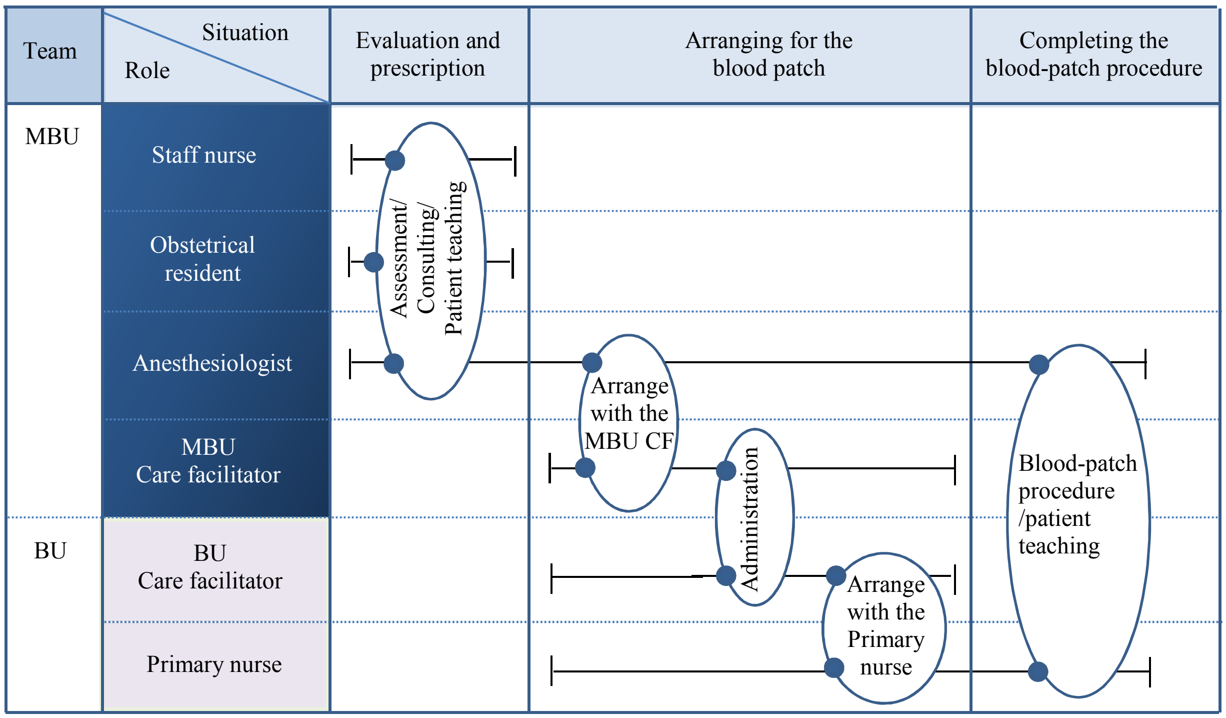


Figure 36. Team Contextual Activity Template for the Healthcare Scenario.

Jenkins, Stanton, Salmons, and Walker (2008a) suggest a different approach to map roles and responsibilities to the CAT. They recommend a colour-coded CAT that shows who performs what functions and in what situations. Figure 37 shows the colour-coded CAT for the healthcare scenario. In this approach, each actor is represented by a specific colour, which could become complicated for larger groups.

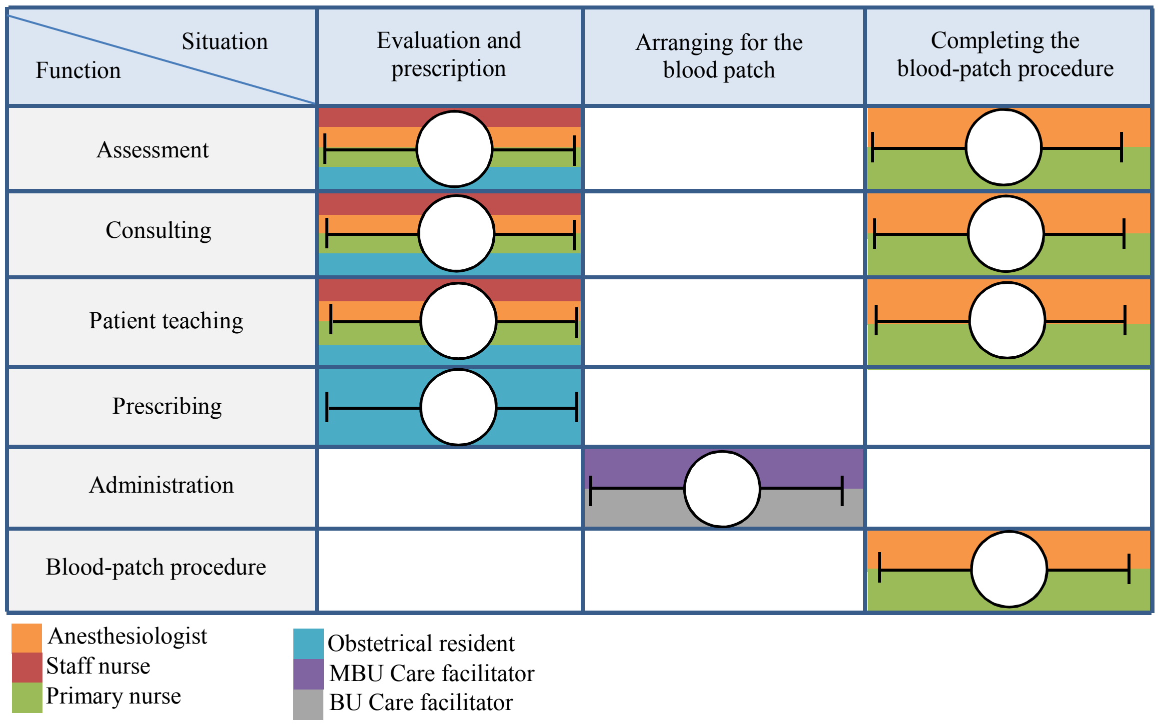


Figure 37. Colour-Coded Contextual Activity Template for the Healthcare Scenario. Jenkins et al. (2008a) suggests representing each actor with a single colour, which could become complicated for larger groups.

3.4.4 Value from Team Control Task Analysis

Team ConTA methods may supplement traditional ConTA with methods to analyze various aspects of teamwork or team requirements. A regular ConTA is still conducted as the base for the Team ConTA extensions, then, depending on the nature of the team situation to be analyzed, the base ConTA can be re-examined for team aspects. Several key requirements are identified by Team ConTA:

1. Type of interaction: synchronous vs. asynchronous. With respect to interaction requirements, CSCW taxonomy recommends an examination of synchronicity, communication channels, and a system distribution for each interaction (Reinhard et al., 1994). When extracting design requirements for communication devices, it is essential to examine different types of team interactions and the way individuals communicate in a team. While the decision ladder may provide a graphical illustration of synchronicity of interactions, the abstraction wheels present

the interaction requirements in terms of synchronicity, communication channels, and system distribution. In Chapter 4, I will examine these criteria for a real application domain.

2. Boundary objects. As discussed in the Team WDA section, boundary objects are a critical theoretical construct in CSCW (Lutters & Ackerman, 2002) and need to be carefully designed to be compatible with the needs and purposes of different team members (Star & Griesemer, 1989).

3. Intra-team interactions. An understanding of intra-team interaction at various cognitive states and cognitive processes, shortcuts, and shunts, allows examining the cognitive aspect of collaboration and designing better suited technologies for teams.

4. Interactions between teams. An identification of the collaboration points between multiple teams and the boundary objects they share within each interaction allows better suited technologies to be designed for connecting multiple units across an organization.

5. Potential for designing new teams or identifying poor team structures. Organizing along inter-team interactions, allows more effective team structures to be built.

6. Support Team SA devices. The decision wheel could also be used to support the Team SA devices through an examination of the distribution and synchronicity of interactions. Knowing when people are collocated, collaborating synchronously or asynchronously would be important in building a design that can support Team SA.

7. Support Team SA mechanisms. The decision wheels show when teams must collaborate on knowledge-based tasks together (the centre of the wheel), where shared mental models might be most needed.

8. While the modified CAT for teams distributes multiple activities over multiple operators, the chained ladders and the decision wheels distribute one activity over multiple operators.

9. The modified CAT for teams may be used to extract the design requirements for different modes of operations required for an effective collaborative system to adapt to the changing demands of a dynamic environment.

10. The decision wheel, like the collaboration table, is aimed at showing interactions in larger teams. The decision wheel is a new adaptation of the decision ladder used to look at larger team interactions.

In this section, I explained different models and methods of Team ConTA, as the second phase of Team CWA. In the following section, I will explain Team StA models and demonstrate the value of the extended models using examples.

3.5 Phase III: Team Strategies Analysis

While ConTA is concerned with what tasks are needed, StA is concerned with how those tasks can be done. Many of previous attempts to use StA for strategies analysis have focused on an examination of information flow maps for modeling a descriptive characterization of strategies for single operators (e.g., Vicente, 1999; Ahlstrom, 2005). Naikar (2006) supports this descriptive approach, but she comments that StA is more concerned with identifying a range of possible strategies rather than a detailed sequence of actions to accomplish tasks.

Although StA identifies various strategies that can be used by operators to perform control tasks, StA leaves open the issue of who is responsible for performing different actions in a strategy (Vicente, 1999). Rasmussen (1981) argues that the information flow maps can be reused to address this shortcoming. He suggests mapping the operators' responsibilities to the information flow maps to a distribution of demands to the operators. I support this approach, but argue that a description of strategies might not be sufficient to serve as the basis for the design of socio-technical systems.

With respect to Team StA, I would argue that, possible team strategies can be examined within four categories of (1) operational, (2) coordination, (3) team development, and (4) structural strategies. Operational strategies focus on different ways of accomplishing control tasks. Coordination strategies are used to analyze coordination structures and the processes underlying coordination. Team development strategies arise from the Tuckman's team development model (Tuckman & Jensen, 1977) for examining how operator's behaviours change during the team lifecycle. Structural strategies inherit and build on the work-domain constraints for examining a feasible set of actions.

In the following sections, I will further explain these four categories of team strategies with using examples from the healthcare scenario.

3.5.1 Operational Strategies

Operational strategies provide a process description of how to carry out control tasks. Each strategy has its own unique requirements and provides a different level of performance and costs for the system. For example, Figure 38 shows a typical IFM for patient assessment in the healthcare scenario. I should acknowledge that the given healthcare scenario lacks specifics about the process description as it only explains one narrative, one trajectory of action. The information used for the strategy analysis in this section was supplemented with discussions with the SMEs at the Labour and Delivery Department of The Ottawa Hospital.

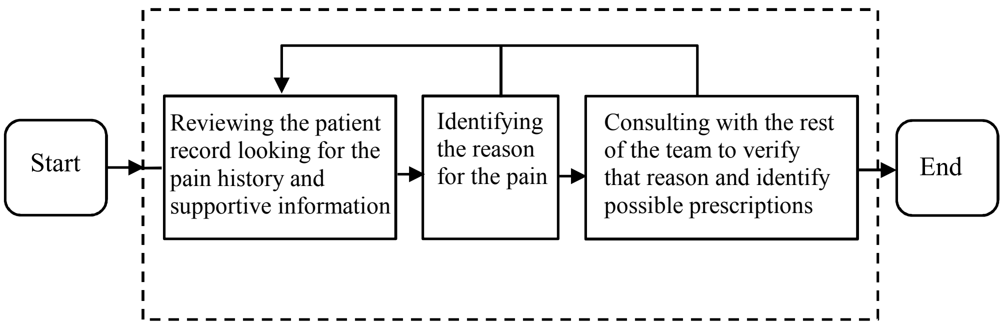


Figure 38. The Information Flow Map for Patient Assessment.

Although the basic IFM can be used to identify a list of actions for performing patient assessment, it does not reveal any information about team interactions and how the healthcare team collaborate to complete the assessments. The basic StA concerns operators' contributions, but doesn't distinguish between the contributions of different operators. Jenkins et al. (2009) suggest a colour-coded IFM to represent operators working together on an action. Figure 39 shows this representation for patient assessment. Although this representation can be used to identify the contribution of each team member to the sequence of actions, the colour-coded IFM does not reveal any information about the sequence of interactions, coordination structure, and viable strategies in various situations.

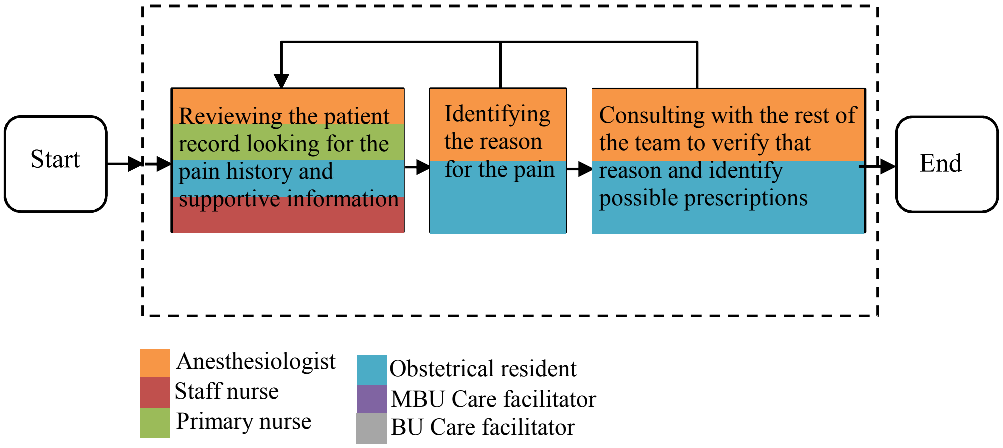


Figure 39. Colour-Coded Information Flow Map for Patient Assessment.

As discussed in Section 3.4, operators may switch between several strategies to cope with changing demands. While the basic IFM (Vicente, 1999) represents a sequence of actions for completing an information-processing activity, it does not examine strategy changes in a variety of situations. Jenkins et al. (2009) suggest using the CAT for examining strategies in various situations. However, this approach still falls short in identifying coordination structures or the sequence of interactions in various situations. Figure 40 illustrates how a CAT can be extended to represent the IFMs of patient assessment in a normal and emergency situation.

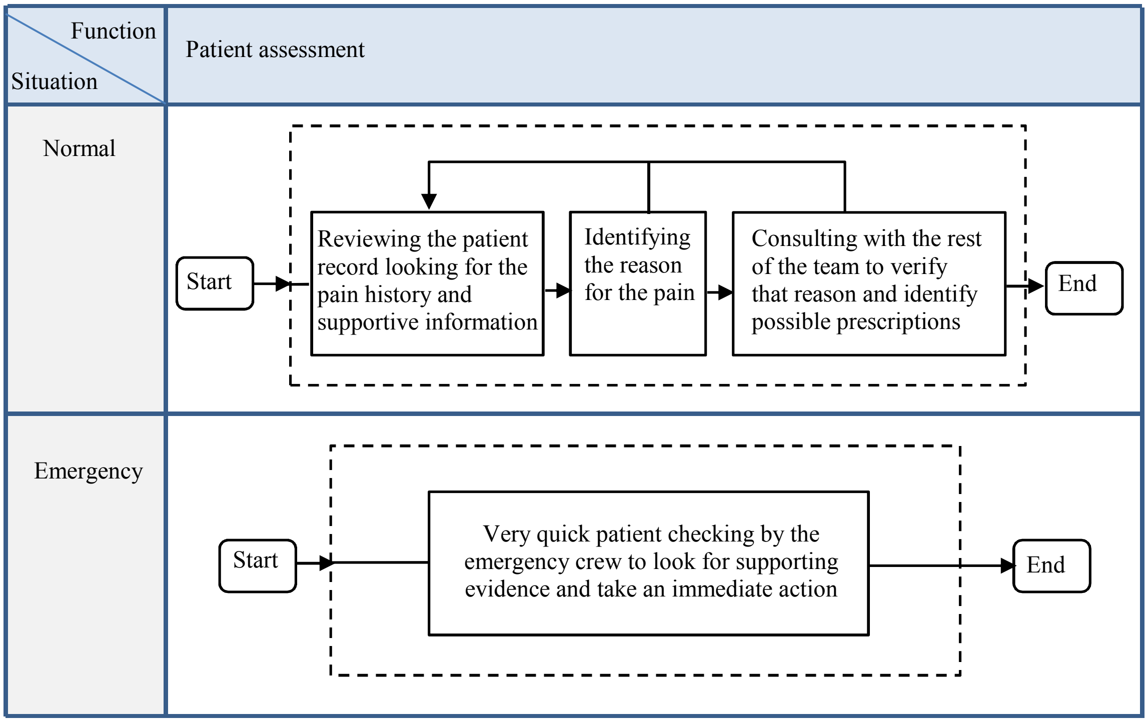


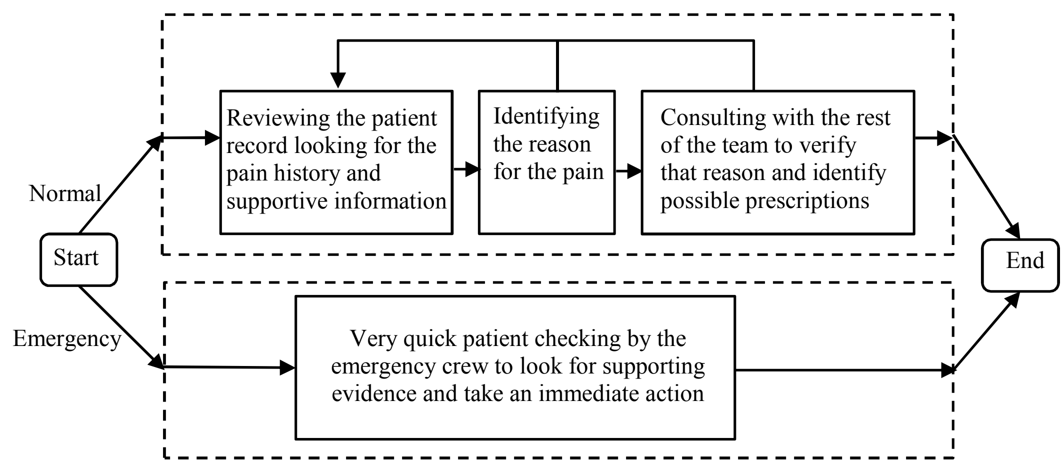
Figure 40. The Information Flow Map Plotted on the Contextual Activity Template for Patient Assessment.

I argue that a strategy can be described in terms of the factors, such as resource access, task priority, the expertise level, and time constraints, that may influence strategy selection in a variety of situations. Table 10 shows an example explanation of different patient assessment strategies in terms of coordination structure, resource access, task priority, sequence of actions, experience level of the operators involved, location constraints, time constraints, and existing systems used. Later, in Section 3.5.4, I will come back to this discussion and provide a list of some of the strategy selection factors recorded in the literature. Again, I should acknowledge that the given healthcare scenario lacks specifics about the resources availiable and the expertise of the healthcare team.

Table 10: A Modified Contextual Activity Template to Identify Different Strategies in Various Situations.

Team Function: Patient assessment								
Factors / Situation	Team Structure	Resource access	Expertise level	Task priority	Procedures	Location	Duration	Systems used
Emergency	-Pediatrician -Staff nurse -Obstetrical resident -Anesthesiologist -Primary nurse To guarantee a quick reliable response, more experienced people will be called.	Full access	Mostly experienced	High	In case of an emergency, the emergency crew is expected to rush into the patient room for an immediate patient assessment	MBU, the patient is transferred to ICU if needed	Quick response is required	Electronic patient record and the internal systems as needed
Normal	-Staff nurse -Obstetrical resident -Anesthesiologist -Primary nurse	Limited access	Novice and expert	Medium	The staff nurse visits the patient. If needed, an obstetrical resident comes to prescribe a blood patch, which later gets confirmed by an anesthesiologist	MBU	It usually takes 5 to 10 min	Electronic patient record

Information flow map:



In summary, an analysis of operational strategies can result in a better understanding of team structures and interaction patterns between team members. Operational strategies in a Team StA are structured and built using the results of the analysis of team activities in a Team ConTA. Figure 41 shows the connections between the extended models of the strategies analysis and the first two phases of the Team CWA.

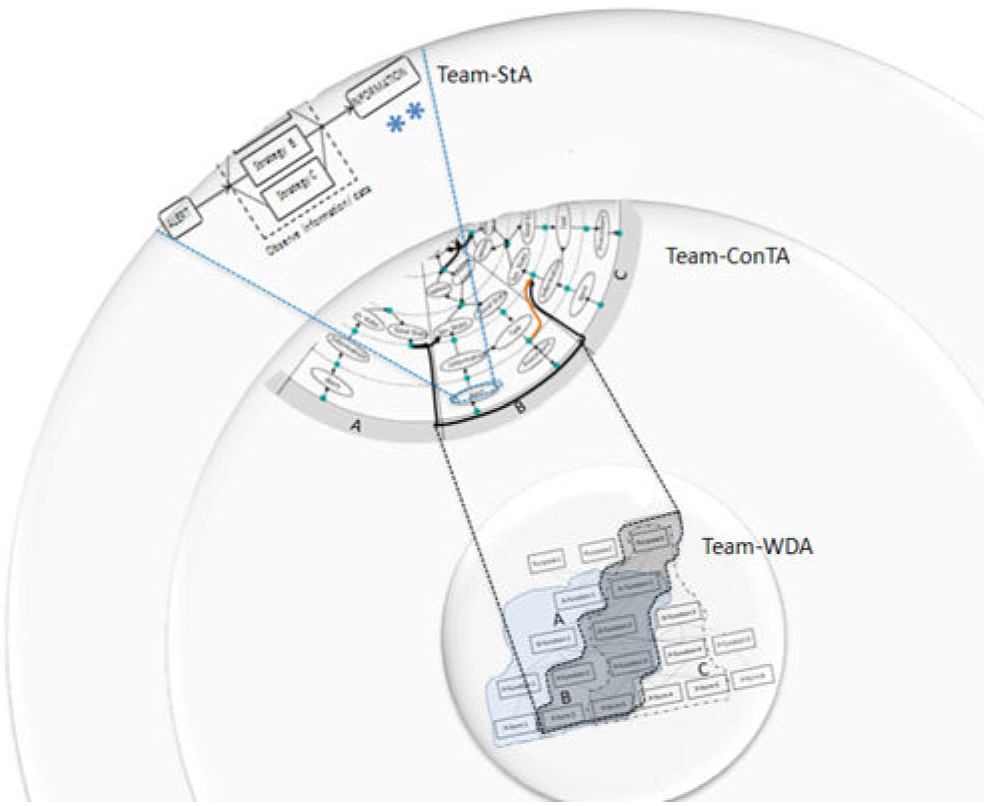


Figure 41: Binding Team CWA Phases Together.

In this section, I reviewed operational strategies and explored some of the connections between Team StA and the methods and models of Team WDA and Team ConTA. In the following section, I will explain coordination strategies with examples, and will discuss how the StA models may be extended to support management styles and coordination structures.

3.5.2 Coordination Strategies

Coordination strategies are used to analyze coordination structures and the processes underlying coordination. The most recognized definition of coordination is taken from coordination theory (Malone & Crowston, 1990). Malone and Crowston (1990) define coordination as "the act of managing interdependencies between activities performed to achieve a goal" (p.6). In this section, I adopt this definition of coordination and extend the Team StA models to identify different strategies of managing interdependencies between activities. Very few attempts have been made to use the CWA methods for analyzing coordination strategies (e.g., Rasmussen, 1989; Vicente, 1999; Pfautz & Pfautz, 2009).

Vicente (1999) suggests an analysis of social organizational elements with respect to (1) communication related to the coordination of work, and (2) organizational structure supporting that communication. Crowston and Kammerer (1998) argue that the processes underlying coordination can be discussed in four levels: (1) group decision-making level, (2) communication level, (3) coordination level, and (4) the perception of common objects level. At the decision-making level, coordination involves an examination of team goals, alternatives, evaluations, and choices (Malone & Crowston, 1990). For example, when a team decides on what goal to select, the coordination strategy for goal selection requires information about the team goals and how different team members contribute to achieve them.

At the communication level, the physical elements of the work domain, such as senders, receivers, messages, and resources involved in communication should be identified. At the coordination level, the main focus is on an examination of information flows, tasks, and interdependencies between tasks (Malone & Crowston, 1990).

At the perception of common objects level, the coordination strategy should address boundary objects and physical work-domain resources. The processes at different levels are dependent and one level may use processes from other levels. For example, when a team decides on which resources will be allocated to what team members, the coordination strategy at the decision-making level is concerned with the alternatives and evaluation of choices. At the coordination level, picking a coordination strategy requires an examination of interdependencies between the tasks. At the perception of common objects level, the physical work-domain resources should be examined to see what resources are available.

As discussed in the previous sections, Team WDA and Team ConTA can be used for an analysis of shared work-domain elements and interdependencies between control tasks. Consequently, the findings from the previous two phases can be used for an examination of the processes underlying coordination. Rasmussen et al. (1994) argue that a multi-layer architecture of the work domain can be used for this purpose. They discuss a bottom-up propagation of control requirements of the work domain and a top-down propagation of the management style that can be used as a model to identify interaction patterns in a team. Figure 42 shows an illustration of this method.

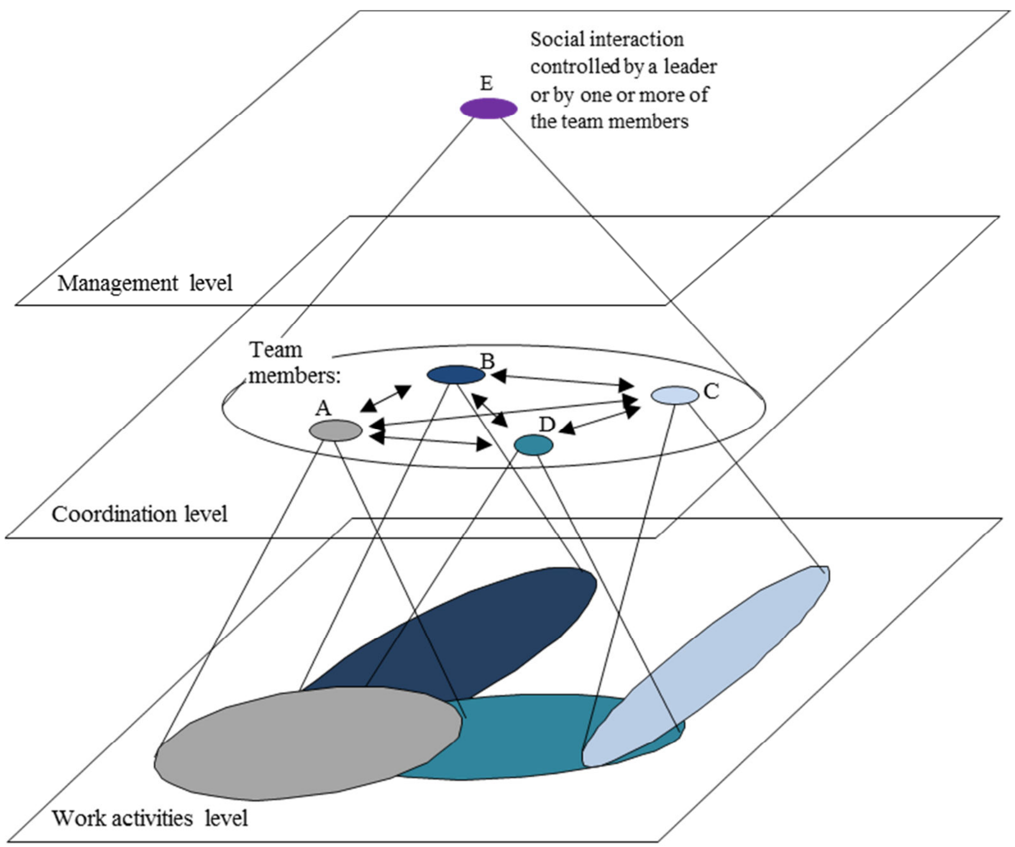


Figure 42. Mapping Operators onto a Social Organization.
(Adapted from Rasmussen, Pejtersen, and Goodstein, 1994)

The higher level identifies management styles and coordination strategies and the lower level examines work activities and functional competencies. The work-activities level, the lower level, is represented by the responsibility maps for each team player. The coordination level, the middle level, illustrates interaction patterns and can be used as a model to represent coordination structures. The connection between these two levels provides a direct mapping between the coordination structure and the interaction patterns between team members. This complementary information can be used for examining how different team members coordinate to share the same work-domain resources.

The management level, the top level, complements the coordination structures in the middle level and provides further information about the leadership style and management strategies.

Rasmussen (1989) further describes the two upper levels and provides an example of different coordination structures. His explanation is independent of the task, the role allocation principle adopted, and the characteristics of the work domain. Table 11 represents Rasmussen's explanation of coordination structures with some examples. Rasmussen's (1989) explanation can be used as a reference for an identification of different coordination structures.

Operators may switch between different structures in order to deal with changing demands. Malone and Smith (1988) analyze the trade-offs in choosing different coordination structures in terms of *production costs*, *coordination costs*, and *vulnerability costs*. For example, they show that the centralized structures have lower coordination costs, but are more vulnerable to system failures. Decentralized coordination is much less vulnerable to system failures, but has high coordination cost.

In the healthcare scenario, the coordination structure is very similar to the diplomatic structure in the Rasmussen's explanation. In a diplomatic structure, each team member may only negotiate with his or her neighbours (Rasmussen, 1989). For example, during patient assessment, the staff nurse discusses the patient's headache with the obstetrical resident. Then, the obstetrical resident consults with the anesthesiologist about the reason for headache. Eventually, the primary nurse and the anesthesiologist perform a final patient assessment right before the blood-patch injection. A chain of communications and a sequence of interactions can be identified for this example.

Table 11: Rasmussen's Explanation of Coordination Structures.

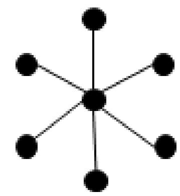
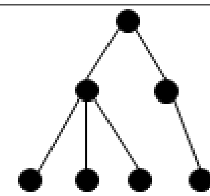
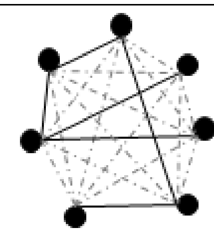
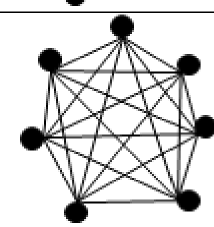
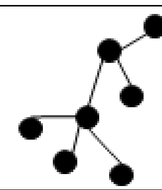
Coordination Style	Rasmussen's explanation (1989)	Example
Autocratic (Centralized)	*"One decision maker is responsible for the co-ordination of the activities of all other operators."*	
Hierarchical	*"Co-ordination is distributed in the organization which is stratified such that one level of decision makers evaluates and plans the activities at the next lower level."*	
Anarchistic	*"Each operator plans his own activity without interaction with other decision makers on the meta level. Communication is entirely through the work content."*	
Democratic (Decentralized)	*"Coordination involves interaction and negotiation among all decision makers of the organization."*	
Diplomatic	*"The individual decision makers negotiate with only the neighbors' involved and the information traffic is locally planned."*	

Figure 43 shows the coordination structure for patient assessment. Each team member is represented with a solid circle and the links between two team members represent their interactions. Different teams are represented by the dashed circles. In case of an emergency, team members might follow a different coordination structure. As discussed earlier, the given scenario does not provide enough information about multiple situations. In Chapter 4, I will explore coordination structures for various situations with examples from a real application domain.

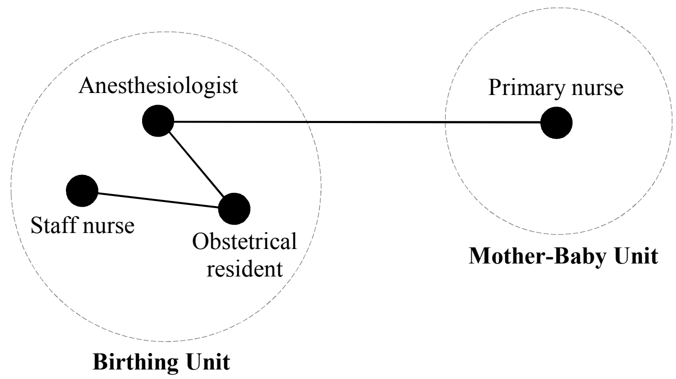


Figure 43. Coordination Structure for Patient Assessment.

In Figure 43, there is a connection between the anesthesiologist and the primary nurse that shows their contribution to the final patient assessment prior to the blood-patch injection. Although there is a direct link between the primary nurse and the anesthesiologist for patient assessment, they are not necessarily responsible for coordinating inter-team interactions. Indeed, in the given scenario, any inter-team interaction between the BU and the MBU will be coordinated with the care facilitators. Figure 44 shows the coordination structure for the blood-patch procedure, including the inter-team arrangements prior to the procedure.

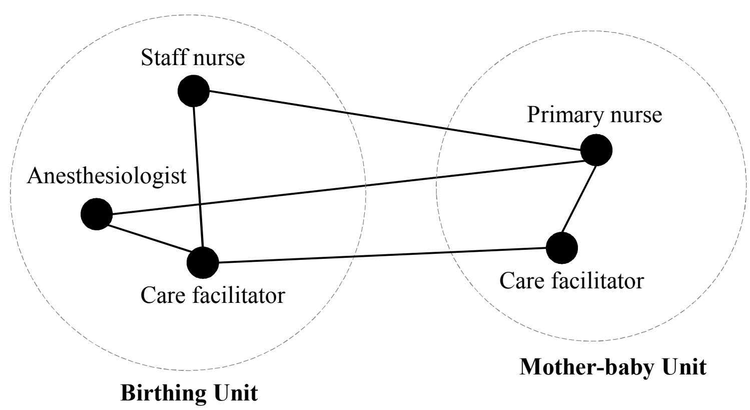


Figure 44. Coordination Structure for Blood-patch Procedure.

The coordination structure, at this point, is similar to what Rasmussen (1989) explained as autocratic, where the care facilitator at each unit is responsible for coordinating activities.

As shown in the figure, the anesthesiologist initiates the process by contacting the care facilitator at the MBU and requesting to arrange for the blood-patch procedure. Then, the care facilitator at the MBU contacts the care facilitator at BU to arrange a time for the procedure. Depending on the availability of resources, the care facilitator at the BU assigns a nurse to the procedure, finalizes the time for the procedure, and updates the care facilitator at the MBU with details. The main coordination strategy in the given scenario involves role allocation, resource allocation, and an effective communication. After transferring the patient to the BU, the primary nurse assigned to the procedure helps the anesthesiologist for the final patient assessment before the injection. The coordination strategy between the anesthesiologist and the primary nurse involves group decision-making for patient assessment and effective communication during the injection.

In an emergency, the team might adopt a different coordination strategy. While in a normal situation, the care facilitators are responsible for coordinating inter-team interactions, in an emergency, the obstetrical resident might take over the responsibility of coordinating the team. In Section 3.5.4, I discuss some of the work-domain constraints that influence strategy selection in various situations.

To summarize, the analysis of coordination strategies could identify how different team members engage in effective processes for sharing SA information. An analysis of coordination strategies may result in a better understanding of the processes underlying effective coordination. With a high-level analysis of interaction patterns and the connections between the team members, poor coordination structures may be identified. By organizing along the connections between the team members and removing any unnecessary interaction, more effective coordination structures may be built.

In the following section, I will examine team development strategies and will explore how team strategies change during the team lifecycle.

3.5.3 Team Development Strategies

Fidel and Pejterson (2004) argue that the design of an information system requires an ability to predict an operator's behaviour under various situations. Since team development models analyze the change of team's behaviours over different stages of the team lifecycle, they have potential to be used for an analysis of changing interaction patterns in a team. I explored team development models for an examination of various strategies that a team adopts at different stages of its lifecycle. The Tuckman's five-stage development model (1965) is one of the most recognized team development models to describe how operator-behaviour changes during the team lifecycle. Different stages of the Tuckman's team development model (1965) are already explained in Chapter 2. In this section, I discuss how team development models can be used for an examination of strategies at different stages of the team lifecycle.

Tuckman (1965) introduces an elegant explanation of team development, called Forming-Storming-Norming-Performing-Adjourning model. Forming is the initial orientation period, when people gather together and start exploring work-domain constraints. At this point, team members tend to behave quite independently. They learn about the organization, values, priorities, and principles and, then, they agree upon purposes and processes to overcome the projected challenges. Strategies, at this point, mostly revolve around individual strategies to discover opportunities to learn and grow. WDA and ConTA can be extensively used at this stage for understanding the work-domain constraints as well as the challenging tasks to tackle. For example, at the forming stage, team members may seek to identify the purpose of teamwork, resources available, result-oriented tasks, intentional constraints, team size, overall team composition, member recruitment procedures, and individual competencies.

At the second stage, the storming stage, members accept the existence of the team, but conflicts arise as team members resist the constraints that the team imposes on individuality. This stage is the start of intra-group conflicts as the team decides on the leadership model. Leadership (e.g., Vroom & Yetton, 1973) and conflict management strategies (e.g., Pondy, 2011) are two main types of strategies that need to be addressed at this stage. Some of the constraints that team members may seek to identify may include team roles, team leaders, and team liaison members.

The third stage, the norming stage, is focused on the period when close relationships develop and the team demonstrates cohesiveness. At this stage, the team sets the norms that guide how the team members will work together (norms for conflict resolution is an example). Team strategies, at this point, involve coordination strategies and effective communications.

At the fourth phase, the performing stage, team members have learned how to work together, manage conflicts, and contribute to meet the team's purposes. Team energy has moved from getting to know and understand each other to performing the task at hand. Strategies to manage this stage are more focused on the operational strategies and different ways to tackle a task. Table 12 summarizes this explanation.

Table 12: Strategies for Different Stages of the Tuckman's Team-Development Model.

Development stage	Tuckman's explanation (1965)	Sample constraints to identify
Forming	Team members try to determine their positions in the team, and identify the acceptable behaviours and procedures to follow.	-Purpose of teamwork (Vicente, 1999) -Resources available to support the teamwork (Rasmussen et al., 1994) -Result oriented tasks -Intentional constraints (Burns et al., 2005) -Team size (Naikar, 2003) -Overall team composition (Tuckman, 1965) -Individual competencies (Hager & Gonczi, 1996)
Storming	Operators accept the existence of the team but conflict occurs as they resist the constraints that the team imposes on individuality.	-Team roles (Belbin, 1981) -Team leaders (Tuckman, 1965)
Norming	Close relationships develop and the team demonstrates cohesiveness and sets norms for appropriate behaviours.	-Norms and methodologies that guide how the team will work together (e.g., norms for conflict resolution)
Performing	The structure at this point is fully functional and accepted. Team energy has moved from getting to know and understand each other to performing the task at hand.	-Workload (Naikar, 2006) -Expertise level (Cary & Reder, 2002) -Task interdependencies (Crowston & Krammer, 1998)

A good understanding of team development models may lead to a better examination of operators' behaviours and, consequently, designing an adaptive solution to respond to changing behaviours. Team development strategies can be used to explore various strategies that a team adopts at different stages of its lifecycle. For example, during the storming and norming stages, teams mostly adopt coordination strategies for conflict resolution and managing the team. However, during a performing stage, team members may leverage operational strategies to explore different ways of accomplishing control tasks. At the forming stage, a socio-technical system may be most helpful in providing an individual support rather than a team support. As an example, automated personality tests or self-awareness workshops can be used to help team members obtain a better understanding of each other's strengths or weaknesses. Similarly, the socio-technical system for the norming or storming stages can be used to support individuals in conflict resolution and norm setting. The main stage that a collaborative piece of technology can really contribute to the team performance is the performing stage, where the team members actually start performing their tasks and work closely to achieve the team goals.

In this section, I described team development strategies and explored how operator-behaviour changes at different stages of team development. In summary, Team StA suggests an examination of team strategies by looking at (1) the operational strategies to evaluate different ways of accomplishing a task; (2) coordination strategies to identify the coordination structure and management style; (3) team development models to study how operator-behaviour changes over time; and (5) structural strategies for examining the feasibility of strategies considering the work-domain constraints. In the next section, I will explain structural strategies using examples from the given scenario.

3.5.4 Structural Strategies

Structural strategies inherit, and build on, the work-domain constraints and can be revealed by Team WDA. For example, in the given healthcare scenario, because the blood-patch equipment is located in the BU, the patient must be transferred for the procedure.

DURESS (Dual Reservoir System Simulation) II is a good example for examining the structural strategies inherent in the structure of the work domain (Vicente 1999; Kilgore et al., 2009). DURESS II is a thermal-hydraulic process control "microworld" that was designed to be representative of industrial control systems (Vicente, 1999, p. 141). Vicente (1999) first illustrates the physical structure of DURESS II and identifies some of the equations governing its behaviour (i.e., work-domain constraints). Then, he breaks down the operation of DURESS II into different operating modes and examines the ConTA for each mode. In a strategies analysis, Vicente starts with revisiting the ConTA results to identify the inputs, outputs, and constraints associated with the information-processing activities. Vicente (1999) suggests the term "product constraints" to describe the constraints associated with information-processing activities (p.234). Product constraints are often associated with physical work-domain constraints and cannot be violated. Burns et al. (2005) discuss the product constraints within two different categories of "hard constraints" and "soft constraints" (p.607). The physical constraints cannot be violated, and are thus "hard constraints", but the social organizational constraints can be broken, and are thus "soft constraints". Although the soft constraints, such as values or priorities, can be broken, the resulting action might be socially unacceptable (Burns et al, 2005). In the discussion of product constraints in this section, I consider both physical and soft constraints.

As discussed earlier, operators have freedom in choosing how to accomplish a control task. Although there are degrees of freedom available after the product constraints have been considered, the operator still has to determine what strategies are feasible to implement. Vicente (1999) discusses the feasible strategies as "process constraints" and argues that the objective of a StA is to identify the process constraints for each viable and effective strategy (p.235). He associates each strategy with a set of process constraints that can be mapped out as an information flow map. Then, the most feasible strategy may be selected depending on operator's criteria and changing demands.

To clarify the connection between strategies and work-domain constraints, Cornelissen et al. (2011) suggest the use of a Strategy Analysis Diagram (SAD). The SAD is an extension to the AH with an additional level below the physical-form level to associate the functions to the physical objects. The additional layer to the AH then lists a set of verbs that represent the actionable part of the strategies. Although the SAD provides a structured model to describe strategies within a set of actions to manipulate physical objects, the SAD falls short in describing a majority of complex business processes. Figure 45 shows a modified SAD generating feasible strategies for patient assessment. The highlighted elements in the figure represent various strategy pathways and the work-domain elements involved in each pathway. The physical constraints, represented at the lower level of the AH, can be used to determine which strategies are feasible to implement. Then, when a set of feasible strategies are identified, the values and priorities at the abstract-function level can be used as evaluation criteria to determine the best feasible strategies to implement.

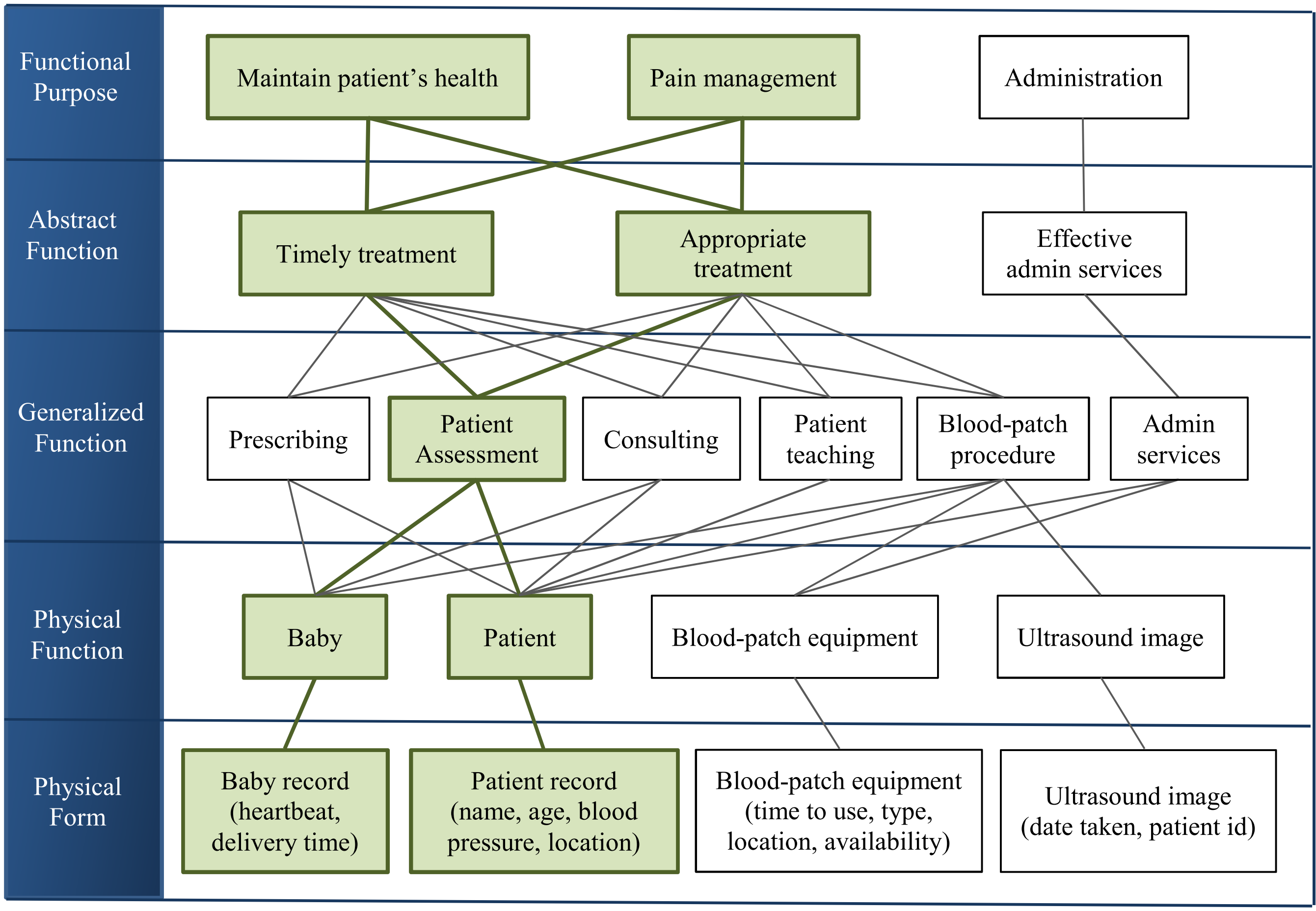


Figure 45. Strategy Pathway for Patient Assessment.

In the healthcare scenario, the staff nurse, obstetrical resident, anesthesiologist, and primary nurse contribute to patient assessment. While the physical layers of the work domain can be used to identify which strategies are feasible to implement, the higher levels of the work domain can be used as criteria to evaluate the efficiency of strategies. This approach can be used to identify the strategy pathways and the work-domain elements involved. The collaboration table and the abstraction wheels, as the complementary tools to the basic WDA, can be used to identify whether the work-domain elements that are involved in a strategy are shared and by whom. Discussion of the shared work-domain elements for each strategy can be used to determine how different team members contribute to the strategy pathways. For example, at the physical level in Figure 45, patient assessment requires reviewing the patient information. Since the patient record is the boundary object between the staff nurse, anesthesiologist, obstetrical resident, and the primary nurse, a sample strategy for patient assessment requires a contribution of all these four team members to review and update the patient information.

Earlier in the operational strategies section, a couple of strategies were suggested to complete patient assessment. However, the discussion of feasible strategies or performance criteria to evaluate different strategies was left out. Structural strategies complement operational strategies by bringing up a clear discussion of what is feasible to implement, when the product constraints have been considered.

In summary, structural strategies inherit, and build on, the work-domain constraints and can be revealed by Team WDA. From an individual perspective, an operator can use an examination of the physical constraints to identify what strategies are feasible to implement. Then, depending on his or her criteria and the current demand, the operator can decide on the best strategy to take. Some of the evaluation criteria in selecting the best strategies are listed in Table 13.

To summarize, an examination of structural strategies may be used to identify (1) feasible strategies to implement, (2) the work-domain elements involved in each strategy, (3) the various available strategy pathways, and (4) team member contribution to the strategy pathways. In the following section, I will summarize different categories of team strategies and explore the value gained from each category.

Table 13: Sample Strategy-Evaluation Criteria.

Constraints		Examples	Tools for knowledge acquisition
Work load (Naikar, 2006)		When an operator's work demands are low, he or she is more likely to adopt a strategy that is cognitively more intensive; whereas, in high work demands they may adopt less intensive strategies.	Task Analysis, such as Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003)
Expertise level (Cary & Reder, 2002)		Prior experience in performing a task, task instructions, or prior history of success with a strategy can affect the strategy selection for individuals (Cary & Reder, 2002). Experienced operators with various skills may complete the same task in a different way comparing to a novice operator with limited knowledge of the task (e.g., Robinson & Burns, 2011).	Field observations, structured interviews with SMEs, questionnaires, and review of past critical cases.
Task Interdependency (Ball et al., 1998)	Shared resources	When multiple activities require sharing limited resources, a resource allocation strategy is required to manage the interdependencies among those activities.	Team WDA-Abstraction hierarchy
	Prerequisite	Tasks required to be done in a certain order.	Team ConTA-Decision wheels
	Simultaneity	Synchronizing tasks.	Team ConTA-Decision wheels tables
Values, priorities, or principles (Burns, Bryant, and Chalmers, 2005).		Cost efficient vs. timely.	Team WDA-Abstraction hierarchy
Emotional factors (Rasmussen, 1981)		Emotional qualities, such as curiosity and excitement (Rasmussen, 1981; Rasmussen, Pejtersen, & Goodstein, 1994), or changes in operator fatigue (Burns, Enomoto, Momtahan, 2009) clearly affect the effort an operator is willing to spend in a task.	Focus groups, Cognitive walkthroughs, Questionnaires, surveys, and interviews

3.5.5 Value from Team Strategies Analysis

Team StA may supplement traditional StA with methods to analyze various aspects of teamwork or team requirements. Team StA emphasizes both formative and descriptive approaches to strategies analysis. With respect to a formative approach, Team StA provides four general categories for examining individual and team strategies: (1) operational strategies, (2) coordination strategies, (3) team development strategies, and (4) structural strategies. While operational strategies focus on different ways of accomplishing control tasks, coordination strategies examine coordination structures and the processes underlying coordination. Team development strategies are used to analyze how operator-behaviour changes during the team lifecycle and structural strategies, inherit and build on work-domain constraints and indicate what is feasible and how to evaluate different strategies.

In a formative approach, strategies are defined as categories; therefore, they accommodate many different action sequences. In a descriptive approach, Team StA focuses on identifying the sequence of actions for different categories of strategies. For example, the sequence of actions in an operational strategy can be described using the IFM. As discussed in Chapter 2, different empirical methods, such as think-aloud analysis (Gray & Kirschenbaum, 2000) or Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003) can be leveraged to uncover practitioner knowledge and strategies. A description of strategies as a sequence of actions can result in compatible information systems with the knowledge of actual domain practitioners. Several key requirements are identified by Team StA:

1. Coordination structures. Team StA provides a better understanding of the processes underlying effective coordination. With a high-level analysis of interaction patterns and the connections between team members, poor coordination structures may be identified. By organizing along the connections between team members and removing any unnecessary interaction, more effective team structures may be built.
2. Feasible strategies. Structural strategies inherit, and build on, work-domain constraints and can be revealed by Team StA. The discussion of structural strategies in Team StA can be used to identify what strategies are feasible when the work-domain constraints have been considered.
3. Criteria to evaluate different strategies. Operators may switch between several strategies to deal with changing demands. Discussion of different types of strategies - operational, coordination, structural, and team development- may result in a wide range of different

strategies for a single control task. Depending on the work-domain constraints, implementing these strategies may or may not be feasible. The operators are required to explore different feasible strategies and decide on the best strategies to implement. Structural strategies provide discussion of what is feasible along with some evaluation criteria such as, workload, intentional constraints, task interdependencies, and emotional factors.

4. Sequence of actions for each viable and effective strategy. The value added by the analysis of operational strategies lies in understanding different ways to carry out shared activities in a team. Team StA suggests an examination of information flow maps to identify the sequence of actions for each strategy. An extended CAT can also be used to further explain process constraints in terms of team structure, resources needed, the expertise of the team members involved, task priorities, time constraints, or existing automated systems.
5. Operator-behaviour changes during the team lifecycle. Team development strategies examine how operator behaviours change over time. Team StA analyzes various team strategies for different stages of the Tuckman's team development model (1965). For example, at the storming stage, team members accept the existence of the team, but conflict arises as they resist the constraints that the team imposes on individuality. At this stage, team strategies mostly revolve around different ways to manage conflicts in the team.
6. Team SA processes. The analysis of coordination strategies could be used to identify how different team members engage in effective processes for sharing SA information.
7. Strategy pathways. Team StA can be used to identify the work-domain elements involved in each strategy and the various available strategy pathways. By mapping the strategies to the work-domain model, Team StA can be used for examining various strategy pathways, the work-domain elements involved in each strategy, and team member contributions to the strategy pathway.

This section reviewed different categories of strategies and discussed the connections between the strategies of each category. In the following section, I will describe Team WCA and demonstrate the value of the extended models using examples. After that, in the last section of this chapter, I will summarize different phases of Team CWA and discuss the value gained from each extended model.

3.6 Phase IV: Team Worker Competencies Analysis

The overall objective of Team WCA is to allow the determination of a series of desirable attributes for operators based on the requirements of the application domain instead of a general assumption of the operator requirements. Team WCA consolidates all the requirements imposed by the preceding Team CWA phases for examining the implications of human characteristics in systems design. In this last phase, the focus is on psychological constraints to identify profiles of competencies that operators must possess in order to effectively work on a team. Much of the previous attempts to use WCA for an examination of competencies have focused on an identification of the skill-set required for operators to take over their functional roles (e.g., Rasmussen, 1983; Vicente, 1999; Kilgore & St-Cyr, 2006). It leaves open the consideration of social competencies and the desired behaviours that operators should exhibit in order to effectively interact with another (Belbin, 1981). Team WCA consolidates both approaches to analyze operator competencies with respect to (1) functional competencies and (2) social competencies. While functional competencies look at the cognitive skills of individuals, such as problem solving or analytical reasoning, social competencies focus on interpersonal skills required for effective teamwork. In the following sections, I will discuss the regular WCA for an examination of functional competencies and explore how the existing models can be expanded to accommodate social competencies.

3.6.1 Functional Competencies

Functional competencies examine profiles of competencies in terms of the knowledge, abilities, and skills that operators must possess in order to effectively carry out control tasks. Hager and Gonczi (1996) define competence "in terms of knowledge, abilities, skills, and attributes displayed in the context of a carefully chosen set of tasks which are of an appropriate level of generality" (p. 15). By adopting this definition, functional competencies define the job-specific competencies that directly reflect the requirements of the application domain. Much of previous works to use WCA for an identification of functional competencies have used Rasmussen's (1983) SRK taxonomy (e.g., Vicente, 1999; Kilgore & St-Cyr, 2006; McIlroy & Stanton, 2011).

As discussed in Chapter 2, the SRK taxonomy describes three different categories of human behaviours: skill-based, rule-based, and knowledge-based. In skill-based behaviours, no conscious behaviour control is involved and perception is directly mapped to actions. In a rule-based behaviour, a pre-planned sequence of actions guides operator's behaviour. Decision making in rule-based behaviours mostly involves recognition of the sensory input, comprehension of the state, and association of the sensory input to the output actions based on the stored rules for activities (Rasmussen, 1983). The last category of behaviours, knowledge-based behaviours, involves decision making, situation analysis, planning, and reacting to contingencies. Rasmussen (1986) argues that this explanation can be mapped out to the decision ladder to understand the operator behaviours at the control-task level. Figure 46 illustrates Rasmussen's explanation.

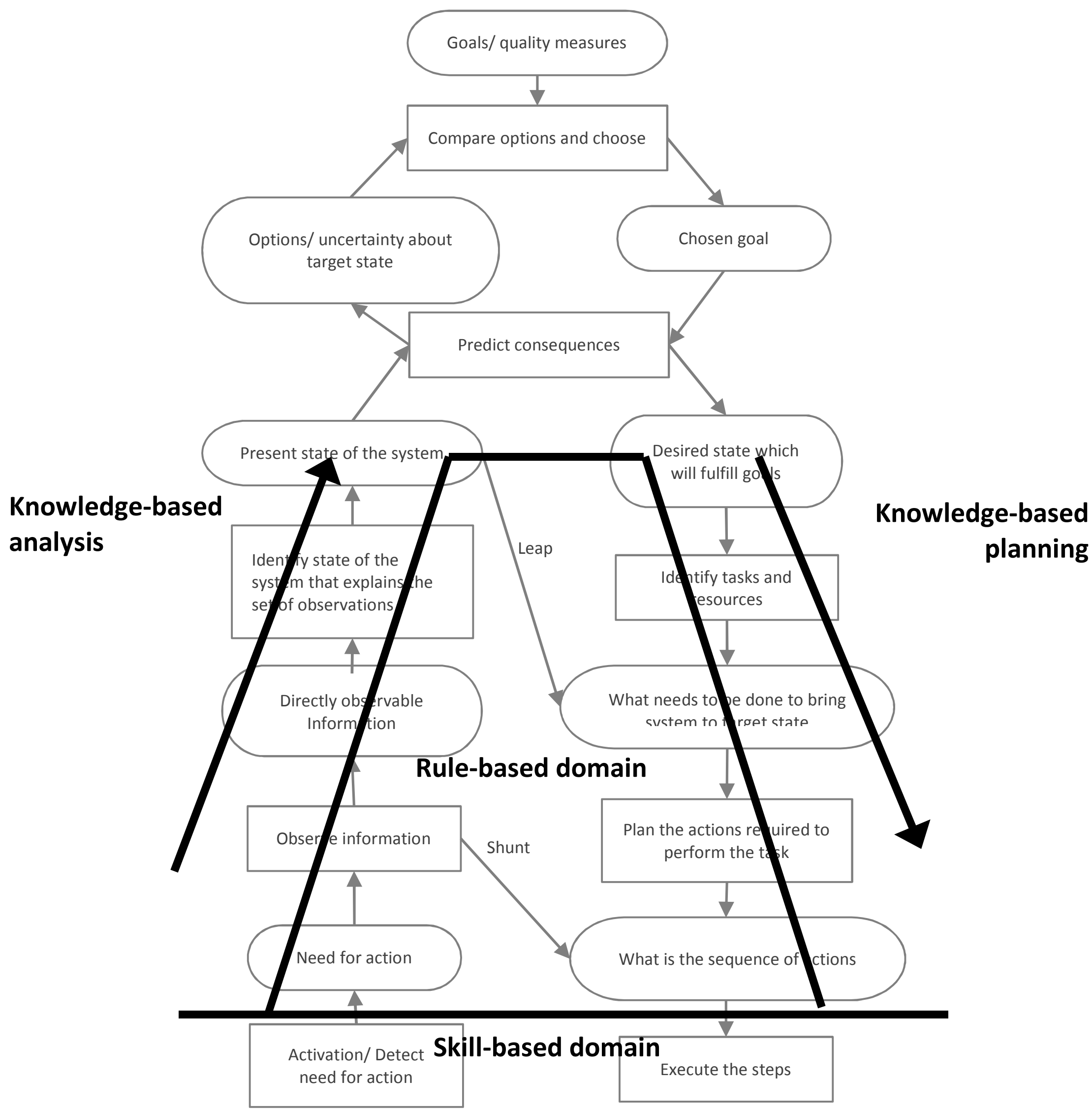


Figure 46. Rasmussen's SRK Taxonomy Mapped to the Decision Ladder. (Adapted from Rasmussen, 1986)

The lower level of the decision ladder can demonstrate a direct mapping between the alerts and the set of actions, which describes the skill-based behaviours of the operators. Leaps and shunts indicate the rule-based behaviours, where the operator implements a pre-planned sequence of actions. The left part of the decision ladder involves knowledge-based analysis and includes observation, information gathering, comprehension, and situation analysis. The right part of the decision ladder involves knowledge-based planning and includes decision making and reacting to contingencies. Kilgore and St-Cyr (2006) expand on this explanation and present a matrix format to identify the functional competencies for each information-processing activity. Table 14 demonstrate how a SRK inventory can be used to explain the behaviours of an obstetrical resident when he or she performs a patient assessment.

Table 14: Sample SRK Inventory Informed by the Decision Ladder.

Information-processing activity	Resultant knowledge state	Skill-based behaviour	Rule-based behaviour	Knowledge-based behaviour
Observe information (patient assessment and identification of the cause for the headache)	The cause of the headache is identified.	An experienced obstetrical resident should be aware of the signs and symbols of the lumbar puncture.	The obstetrical resident should be able to use the fact sheets and best practices to interpret the signs and symbols and identify the cause of the headache.	The obstetrical resident should be able to collect supplementary information that can help to identify the cause of the headache.
Interpret/Predict consequences	An epidural blood patch can relieve the low pressure state in the head ("Epidural blood patch," 2011).	An experienced obstetrical resident should be aware that the epidural blood patch may relieve the pain.	The obstetrical resident should be able to use the fact sheets and best practices to identify possible options to relieve the headache.	Severe headache on the day of surgery can have many reasons. The obstetrical resident should be able to analyze supplementary information and make a decision about the cause of the headache.
Compare options and issue a prescription	Epidural blood patch is prescribed to relieve the pain.	An experienced obstetrical resident should be able to evaluate the situation and identify the best option for the patient.	The obstetrical resident should be able to look up the fact sheets, best practices, or instructions to compare options and identify which one fits the situation.	By using the instructions, fact sheets, standards, and forums, the obstetrical resident should be able to interpret possible consequences of the blood-patch procedure.

In this approach, separate SRK inventory tables are created for different operators. Each row within a given table describes a single information-processing activity of an individual decision ladder. Columns represent a conceptualization of behaviours that operators may exhibit when they perform an information-processing activity. I should acknowledge that the given scenario is limited in this regard and does not provide information about the behaviour patterns. The hypothetical information in Table 14 is just presented to demonstrate the idea.

McIlroy and Stanton (2011) support this notation, but argue the need to consider the SRK discussion much earlier in the design lifecycle. While Kilgore and St-Cyr (2006) examine competencies at the control-task level, McIlroy and Stanton (2011) recommend an examination of competencies at the work-domain level. Instead of mapping the decision ladder steps to the SRK behaviours, they discuss the operator behaviours for the work-domain processes of the AH. Table 15 shows this representation for the obstetrical resident. The first column shows the work-domain processes at the generalized-function level of the AH. The rest of the columns indicate the skill-, rule-, and knowledge-based behaviours that apply to those processes. The empty rows in the table indicate that the obstetrical resident does not contribute to performing the corresponding processes.

As shown in Table 15, experienced operators gravitate naturally towards demonstrating skill-based behaviours, but may switch to rule-based behaviours when an appropriate rule set or a best practice is available (Lintern, 2009b). Rasmussen et al. (1994) argue that complicated activities often require frequent and subtle transition between the SRK behaviours. For example, the obstetrical resident may exhibit a skill-based behaviour to identify the cause of the headache, but switch to a rule-based behaviour to find an appropriate prescription to relieve the pain.

Vicente (1999) argues that the socio-technical systems should encourage the use of skill- and rule-based behaviours whenever possible, while at the same time, allowing for operator's seamless transition to knowledge-based reasoning in unanticipated circumstances or when operator is not completely familiar with the task.

Table 15: Sample SRK Inventory Informed by the Abstraction Hierarchy.

Generalized function	Skill-based behaviour	Rule-based behaviour	Knowledge-based behaviour
Patient assessment	An experienced obstetrical resident should be aware of the symptoms and know what signs and symbols should be observed. He or she should be able to detect that the patient suffers from lumbar puncture.	The obstetrical resident should be able to look up the fact sheets, best practices, or instructions to find a list of the complementary signs and symbols to observe and, then, be able to find the cause for the headache.	The obstetrical resident should be able to identify the list of signs and symbols to observe. Then, he or she should be able to review the patient record looking for the pain history and supportive information. Once the required information is collected, the obstetrical resident should be able to analyze supplementary information and make a decision about the cause of the headache.
Prescribing	An experienced obstetrical resident should know that a blood-patch procedure can relieve the pain.	The obstetrical resident should be able to look up the fact sheets, best practices, or instructions to find a list of possible prescriptions to cure lumbar puncture and see which one fits the situation.	The obstetrical resident should be able to understand the side effects and possible consequences of the blood-patch procedure by using the instructions, fact sheets, standards, forums, and peer discussions.
Consulting	An experienced obstetrical resident should know the appropriate people to reach out. He or she understands what sort of information should be provided in a quick and effective discussion.	The obstetrical resident should be aware of the fact sheet and the best practices and should be able to discuss them with the peers.	The obstetrical resident should know who is available for help, what type of information should be provided, and what sort of insights the peers can offer. The obstetrical resident should be able to effectively describe the observation, discuss the options with others, analyze the situation, and finally make a decision about the best prescription to relieve the pain.
Patient teaching	An experienced obstetrical resident should know what sort of information is required to be provided to the patient.	The obstetrical resident should be able to look up what sort of information are required to be provided for a patient, who is experiencing a severe headache.	The obstetrical resident should be able to analyze the situation and figure out what sort of information is required to be provided for the patient. The obstetrical resident should identify if it is required to inform the patient about the reason for the headache, available solutions, the blood-patch procedure, and the potential side effects.
Blood-patch procedure	-	-	-
Admin services	-	-	-

At the strategy level, discussion of operator behaviours may lead to identify the functional competencies required for performing various strategies. The SRK inventories at the strategy level may be used for examining how information is used, exchanged, or transferred, and suggest profiles of competencies that operators must possess in order to effectively use that information. For example, the functional competencies required for the obstetrical resident for performing a patient assessment strategy are shown in Table 16.

Table 16: Sample SRK Inventory Informed by the Information Flow Map.

Actions	Skill-based behaviour	Rule-based behaviour	Knowledge-based behaviour
Reviewing the patient record, looking for the pain history and further supportive evidence	An experienced obstetrical resident should be aware of the symptoms and know what signs and symbols to observe.	The obstetrical resident should be able to look up the fact sheets, best practices, or instructions to find a list of the complementary signs and symbols to observe.	The obstetrical resident should be able to identify a list of signs and symbols to observe. He or she should be able to analyze the symptoms and plan for further assessments, if required.
Identifying the reason for the pain	An experienced obstetrical resident should know that a lumbar puncture can cause a headache.	The obstetrical resident should be able to look up the fact sheets, best practices, or instructions to find the cause for a post-dural puncture headache.	Severe headache on the day of surgery can have many reasons. The obstetrical resident should be able to analyze supplementary information and make a decision about the cause of the headache.
Consulting with the rest of the team to verify that reason and discuss possible prescriptions	An experienced obstetrical resident should know the best person to get opinion from. He or she should know what sort of information should be provided for effective discussion.	The obstetrical resident should be aware of the fact sheets and the best practices and be able to discuss them with the peers.	The obstetrical resident should be able to effectively describe the observation, discuss the options with the peer, analyze the situation, and finally make a decision about the reason for the pain.

The first column represents the sequence of actions, and the rest of the columns indicate the skill-, rule-, and knowledge-based behaviours that apply to those actions. The sequence of actions for the strategy is taken from Figure 38. As in Table 14 and Table 15, hypothetical information is represented to demonstrate the idea. In the next two chapters, I will explore the SRK inventory tables for the real application domains.

To summarize, Team WCA consolidates all the requirements imposed by the preceding Team CWA phases for examining the functional competencies required for effective teamwork. At the work-domain level, a representation of functional competencies may lead to a more informed task allocation. By describing the required skill-set for fulfilling a process, it is possible to identify the competent people for each process and determine which processes are more suited to which operators. At the control-task level, Team WCA may be used for an examination of a series of context-dependent situation-specific behaviours that are required for effective teamwork. At the strategy level, Team WCA identifies what strategies are available in terms of experience, ability, and knowledge of the team members. For example, an operator may select a strategy based on the team goals, implement that strategy, evaluate its outcome and, then, decide on a subsequent action. In this case, Team WCA can be used to understand the functional competencies required for an interpretation of team goals, implementation of the strategy, and evaluation of the outcomes.

While functional competencies describe the skill-set required for operators to take over their functional roles, social competencies indicate the desired behaviours that operators should exhibit for effective interaction with each other (Belbin, 1981). In the following section, I will describe social competencies and demonstrate how Team WCA can be used to identify the social competencies in the given scenario.

3.6.2 Social Competencies

When designing complex socio-technical systems, it is essential to leverage the social competencies that operators must possess in order to effectively work in a team.

Social competence is generally recognized as the ability to interact successfully with other operators and includes but is not limited to interpersonal skills, such as effective social problem solving, direct constructive communication, empathy, relationships, and social self-efficacy (Rose-Krasnor, 1997). I use the term *social competence* rather than the more commonly used *social skills* because social skills are not all that is required for a person to be socially competent. For example, an operator may possess social skills, but lack the ability to use them to act in a socially competent manner.

In a high performance team, operators need to perform a team role and a functional role together. For two operators with a same set of professional skills that work together on the same task, a natural leader might gravitate towards taking the lead of the team. Several attempts have been made to understand common team roles in an effective team (e.g., Mumford, Campion, & Morgeson, 2006; Parker, 2008). One of the most recognized models is the Belbin team-role theory (1981). Belbin (1981) defines a team role as “a pattern of behaviour characteristic of the way in which one team member interacts with another so as to facilitate the progress of the team as a whole” (p. 169). He proposes nine team roles to reflect the way in which individuals interact with one another while they perform a task in a team: (1) plants, (2) resource investigator, (3) coordinators, (4) shapers, (5) evaluators, (6) team-workers, (7) implementers, (8) completers, and (9) specialists. Table 17 provides an explanation of these team roles.

Table 17: Belbin Team-Role Summary Descriptions.
(Adapted from Belbin, 1981)

Team Role	Contribution
Plant	Solves difficult problems.
Resource investigator	Explores opportunities, develops contacts.
Coordinator	Clarifies goals, promotes decision-making, delegates well.
Shaper	Has the drive and courage to overcome obstacles.
Monitor evaluator	Sees all options, judges accurately.
Team-worker	Co-operative. Listens, builds, averts friction.
Implementer	Turns ideas into practical actions.
Completer-finisher	Searches out errors and omissions, polishes and perfects.
Specialist	Provides knowledge and skills in rare supply.

Plants in a team usually prefer to work by themselves at some distance from other members of the team. They bring new ideas and solve difficult problems, but they may be weak in communicating with other people on the team. Resource investigators are expert at exploring new opportunities and developing contacts. They are good at communicating with other people both inside and outside the team. Coordinators have an ability to cause others to work towards shared goals. Shapers like to lead the team and push other team members into action. They generally make good managers. Evaluators are best suited for analyzing problems and evaluating options. The role of the team-worker is to prevent interpersonal problems arising within a team. Team-workers are often the most supportive members of a team. Implementers favour hard work and do whatever needs to be done. Completers have a great capacity to get things done. They are unlikely to start anything that they cannot finish. Specialists provide the rare skill to the team, and they usually lack interest in other people.

As in the functional competencies section, the SRK inventory can be adopted for examining the SRK behaviours for different team roles. For example, the care facilitators in the given scenario may act as coordinators. The primary nurse and the staff nurse can be considered as team-workers and the anesthesiologist and the obstetrical resident may play as specialists. Table 18 shows a summary of team roles and the social skills required for the healthcare scenario. The care facilitators as the coordinators should delegate well and have a strong sense of who is available and with what level of expertise. The anesthesiologist and the obstetrical resident do not need to delegate.

Table 18: Team-role Summary for the Healthcare Scenario.

Function Role	Team role	Social skills required (Belbin,1981)
Care facilitator at MBU Care facilitator at BU	Coordinators	Mature, confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well
Primary nurse Staff nurse	Team-workers	Cooperative, mild, perceptive and diplomatic. Should be able to listen, build, and avert friction
Anesthesiologist Obstetrical resident	Specialists	Single-minded, self-starting, dedicated to provide knowledge and skills in rare supply

Depending on the situation, operators may switch between different team roles and take over a different team responsibility. For example, a leader in a hierarchical coordination structure might be a team-worker in a decentralized structure. In spite of the dynamic nature of team-role allocation, operators may or may not have flexibility to switch between functional roles. For example, an obstetrical resident is specialized in obstetrics and an anesthesiologist is specialized in anesthesia. Specializing in different skill-sets, an obstetrical resident cannot replace an anesthesiologist in most cases, but they can both take over the responsibility of coordinating the team.

In this section, I explained Team WCA with respect to social and functional competencies. While functional competencies look at the cognitive skills of individuals, such as problem solving or analytical reasoning, social competencies focus on interpersonal skills required for effective teamwork.

3.6.3 Value from Team Worker Competencies Analysis

Much of the previous attempts to use WCA for an examination of competencies have focused on an identification of the SRK behaviours required for operators to take over their functional roles (e.g., Rasmussen, 1983; Vicente, 1999; Kilgore & St-Cyr, 2006). It leaves open discussion of social competencies and desired behaviours that operators should exhibit for an effective interaction with another (Belbin, 1981). Team WCA consolidates both approaches and supplements traditional WCA with methods to analyze social and functional competencies.

Several key requirements are identified by Team WCA:

1. Skill gaps. Team WCA can draw attention to skill gaps. For example, a comparison between the qualifications of the obstetrical resident and the description of functional competencies required to perform a process can be used to identify if extra training, recruitment, or automation procurement is necessary. Team WCA is useful for the design of the training programs that are tailored to the responsibilities and competencies of each operator.

2. SRK behaviours. Team WCA adopts the Rasmussen's (1983) SRK taxonomy to evaluate operators' behaviours in three different levels of interaction with system: skill-based, rule-based, and knowledge-based. Discussion of the SRK behaviours at the work-domain level may lead to identify the functional competencies required for performing work-domain processes. At the control-task level, Team WCA may be used for examining a series of context-dependent situation-specific behaviours that are required for effective teamwork. At the strategy level, Team WCA identifies what strategies are available in terms of experience, ability, and knowledge. Indeed, Team WCA consolidates all requirements imposed by the preceding Team CWA phases for examining functional and social requirements that an operator should possess in order to effectively perform a task in a team. For example, the social values and teamwork purposes extracted from the work domain can provide a direction and motivation for social behaviours (Duck, 1989).

3. Task allocation. A representation of functional competencies in Team WCA may result in a more informed task allocation. For example, by describing the required competencies to fulfill a process, it is possible to determine which processes are more suited to which operators.

4. Team role allocation. Team WCA adopts Belbin's (1981) team-role model for examining how individuals interact in a team and describe a set of social skills for different team roles. By comparing social skills of individuals and the description of social skills required for each team role, Team WCA can be used to identify which team roles are more suited to which team members.
5. Switching between roles. In spite of the dynamic nature of team-role allocation, operators may or may not have flexibility to switch between functional roles. Organizations often hire new employees for specific functional roles, such as the anesthesiologist and later, may assign different team roles to them based on the coordination structure and the social competencies of the new hires. The functional role of operators usually does not change as each role requires a certain specialties and expertise; whereas, team roles and social responsibilities might change based on the scenario, business process, or coordination structure.
6. Expertise level. Experienced operators gravitate naturally towards demonstrating skill-based behaviours, but may switch to rule-based behaviours when an appropriate rule set or a best practice is available. Complicated activities often require frequent and subtle transition between the SRK behaviours. An analysis of the SRK behaviours in a team may inform interface design such that both novice and expert behaviours are supported. The socio-technical systems should encourage the use of skill- and rule-based behaviours whenever possible, while at the same time, allowing for operator's seamless transition to knowledge-based reasoning in unanticipated circumstances or when operator is not completely familiar with the task. Team WCA can be used to design displays that are tailored to the capabilities and the expertise of operators. Table 19 lists some of the implications of WCA for interface design.

Table 19: Design Implications.

SRK taxonomy	Recommendations for design (Vicente, 1999)	Characteristic of information (Lintern, 2009a)
Skill-based behaviour	Operators should be able to act directly on the display.	Information is in the form of space-time patterns.
Rule-based behaviour	System should provide a consistent one-to-one mapping between the work-domain constraints and the cues provided by the interface.	Information is in the form of symbols associated with specific activity.
Knowledge-based behaviour	System should present the work domain in a form that can support knowledge-based problem solving.	Information is in the form of semantics carried by complex perceptual patterns, such as text, graphics or speech.

7. Team design. Team WCA can be used for an examination of the social and functional competencies that are required for designing new teams, redesigning poor team structures, and hiring new people. An analysis of skill gaps between operator competencies and the set of skills required for effective teamwork may be used to identify if extra training or recruitment is necessary. By allocating appropriate team roles to the social competent people, more effective coordination structures may be built. The information extracted from Team WCA can also be used to identify the competencies required for a team expansion or hiring new team members.

In this section, Team WCA was described with respect to social and functional competencies. In the following section, I will summarize different methods and models of Team CWA and discuss the value of the extended models.

3.7 Summary

While CWA has shown success in modeling the work of single operators, very few studies have focused on using CWA for improving team performance. I propose that it can be useful to modify the traditional five-level CWA approach to a 2x4 approach, where there is a parallel set of social or team models. Team CWA may supplement traditional CWA with methods to analyze various aspects of teamwork or team requirements. Table 20 summarizes the knowledge acquisition and knowledge representation tools for Team CWA.

From a teamwork perspective, the goal in using a WDA is to create a set of models to describe shared values, purposes, and priorities of teamwork. However, the basic WDA does not provide sufficient guidance on extracting which work-domain elements are shared and by whom. Team WDA addresses this shortcoming and provides models and techniques for analyzing shared and individual purposes; values, priorities, and principles; processes; and boundary objects that are shared during a team interaction. While the collaboration table may provide a clear table format to represent the work-domain elements, the abstraction wheel may offer a graphical illustration of team structure and shared work-domain elements both within a team and across multiple teams. Team WDA models have shown potential to design new teams and identify poor team structures. By organizing along shared purpose and values, or shared process and objects, more effective team structures may be built.

At the control-task level, the objective of Team ConTA is to provide tools and methods for an examination of team structures, team interactions, shared workflows, and boundary objects. Team ConTA models expand decision ladders (Rasmussen et al., 1994) into decision wheels (Ashoori & Burns, 2010) and provide suggestions to revamp the CAT for team analysis (Ashoori & Burns, 2011). While the CAT distributes multiple activities over multiple operators, the chained ladders and the decision wheels distribute one activity over multiple operators.

Table 20. Summary of the Team CWA Tools.

Phase	Tools	
	Knowledge acquisition	**Knowledge representation**
Team WDA	- Interviews with SMEs using questionnaires, surveys, and walkthroughs (Naikar et al, 2005; Bisantz & Mazaeva, 2009) - Field observations (Naikar et al, 2006; Rasmussen, 1980) - Document analysis (Bisantz & Mazaeva, 2009)	- Abstraction hierarchy - Responsibility maps - Collaboration tables - Abstraction wheels - Abstraction-wheel tables
Team ConTA	- Field observations (Naikar et al, 2005; Rasmussen, 1980) - Interviews with SMEs using questionnaires, surveys, and walkthroughs (Naikar et al, 2005; Rasmussen, 1980) - Task analysis methods, such as Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003)	- Team decision ladder - Extended CAT for teams - Decision wheel - Decision-wheel tables

Team StA	- Document analysis, interviews (Rasmussen, 1981)
	- Empirical methods, such as think-aloud analysis (Gray & Kirschenbaum, 2000), Goal-Directed Task Analysis (Endsley, Bolte, & Jones, 2003), or Contextual Design (Beyer & Holtzblatt, 1998)
		- Operational strategies
		    - IFMs
		    - StA plotted on the CAT
		- Coordination strategies
		    - Coordination structure
		- Structural strategies
		    - Strategy pathways
		- Team development strategies
		    -Tuckman development model

Team WCA	There are no constraint-based data collection methods unique to a basic WCA (Crone, 2011). I would recommend:
	- Best practices
	- Structured interviews with SMEs
	- Review of the career progression ladders in the organization
		- Behaviour analysis for functional competencies
		    - SRK inventory informed by the decision ladder
		    - SRK inventory informed by the AH
		    - SRK inventory informed by the IMFs
		- Behaviour analysis for social competencies
		    - Belbin's team role model

At the strategy level, Team StA provides discussion of (1) range of strategies possible, (2) viable and effective strategies with respect to work-domain constraints, (3) sequence of actions in a strategy and team members contributions to execution of the actions, (4) strategy pathways and the contribution of each team member to the pathways. Team StA consolidates the existing formative and descriptive approaches to StA and examines strategies within four categories of (1) operational, (2) coordination, (3) team development, and (4) structural strategies. The value added by the operational strategies lies in understanding different ways to carry out the shared control tasks. Although the basic StA identifies various strategies that can be used by operators to perform control tasks, it leaves open the issue of who is responsible for performing different steps in the strategy (Vicente, 1999). Team StA models leverage the IFM representation to identify a descriptive characterization of strategies to reveal how an experienced team of operators may perform a shared task. In addition to the IFMs, an extended CAT is suggested to describe various strategies in terms of factors, such as resource access, task priority, expertise level, and time constraints, that may influence strategy selection in a variety of situations.

An analysis of coordination strategies may provide a better understanding of the processes underlying effective coordination. With a high-level analysis of interaction patterns, poor coordination structures may be identified. By organizing along the connections between team members and removing any unnecessary interaction, more effective coordination structures may be built.

By looking at the team development strategies, Team StA models examine how operator behaviours change during the team lifecycle. Team StA analyzes various team strategies for different stages of the Tuckman's team development model (1965) and identifies how a socio-technical system may adapt to behaviour changes.

Structural strategies inherit, and build on, the work-domain constraints and can be revealed by Team StA. An analysis of structural strategies can help to identify what strategies are feasible when the work-domain constraints have been considered. By mapping strategies to work-domain models, Team StA can be used for examining various strategy pathways, the work-domain elements involved in each strategy pathway, and team member contributions to the execution of that strategy.

At the worker competency level, the overall objective of Team WCA is to allow the determination of a series of desirable attributes for operators based on the application domain requirements instead of a general assumption of operator requirements. Team WCA consolidates all the requirements imposed by the preceding Team CWA phases to identify the social and functional competencies required for effective teamwork. While functional competencies look at cognitive skills of individuals, such as problem solving or analytical reasoning, social competencies focus on interpersonal skills required for effective team interactions. An identification of worker competencies can also draw attention to the skill gaps. The comparison between the qualifications of an operator and the description of functional competencies required to perform a task, can be used to identify if extra training, recruitment, or automation procurement is necessary. Team WCA is useful for the design of the training programs that are tailored to the responsibilities and competencies of the operators.

In the next two chapters, I will represent the results of two sets of observations I completed at the Business Analytics Group of the IBM Ottawa Software Lab and the Labour and Delivery Department of The Ottawa Hospital. The main purpose of these studies was to demonstrate how well my extended models could fit within the real application domains.

Chapter 4
Observational Study 1: IBM Extreme Blue Teams

Figure 47 provides an overview of thesis structure with the highlighted chapter material for Chapter 4. In this chapter, I will review the applicability of my extended models to a small-sized agile software development team.

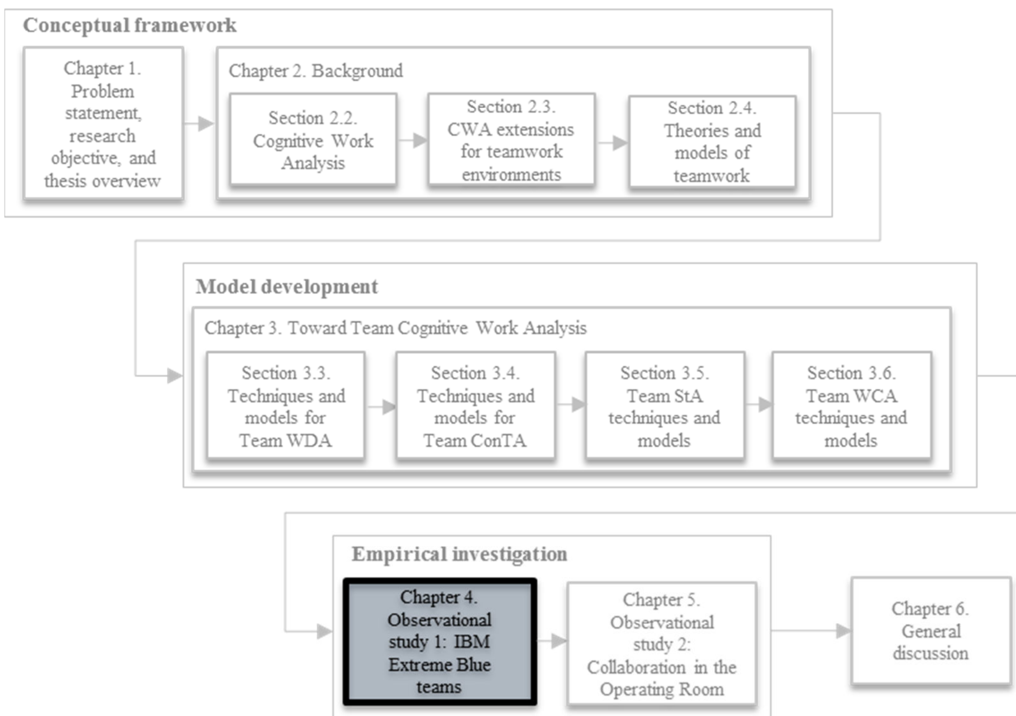


Figure 47. Chapter 4 Overview.

4.1 Introduction

In this chapter, I explore the applicability of the Team CWA methods and models to an analysis of collaborative decision-making of a small software-development team. My first observation was conducted at the IBM Ottawa Software Group where I was a participant observer. During 15 weeks of observations, I studied team interactions within the IBM Extreme Blue (EB) team. In the next sections, I will start with providing some information about the EB team, such as team structure, time constraints, main processes, and deliverables. Then, I will compare a traditional CWA and the Team CWA approach to analyze collaborative requirements for the EB team.

4.2 Setting

In the EB program, a small team of novice interns with limited prior experience join a group of highly skilled senior IBM employees to work on a 4-month project. The intern team is expected to use the guidance of the senior mentors to create a business solution for an existing market challenges. At the end of the program, the intern team is given four minutes to pitch the business idea to senior executives at the IBM's global head office.

An EB intern team consists of three technical interns who have a software engineering background and one MBA from a business school. As a product manager, the MBA's responsibilities revolve primarily around project management and driving a profitable business solution for the target market challenge. The technical interns are responsible for building a prototype that showcases the value of the business solution. In my team, one of the technical interns was specialized in User-Experience (UX) design, the second technical intern was specialized in the front-end development and web programing, and the third technical intern was specialized in back-end development and database programing. Figure 48 shows the hierarchical structure of the EB team.

The mentor team includes a program manager, a business mentor, and a team of technical mentors. The program manager on the team is responsible for facilitating administrative works and coordinating the team to reach out to internal stakeholders, as needed. The technical mentor team consists of a senior manager to manage the team, an experienced technical staff, and alumni to provide technical guidance for the technical intern team.

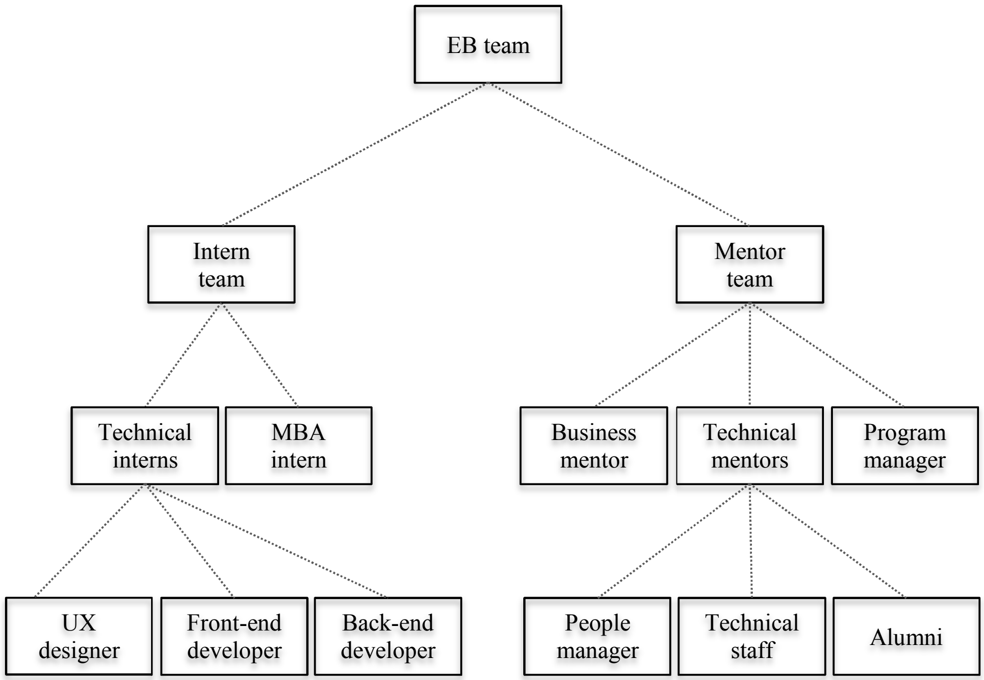


Figure 48. Team Structure in the Extreme Blue Team.

Three monthly evaluation gates are designed to assure high-quality of deliverables. The idea of these evaluation gates, also called Dragon's Den gate, is taken from a reality television show featuring entrepreneurs pitching their business ideas in order to secure investment funds from a panel of venture capitalists. The IBM Dragon's Den committee includes two senior consultants from Global Business Services and two senior technical staff from Software Groups.

The EB team represents a good example of a small team of novice interns paired with a team of highly-skilled senior employees. The hierarchical structure of the EB team makes it a good nominee to evaluate how the extended Team CWA models fit hierarchical team-structures. During this observation, I had a chance to observe the whole team lifecycle from the first day that the team met to the last day at work. Table 21 summarizes characteristics of the EB team.

Table 21: Application Characteristics.

Characteristics	Extreme Blue teams at the IBM Ottawa Software Lab
Observation period	Team lifecycle: 15 weeks Observation period: 15 weeks (May-August 2011)
Team size	A small, hierarchical team of 9 people working within a large high-tech company with more than 400,000 employees worldwide
Team structure	A hierarchical structure with three levels of sub teams. The team structure is shown in Figure 48
Team lifecycle	A complete observation of the whole team lifecycle starting from the first day that the EB participants met for the first time to the last day at work
Expertise level	Wide range of expertise from novice interns to experienced mentors

4.3 Comparison between Work Domain Analysis and Team Work Domain Analysis

In this section, I conduct a traditional WDA and compare the results with the findings of conducting Team WDA for the EB team. My focus, in this section, is on identifying work-domain constraints that are imposed to the EB team. To demonstrate the value of the extended models, I will examine the abstraction hierarchy for the EB program, and will discuss how the hierarchy can be extended to the collaboration tables and the abstraction wheels.

4.3.1 Basic Work Domain Analysis

As discussed in Chapter 2, a typical WDA examines fundamental behaviour-shaping constraints, such as purpose of the work, values, priorities, processes, and resources. Figure 49 shows the basic work-domain model for the EB team.

At the functional-purpose level, the AH elements correspond to the work-domain purposes. There are three purposes identified for the EB team: (1) securing investment funds, (2) proposing a profitable solution, and (3) exceeding the expectations of the Dragon’s Den committee.

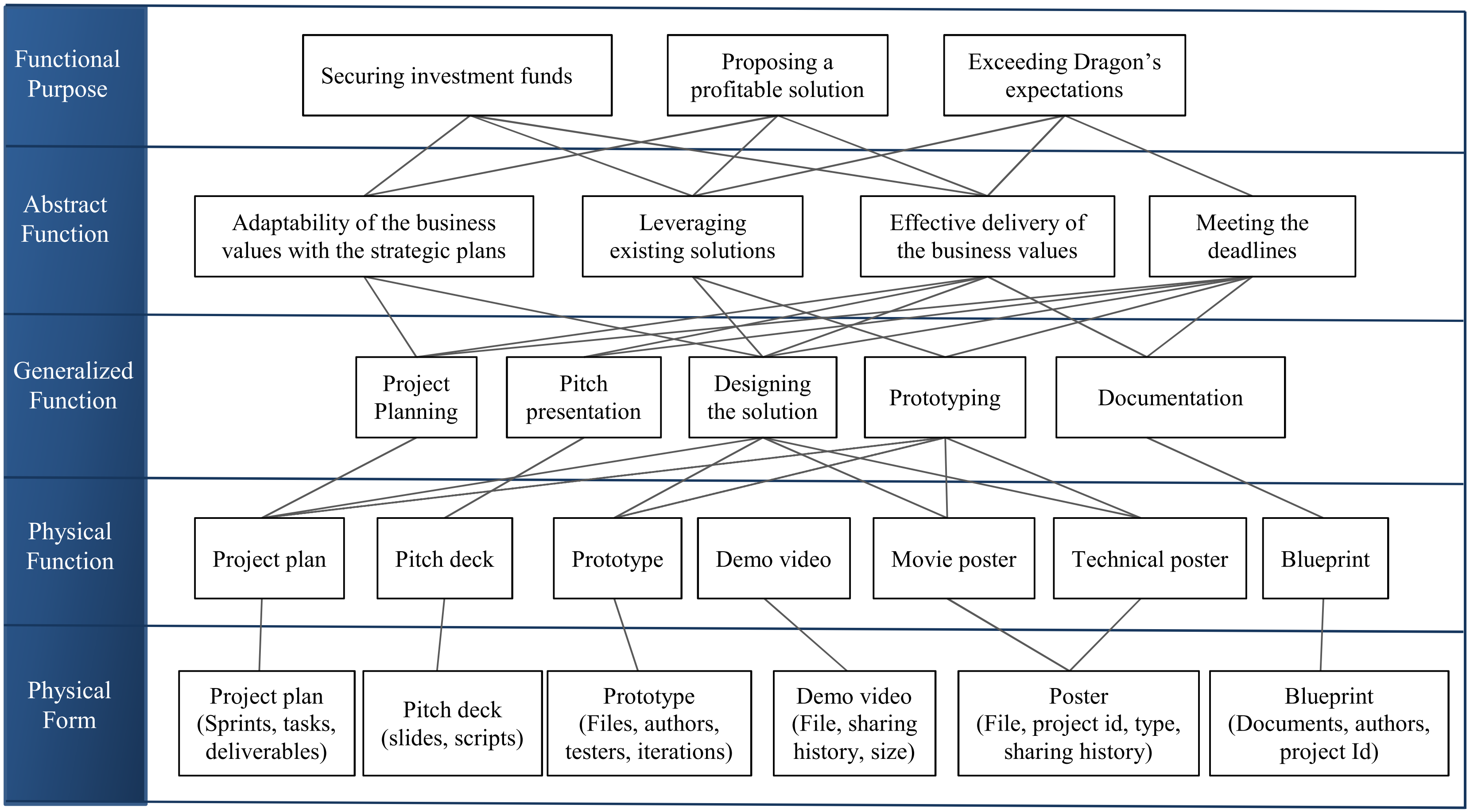


Figure 49. The Abstraction Hierarchy for the Extreme Blue Team.

The AH elements at the abstract-function level correspond to values, priorities, and principles. There are four main values and priorities that the EB participants should respect: (1) adaptability of the business idea with the IBM strategic plans, (2) leveraging existing IBM solutions, (3) effective delivery of the business values, and (4) meeting the deadlines. The structural links of the AH going from the abstract-function level to the level above correspond to a why-how relation between the purposes of the work domain and the values and priorities.

The main processes are described at the generalized-function level. The five processes of the EB program includes: (1) project planning, (2) pitch presentation, (3) solution design, (4) prototyping, and (5) documentation. The structural links of the AH going from the generalized-function level to the level above indicate the work-domain processes to meet the priorities.

At the physical-function level, the physical work-domain resources are identified. Project plan, pitch deck, prototype, demo video, movie poster, technical poster, and blue print are examples of physical elements of the work domain. The structural connections of the AH going from the physical-function level to the generalized-function level indicate the physical resources involved to complete the processes.

At the final level of the AH, the physical characteristics of the work-domain resources are identified. As an example, for a sample prototype, author name, tester name, file name, and stage at which the prototype is delivered should be identified. The structural links of the AH going from the physical-form level to the physical-function level correspond to the physical characteristic of the work-domain resources. Although the basic work-domain model indicates the work-domain purpose and values, it does not provide guidance on identifying which work-domain purposes or values are shared and by whom. The information required for this analysis was collected from my 15-week participation in the EB program as a UX designer. Distributed cognition helped me to plan for my observational studies and seek to study individuals in action.

4.3.2 Responsibility Maps and the Corresponding Collaboration Tables

The overall objective of Team WDA is to provide models and techniques for understanding shared or not shared purposes; shared or not shared values, priorities, and principles; shared or not shared processes; and boundary objects in the team. Figure 50 shows the responsibility maps for the EB team. Complexity of the overlap is managed by replacing individuals' decision-spaces with the decision space of sub-teams.

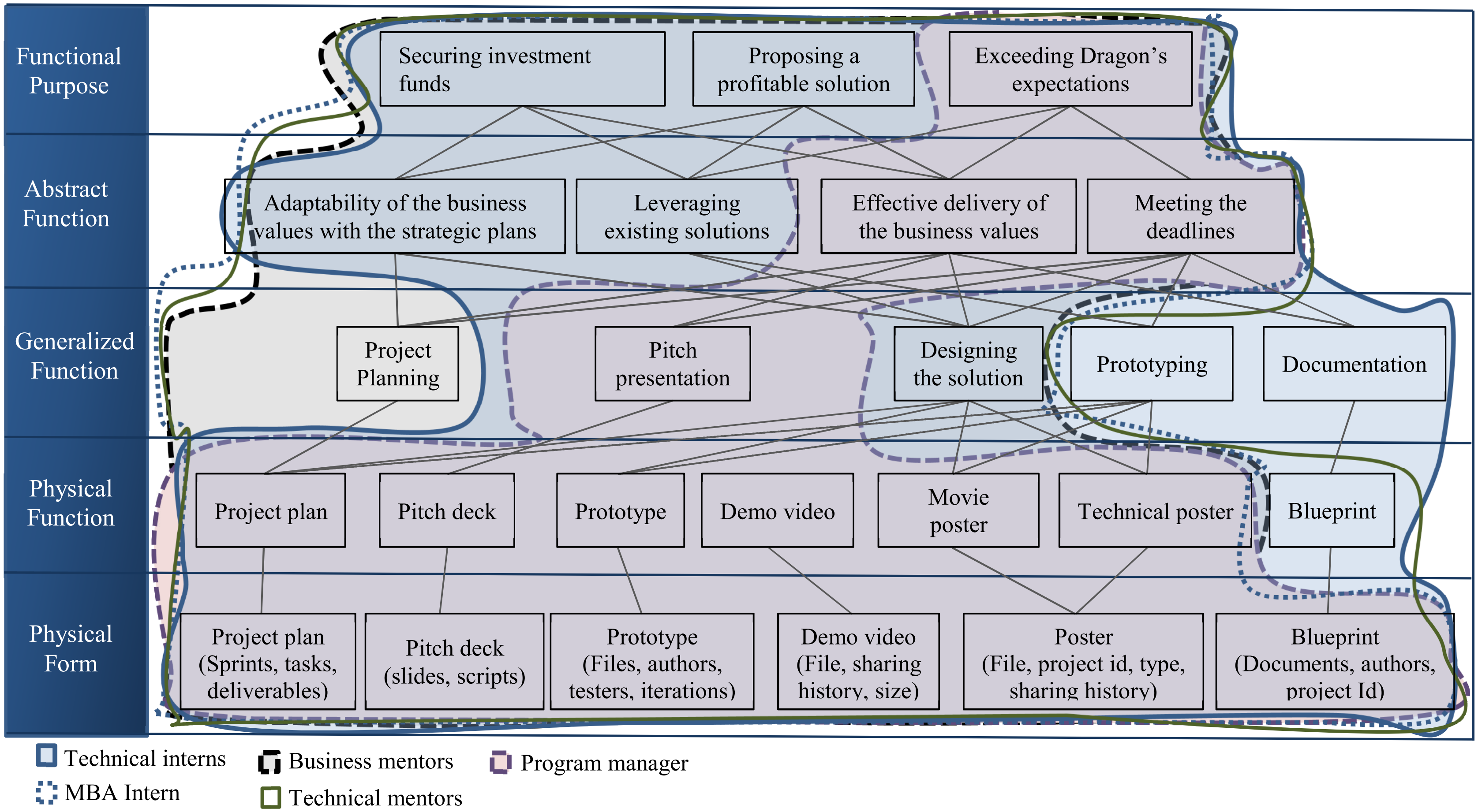


Figure 50. The Responsibility Map for the Extreme Blue Team.

Tables 22-25 show the collaboration tables for the responsibility maps of Figure 50. At the functional-purpose level, Table 22 indicates roles and responsibilities that contribute to a work-domain purpose. In the first 12 weeks of the program, the main purpose of the EB team is to exceed the expectations of the Dragons' Den committee in terms of delivery of business values. The program manager as the coordinator for the whole program is responsible for ensuring a high quality of deliverables with respect to time constraints and expectations of the program.

Table 22: Collaboration Table at the Functional-Purpose Level for the Extreme Blue Team.

	Intern team		Mentor team		
Functional purpose	Technical interns	MBA intern	Business mentor	Technical mentors	Program manager
Securing investment funds	X	X	X	X	
Proposing a profitable solution	X	X	X	X	
Exceeding dragons' expectations	X	X	X	X	X

The ultimate purpose of the EB program is to develop a profitable business solution and secure investment funds from IBM to turn the business solution into a product.

At the abstract-function level, the CT identifies shared or not shared values, principles, and priorities. Table 23 shows that meeting the deadlines and effective delivery of business values are the shared priorities in the EB team. It requires all the EB participants to meet the deadlines and contribute to effective delivery of business values. In addition, the developed business solution should leverage the existing IBM technologies in order to be qualified for receiving investment funds.

Table 23: Collaboration Table at the Abstract-Function Level for the Extreme Blue Team.

	Intern team		Mentor team		
Abstract function	Technical interns	MBA intern	Business mentor	Technical mentors	Program manager
Adaptability of the business value with the strategic plans	X	X	X	X	
Leveraging existing solutions	X	X	X	X	
Effective delivery of business values	X	X	X	X	X
Meeting the deadlines	X	X	X	X	X

At the generalized-function level, the CT describes the overlap between the processes that each team member is responsible for. For example, designing the solution is the shared process between the MBA intern, technical interns, business mentor, and technical mentors. This means every one of them should contribute in designing a business solution. Similarly, pitch presentation is the shared process between the EB participants. The intern team prepares the pitch deck and, then, the mentor team provides feedback on that before the submission of the final presentation to the Dragon's Den committee.

Table 24: Collaboration Table at Generalized-Function Level for the Extreme Blue Team.

	Intern team		Mentor team		
Generalized function	Technical interns	MBA intern	Business mentor	Technical mentors	Program manager
Project planning		X	X	X	
Pitch presentation	X	X	X	X	X
Designing the solution	X	X	X	X	
Prototyping	X				
Documenting	X				

A detailed understanding of shared processes in a team may lead to a better understanding of boundary objects and the way people exchange information in a team. The corresponding physical-function level CT, shown in Table 25, indicates boundary objects. Although the technical interns do not contribute to project planning, the project plan needs to be shared within everyone to inform them about the deadline, deliverables, etc. The final deliverables for the EB program include pitch deck, prototype, demo video, movie poster, and technical poster. The pitch deck is shared with everyone on the EB team to ensure that the feedback from everyone is reflected on the slides. The demo video is a short recorded video of the prototype to demonstrate the business values using stories and personas. The technical poster demonstrates the high-level technical architecture and the required infrastructures for implementing the prototype. The movie poster is a fun way to demonstrate creative skills of the intern team. Since the final deliverables are presented at the IBM's global head office, the program manager is responsible for ensuring high quality of the deliverables in terms of visual presentation and consistency with company guidelines. After the final presentation, the technical interns are expected to document the prototype and submit a blue print to their technical mentors.

Table 25: Collaboration Table at the Physical-Function Level for the Extreme Blue Team.

	Intern team		Mentor team		
Physical function	Technical interns	MBA intern	Business mentor	Technical mentors	Program manager
Project plan	X	X	X	X	X
Pitch deck	X	X	X	X	X
Prototype	X	X	X	X	X
Demo video	X	X	X	X	X
Movie poster	X	X	X	X	X
Technical poster	X	X	X	X	X
Blue print	X			X	

4.3.3 Abstraction Wheels

Abstraction wheels complement collaboration tables by presenting a graphical illustration of shared work-domain elements. Similar to the responsibility maps for the EB team, individual team members are replaced with sub-teams. For example, the decision ladders of the technical interns are replaced with one decision ladder representing the whole technical team. Figure 51 shows the abstraction wheels for the EB team and Table 26 provides complementary information to describe characteristics of the shared elements.

Table 26: The Abstraction-Wheel Table for the Extreme Blue Team.

Team members involved	AH level	Shared element	Scope	Type
-MBA intern -Technical interns -Business mentor -Technical mentors	Functional purpose	- Securing investment funds - Proposing a profitable solution	Intern team-Mentor team	Shared purpose
-MBA intern -Technical interns -Business mentor -Technical mentors - Program Manager	Functional purpose	- Exceeding Dragon's Den committee's expectations	Intern team-Mentor team	Shared purpose
-MBA intern -Technical interns -Business mentor -Technical mentors - Program Manager	Abstract function	- Meeting the deadlines - Effective delivery of business values	Intern team-Mentor team	Shared value
-MBA intern -Technical interns -Business mentor -Technical mentors	Abstract function	-Adaptability of the business value with the strategic plans -Leveraging existing solutions	Intern team-Mentor team	Shared value
-MBA intern -Business mentor -Technical mentors	Generalized function	- Project planning	Intern team-Mentor team	Shared process
- MBA intern -Technical interns -Business mentor -Technical mentors - Program Manager	Generalized function	- Pitch presentation	Intern team-Mentor team	Shared process
-Technical interns -Technical mentors	Generalized function	- Designing the solution	Intern team-Mentor team	Shared process
-Technical interns	Generalized function	- Documenting - Prototyping	Technical team	Shared process
-MBA intern -Technical interns -Business mentor -Technical mentors - Program Manager	Physical function	- Project plan - Pitch deck - Prototype - Demo video - Movie poster - Technical poster	Intern team-Mentor team	Boundary object
-Technical interns -Technical mentors	Physical function	- Blueprint	Intern team-Mentor team	Boundary object

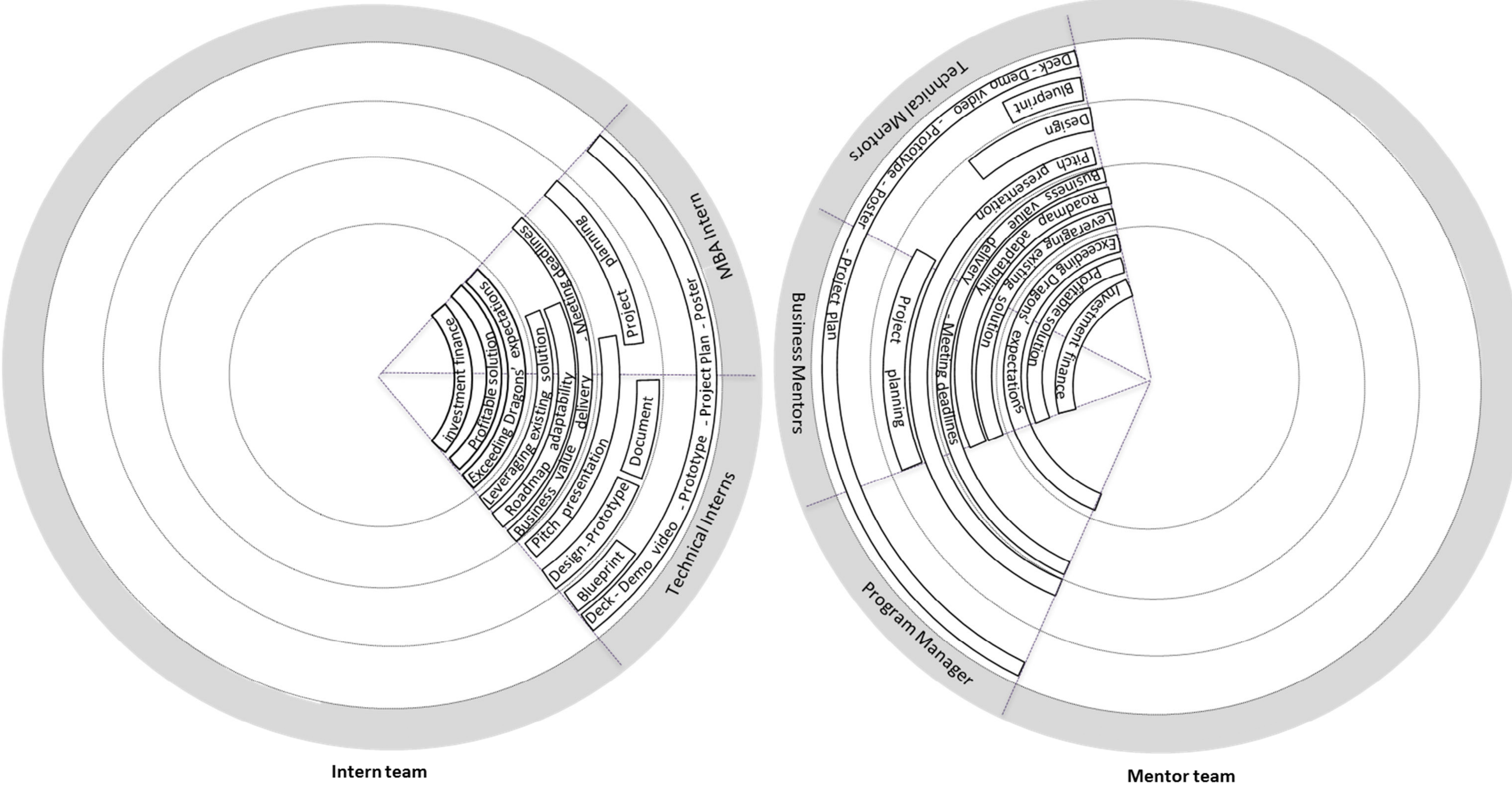


Figure 51. The Abstraction Wheel for the Extreme Blue Team.

Abstraction wheels can be used for examining team structures as well as functional roles and responsibilities in a team. The abstraction wheels, shown in Figure 51, provide a graphical illustration of the team structures for the EB team and represent the shared work-domain elements between the sub-teams.

4.3.4 Summary of the Findings

In this section, I explored a basic WDA as well as the extended Team WDA models for understanding collaborative requirements of the EB team. This small but complex application domain provides a good example of hierarchical team structures. The complexity of the work-domain models is managed with a substitution of individual models with the models of sub-teams, when possible. For example, the decision spaces for the individual technical mentors are replaced with the decision space for the whole team. I recommend this practice for the analysis of hierarchical team structures with layers of sub-teams.

Table 27 summarizes the shared work-domain elements for the EB team. From a teamwork perspective, the goal in using a WDA for the analysis of collaborative requirements of the EB team is to create a set of models for the team that describe shared values, purposes, and priorities of teamwork. However, the basic WDA does not provide sufficient guidance on extracting which work-domain elements are shared and by whom. Team WDA addresses this shortcoming and provides models and techniques for analyzing shared or individual purposes; values, priorities, and principles; processes; and boundary objects in the team.

While collaboration tables may provide a representation of shared work-domain elements for the EB team, the abstraction wheel offers a graphical illustration of the team structures and the shared work-domain elements in the EB team. In the following section, I will explore the collaborative requirements of the EB team at the control-task level.

Table 27: Summary of the Shared Work-Domain Elements for the Extreme Blue Team.

Comparison factors	Team WDA	Basic WDA
Functional-purpose level	Shared purposes: -Securing investment funds and proposing a profitable solution are the shared purposes between the intern team, the business mentor, and the technical mentors. -Everyone on the team contributes to exceed the expectations of the Dragon's Den committee.	Purposes: -Securing investment funds -Proposing a profitable solution -Exceeding the expectations of the Dragon's Den committee
Abstract-function level	Shared values, priorities, and principles: -Adaptability of the idea with the company's strategic plans and leveraging existing IBM solutions are the shared values between the technical intern, business mentor, and technical mentors. -Everyone on the EB team is expected to meet the deadlines and contribute to an effective delivery of the business values.	Values, priorities, and principles: -Adaptability of the idea with the company's strategic plans -Leveraging existing IBM solutions -An effective delivery of the business values -Meeting the deadlines
Generalized-function level	Shared processes: -Project planning is the shared process between the MBA intern, business mentor, and technical mentors. -Solution design is the shared process between the intern team, technical mentors, and business mentor. -The technical interns contribute to building the prototype and documentations. -Everyone on the EB team shares the pitch presentation process.	Processes: -Project planning -Pitch presentation -Designing the solution -Prototyping -Documentation
Physical-function level	Boundary objects: -Project plan, pitch deck, prototype, demo video, movie poster, and technical poster are the boundary objects shared in the EB team. -The blue print is shared only between the technical interns and technical mentors.	Physical work-domain resources: -Project plan -Pitch deck -Prototype -Demo video -Movie poster -Technical poster -Blue print

4.4 Comparison between Control Task Analysis and Team Control Task Analysis

In this section, the results of conducting a traditional ConTA and the Team ConTA for the analysis of the collaborative requirements of the EB team are discussed. The goal of the basic ConTA is to identify the constraints on what needs to be done. The Team ConTA expands this objective to identify team structure, team interactions, shared workflows, and boundary objects. Team ConTA models expand decision ladders (Rasmussen et al., 1994) to decision wheels (Ashoori & Burns, 2010) and provide suggestions to revamp the CAT for team analysis (Ashoori & Burns, 2011). In the following section, I will start with conducting a basic ConTA to identify control-task constraints for the EB team and, then, compare the findings with the results of Team ConTA.

4.4.1 Basic Control Task Analysis

The regular ConTA suggests using the decision ladder to identify control requirements for each application domain. As discussed in Chapter 2, Vicente (1999) analyzes activities as a set of control tasks at different operating modes. In the EB team, activities may be divided into three modes, including: problem analysis, solution design, and implementation. During the problem analysis mode, focus of the team is to understand the market, open challenges, competitors, and available resources. During the solution design mode, team's activities revolve around finding a profitable business solution to address the market challenge. Once the business solution is identified, the EB team starts implementing a prototype to demonstrate the business value of the solution. Each operating mode usually imposes a different set of demands to the team.

Vicente (1999) recommends conducting a separate ConTA for each mode to identify the associated information requirements. To demonstrate this idea, I will start with conducting a regular ConTA for the implementation mode. During the implementation mode, business solution is designed and the team aims for implementing a prototype to demonstrate the business value of the solution. The decision ladder, shown in Figure 52, represents a graphical illustration of the ConTA findings for the implementation mode. Table 28 shows a tabular summary of the analysis and describes the content of information-processing activities, states of knowledge, and shortcuts identified in the decision ladder, shown in Figure 52.

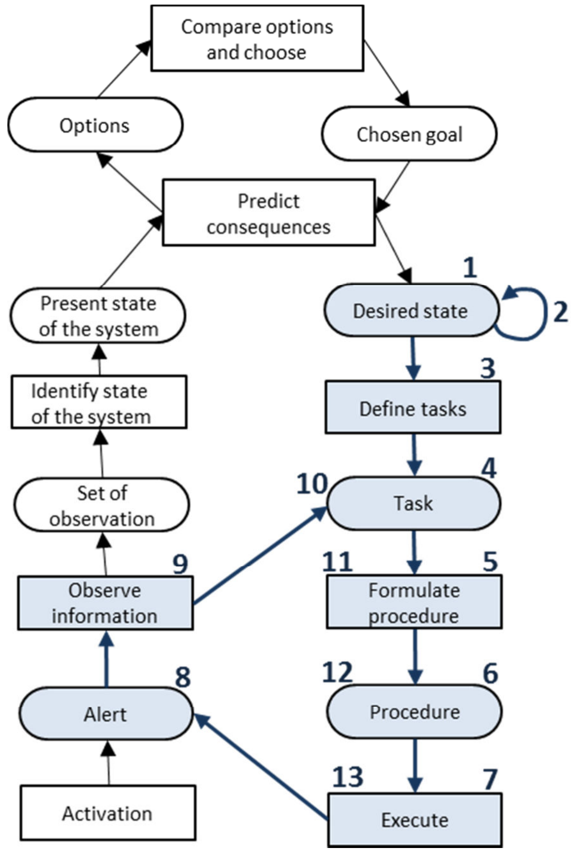


Figure 52. Decision Ladder of the Implementation Stage for the Extreme Blue Team.

Once the business solution is identified, the value of the idea should be demonstrated through implementing a working prototype (Step #1 in Table 28). At the work-domain level, a profitable idea should leverage the existing solutions within the company. Therefore, the next step is to establish the development requirements that depend on the existing solutions and the technologies available (Step #2). The technical intern team that I was part of had a UX designer, a front-end developer, and a back-end developer. In a typical situation, the UX designer refines the design specifications and hand them over to the front-end developer for implementation. The back-end developer provides the required infrastructure to build the user interface. Consequently, at the second step, the development requirements have to be carefully identified with respect to the UX design, front-end development, and back-end development. At the third step, the EB team chooses the development approach and identifies what needs to be done for an implementation of the business idea. The output of this information-processing activity is a development plan that shows what needs to be done to bring the team to the desired state (Step #4).

Table 28. Summary of the ConTA for Implementation Mode.

Step #	Description	Ladder code	Abstraction level
1	Requirements for a profitable solution	Desired state	Functional purpose
2	Establish the requirements for developing the business solution	Desired state	Abstract function
3	Choose the development approach	Define tasks	Generalized function
4	Development plan	Task	Generalized function
5	Identify a list of actions for implementing the development plan	Formulate	Physical function
6	Desired deliverables	Procedure	Physical function
7	Implement the prototype and present it for feedback	Execute	Physical form
8	Feedback on the prototype	Alert	Physical form
9	Collect the feedback and identify a list of changes	Observe	Physical form
10	A list of changes to implement	Task	Physical function
11	Identify a list of actions for implementing the changes	Formulate	Physical function
12	A new development plan and a list of actions for implementing the changes	Procedure	Physical function
13	Update the prototype to apply all changes	Execute	Physical form

Once the development plan is identified, the EB team starts planning a list of actions to implement the development plan (Step #5). The outcome of this activity is a list of deliverables along with a sequence of actions to prepare them (Step #6). At this point, the team is ready to start implementing the prototype (Step #7). When the first version of the prototype is ready, the intern team is expected to present the prototype to the mentor team and receive their feedback. This feedback loop is represented with a shunt from the execution to the alert state (Step #8) followed by an observation to identify what needs to be changed (Step #9). The shunt, shown in Step #10, allows the intern team to go directly from observing the state of the work-domain to knowing what needs to be done. At this point, the EB team should have a list of changes to implement. Based on the list of changes, the EB team plans a list of actions to apply the changes (Step #11). The outcome of this activity is a new development plan and a list of actions to execute (Step #12). The last step is executing the list of actions and implementing the changes (Step #13).

To summarize, the decision ladder can help to identify what information-processing activities need to be done, independently of who is to do them. While the decision ladder provides a generic template for examining the demand associated with the control tasks, it leaves open the issue of task allocation and how different team members contribute to complete the control tasks. Vicente (1999) acknowledges this shortcoming and explains that "there is a great deal of domain knowledge that is required that the ladder simply does not help with" (p. 190). In the Team ConTA discussion, I will come back to decision ladders and demonstrate how a decision wheel can be used for understanding the distribution of information-processing activities.

While Vicente (1999) discusses activities in terms of control tasks and operating modes, Naikar et al. (2006) suggest an analysis of activities in terms of a set of recurring work situations to deal with and a set of work functions to perform. They argue that the work situations can be mapped to the Vicente's definition of operating modes. Naikar et al. (2006) recommend the use of CAT for analyzing work functions in various situations. Similar to the Vicente's (1999) operating modes, the activities of the EB team can be discussed within three main situations: (1) problem analysis, (2) solution design, and (3) implementation. As discussed, the EB team starts with an analysis of the market challenge in the problem analysis situation. During the solution design situation, the team explores the profitable business solutions that address the target market challenge. Once the team decides on the business solution, they start prototyping the business idea to demonstrate the business value of the solution. Figure 53 shows the basic CAT for the EB team.

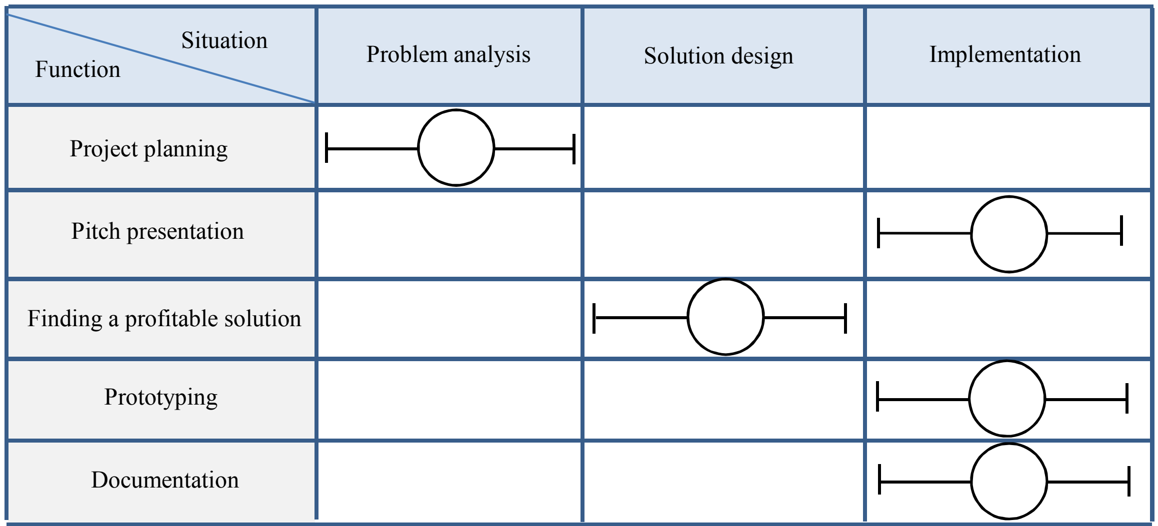


Figure 53. The Contextual Activity Template for the Extreme Blue Team.

Work situations are shown along the horizontal axis and work functions are shown along the vertical axis. The circles indicate the work functions and the horizontal lines connected to the circles indicate all of the work situations in which a work function can occur. Depending on the granularity of the analysis, different work functions at different levels of details may be identified. In order to be consistent with the work-domain processes identified in a basic WDA, five main work functions can be identified: (1) project planning, (2) pitch presentation, (3) finding a profitable solution, (4) prototyping, and (5) documentation. While the basic CAT provides a good illustration of the work functions in various situations, it does not represent the distribution of the shared work functions to different team members. In the discussion of Team ConTA models, I will demonstrate how the extended CAT for the team analysis may be used to understand the distribution of work functions in the EB team.

4.4.2 Decision Wheels

The findings of the basic ConTA for the EB team indicate that the decision ladder can be used for examining the demand associated with the control tasks. But, it leaves open the issue of task allocation and how different team members contribute to complete each control task. Decision wheel as an extension to decision ladders to represent team interactions can be used to identify the team structures, inter-team interactions, interactions between teams, and boundary objects.

In a typical decision wheel, the wheel represents a team with each team member comprising a portion of the wheel. Then, the decision ladder of each team member is drawn within the slices and the connections between the ladders represent the interactions between team members. Figure 54 shows the decision wheels for the implementation mode.

While a decision ladder represents an examination of the control task for the whole team, a decision wheel can be used for an examination of team interactions and distribution of the control tasks in the team. In a decision wheel, the shared work flow and interactions between the team members are shown by the arrows that connect the decision ladders together.

The summary of information-processing activities is already explained in Table 28. In this section, I will focus on an examination of the connections between the ladders to explain where interaction happens. The decision-wheel table, shown in Table 29, represents further details of each interaction. Links are numbered and correspond to the numbers in Figure 54. For the sake of simplicity, the inactive decision ladder boxes, which are not involved within the decision making of the control task, are deleted from the diagram.

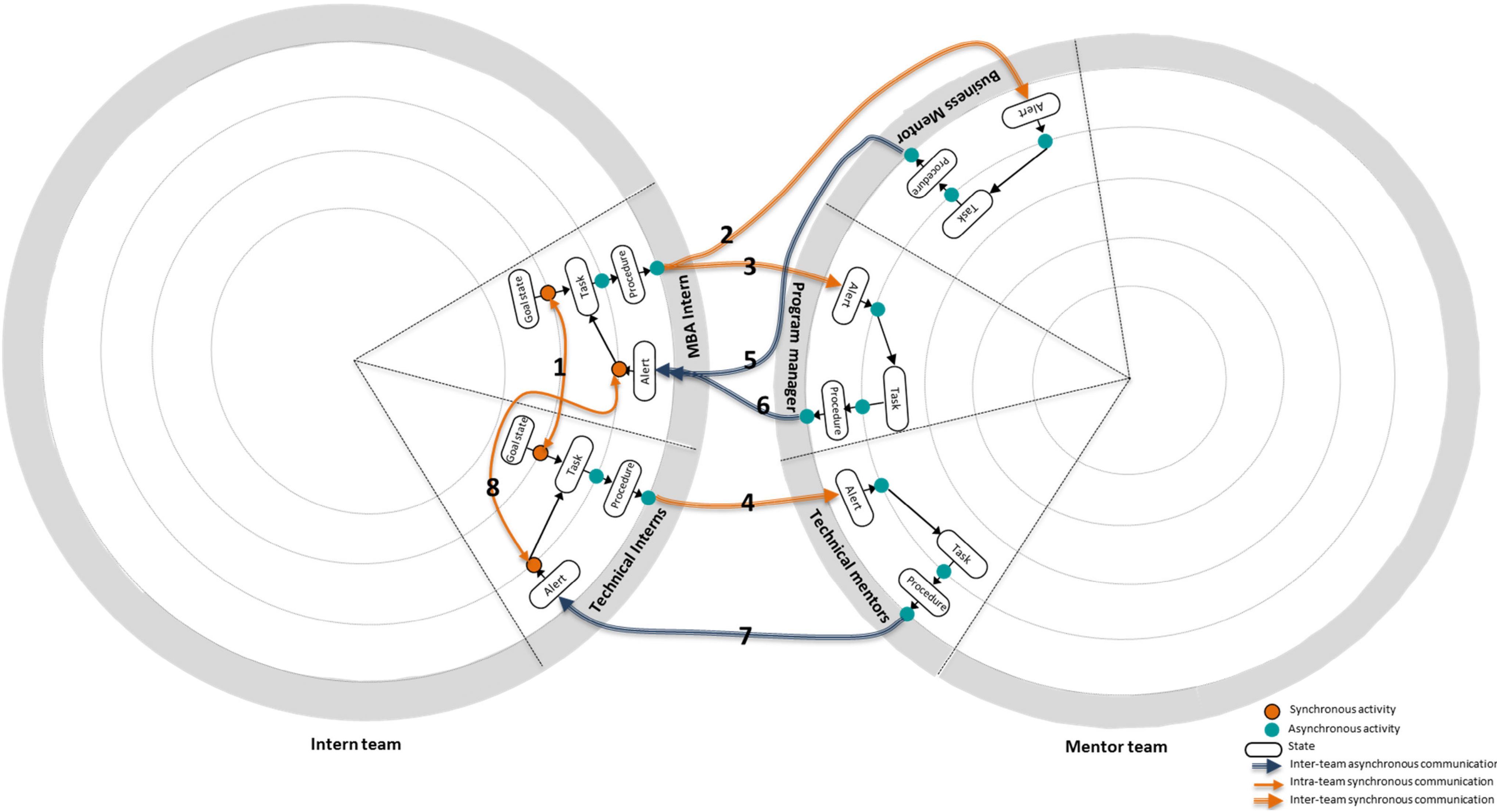


Figure 54. The Decision Wheel for the Extreme Blue Team.

Table 29. The Decision-Wheel Table for the Extreme Blue Team.

						CSCW criteria (Reinhard et al, 1994)		
Link #	Team members involved	Description	Abstraction level	Boundary objects	Scope	Synchronicity	Communication channel	System distribution
1	-MBA intern -Technical interns	Establish the requirements for developing the business solution and choose the development approach	Generalized function	-Project plan	Intern team	Synchronous	Face-to-face	Collocated team, same office space
2	-MBA intern -Business mentor	Pitch and prototype presentation to the business mentor to receive his feedback on the delivery of business values	Physical form	-Pitch deck -Prototype	Intern team-Mentor team	Synchronous with link #3 and #4	Group presentation	Remote places
3	-MBA intern -Program manager	Pitch and prototype presentation to the program manager to receive her feedback on the visual representation	Physical form	-Pitch deck -Prototype	Intern team-Mentor team	Synchronous with link #3 and #4	Group presentation	In the same building
4	-Technical interns -Technical mentors	Pitch and prototype presentation to the technical mentors receive on the architecture	Physical form	-Pitch deck -Prototype	Intern team-Mentor team	Synchronous with link #3 and #4	Group presentation	In the same building
5	-Business mentor -MBA intern	Receiving the feedback on the business values of the prototype from the business mentor	Physical form	-Feedback	Intern team-Mentor team	Asynchronous	Often using email	Remote places
6	-Program manager -MBA intern	Receiving the feedback on the visual presentation of the prototype and consistency with the company guidelines	Physical form	-Feedback	Intern team-Mentor team	Asynchronous	Often using email	In the same building
7	-Technical mentors -Technical interns	Receiving the feedback on the architecture and the technical implementation of the prototype	Physical form	-Feedback	Intern team-Mentor team	Asynchronous	Often using email	In the same building
8	-MBA intern -Technical interns	Sharing the feedback received from the mentor team to identify a list of changes	Physical form	-Prototype -Pitch deck	Intern team	Synchronous		Collocated team

At the implementation stage, the value of the business solution should be demonstrated by implementing a working prototype. At this point, the MBA intern shares the project plan with the technical interns and, then, the technical interns discuss the requirements for implementing the business solution (Link #1). The interactions between the interns can be either synchronous or asynchronous. The intern team that I was part of was a co-located team, who work together from the same office space. As a result, most of the interactions within the team were often a direct face-to-face communication (i.e., synchronous). Once the team decides on the development requirements for implementing the business solution, they can start implementing the prototype. The details of interactions in the technical intern team will be explained later in Figure 55.

When the first draft of the proposal is ready, the intern team presents the prototype to the mentor team for feedback. The technical mentors and the program manager of the EB team of my study were working from the Ottawa office. Therefore, the prototype presentations were often a direct face-to-face discussion between the intern team, technical mentors, and the program manager. The business mentor was calling in from the Toronto office. For that reason, the prototype presentation, shown in Links #2, 3, and 4, is considered synchronous. The feedback from the business mentor, the program manager, and the technical mentors are shown in Links #5, 6, and 7, respectively. Depending on the situation, the feedback might be a direct face-to-face discussion or a follow up email discussion. In my observation, most of the feedback was provided using emails (i.e., asynchronous communication).

For the sake of simplicity, in Figure 54, the decision ladders of individuals are replaced with the team decision ladders of sub-teams. Then, the team interactions between the members of the sub-teams are discussed in a separate decision wheel. I recommend this practice for the analysis of hierarchical team structures with layers of sub-teams.

Similar to the abstraction wheels, each slice represents a sub-team of the EB-team and the individual decision ladders are replaced with the team decision ladders of sub-teams. Each sub team would have a separate decision wheel depending on the control tasks. Figure 56 shows the intra-team interactions between the members of the technical intern team. As explained earlier in this section, at a typical situation, the UX designer refines the design specifications and hand them over to the front-end and back-end developers for implementation. In some situations, the design concepts need a few time revisions depending on the time constraints or resource limitations for the implementations. Figure 55 shows this explanation.

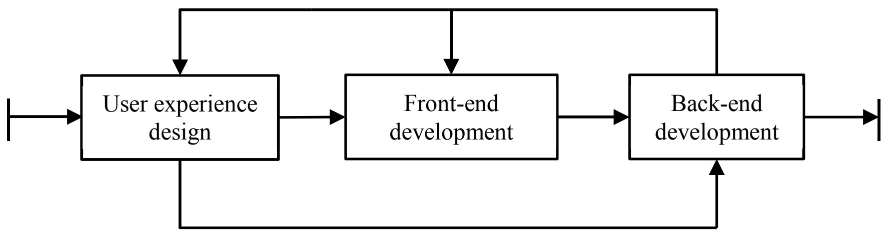


Figure 55. Typical Development Cycle for the Technical Intern Team.

In Figure 56, the connections between the decision ladders of the technical intern team explain the typical development cycle, shown in Figure 55. Additional attributes of the connections is discussed in Table 30.

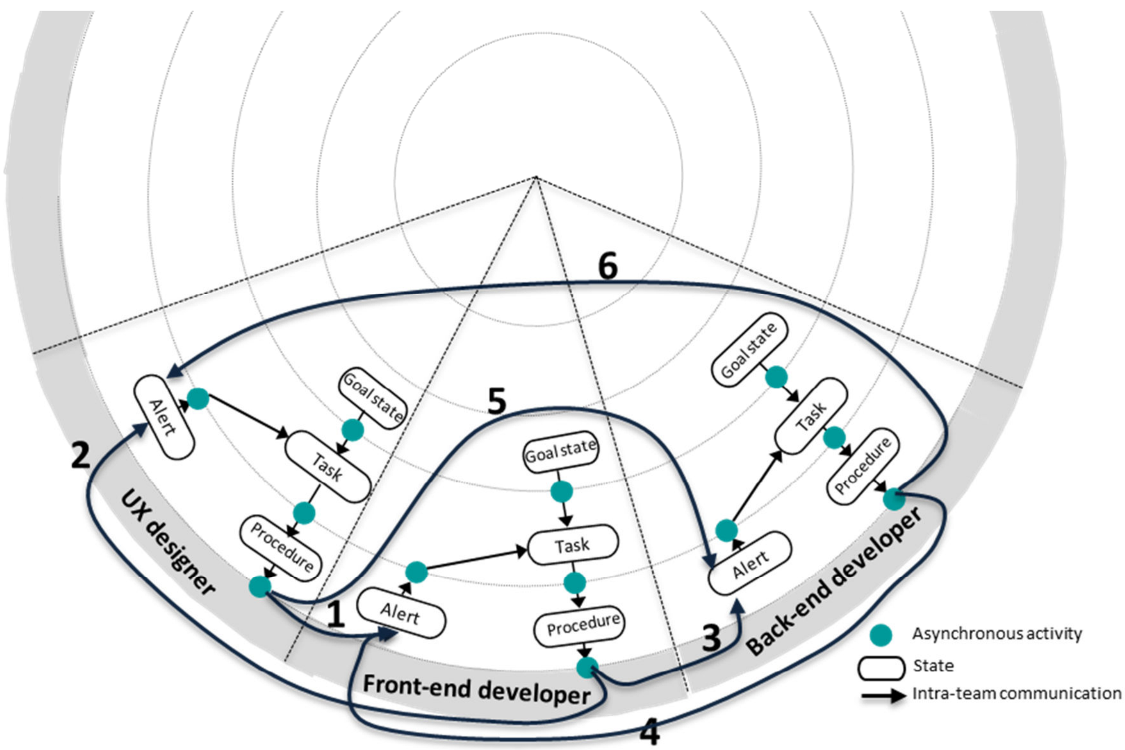


Figure 56. The Decision Wheel for the Technical Intern Team.

Table 30. The Decision-Wheel Table for the Technical Team.

Link #	Team members involved	Description	Boundary objects
1	- UX designer - Front-end developer	UX designer shares the initial design concept with the front-end developer to implement	-Prototype (design concept and mockups)
2	- Front-end developer - UX designer	Front-end developer provides feedback about feasibility of implementation in terms of the back-end requirements	-Prototype (design concept and mockups)
3	- Front-end developer - Back-end developer	Front-end developer shares the design mockups with the back-end developer to see what infrastructures are required to support the user interface	-Prototype (design mockups, data model)
4	- Back-end developer - Front-end developer	Back-end developer provides feedback about the feasibility of implementations in terms of the back-end requirements	-Prototype (design mockups, data model)
5	- UX designer - Back-end developer	UX designer shares the initial design concept with the back-end developer to check the feasibility of implementing the design in terms of the back-end infrastructure	-Prototype (design concept, design mockups, data model)
6	- Back-end developer - UX designer	Back-end developer provides feedback on the design concepts and discuss the feasibility of implementations in terms of the back-end requirements	-Prototype (design concept, design mockups, data model)

To summarize, the decision wheels along with the corresponding tables can be used to understand the distribution of control tasks in the EB team. The decision wheel provides an examination of inter-team interactions, intra-team interactions, and the boundary objects shared. While the decision wheels are a good representation to show how different parties interact on a single control task, the CAT is a good representation to show how individuals are involved in multiple control tasks in various situations. However, the basic CAT does not convey information about team structures, team interactions, or the boundary objects shared. In the following section, I will demonstrate how the Team CAT as an extension to the CAT for team analysis can be used to understand the distribution of work functions to different team members.

4.4.3 Team Contextual Activity Template

Figure 57 shows the modified CAT for the EB program. Work situations are shown along the horizontal axis and roles and responsibilities are shown along the vertical axis. The ovals indicate the teamwork functions and the small solid circles attached to the teamwork functions indicate the EB members that contribute to that function. This adaption clearly identifies what needs to be done in various situations and examines the interactions between the EB participants over time. Depending on the operational strategy that the intern team adopts, there might be different team functions identified for each situation.

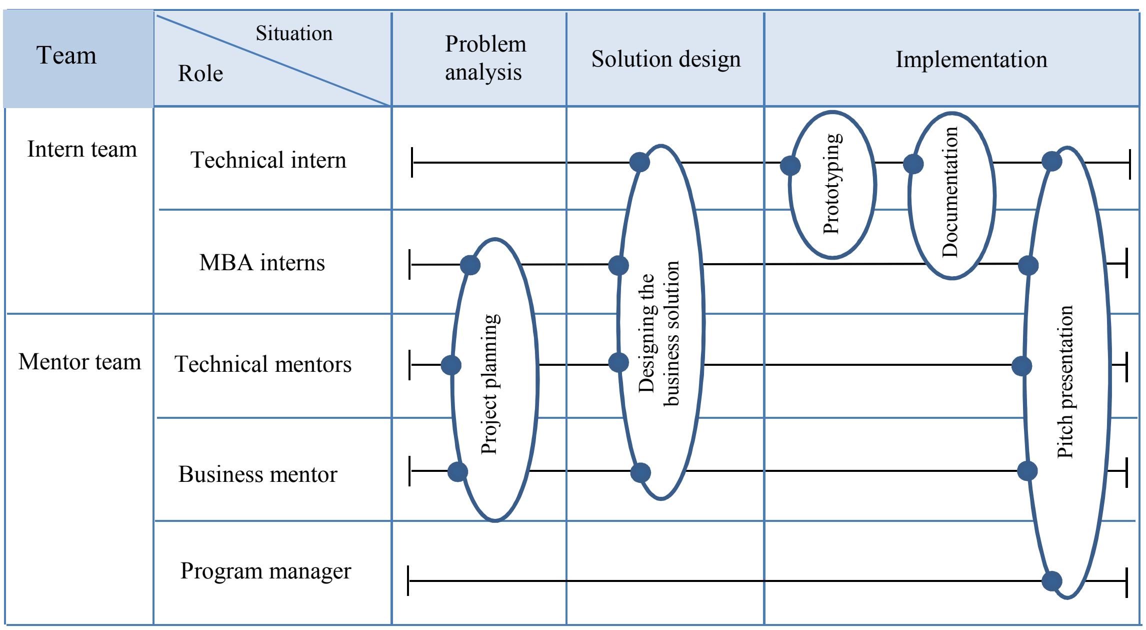


Figure 57. Team Contextual Activity Template for the Extreme Blue Team.

While the basic CAT does not convey information about the distribution of work functions, the extended CAT for teams can be a good representation to show how individuals are involved in multiple control tasks in various situations and identify the team structures and team interactions.

4.4.4 Summary of the Findings

When designing a collaborative system to facilitate data sharing between the EB participants, it is essential to examine the information flow, boundary objects, synchronicity of communications, shared workflow, and interdependencies between the tasks. In this section, I explored a basic ConTA and the extended models of the Team ConTA for understanding the collaborative requirements of the EB team. The goal of the basic ConTA is to identify the constraints on what needs to be done. The Team ConTA expands this objective to identify the team structure, team interactions, shared workflows, and boundary objects. Team ConTA models expand decision ladders to decision wheels and provide suggestions to revamp the CAT for team analysis. Decision wheels leverage the analysis of control tasks in a basic ConTA to identify the required team interactions for the completion of a shared task.

In this section, I explored the decision ladder and the decision wheels to demonstrate the findings of the analyses to understand the collaborative requirements of the prototype implementation in the EB team. At the implementation stage, the EB participants work together to refine the business solution and implement a prototype that can showcase the business value of that solution. The decision wheels were used to understand the shared work flows, the type of interactions, the scope of the interactions, and the boundary objects exchanged during the completion of the control tasks. While the decision ladder lacks the discussion of the inter-team and intra-team communications, the decision wheel provides a graphical illustration of the team interactions between the EB participants. Table 31 summarizes the comparison between the requirements identified by a basic ConTA and Team ConTA.

The complexity of the decision wheels for the larger teams can be managed by replacing the individual decision ladders with the team ladders. A separate decision wheel, then, explains the inter-team interactions behind the team decision ladder. For example, in the EB team, the decision ladders of three technical interns were replaced by the team ladder of the technical intern team. I recommend this practice for managing the complexity of the analysis of hierarchical team structures with layers of sub-teams.

Table 31: Summary of the Comparison between ConTA and Team ConTA for the Extreme Blue Team.

Comparison factors	Team ConTA	Basic ConTA
Operating modes/Situations	<u>Operating mode/ situation:</u> -Problem analysis -Solution design -Implementation	<u>Operating mode/ situation:</u> -Problem analysis -Solution design -Implementation
Work functions	<u>Team functions at problem analysis stage:</u> -Project planning is the team function between MBA intern, technical mentors, and business mentor <u>Team functions at solution design stage:</u> -Designing the business solution is the shared function between the intern team, technical mentor, and business mentor. <u>Team functions at implementation stage:</u> -Prototyping and documentation are the team functions for the technical intern team. - Pitch presentation is the shared function between everyone on the EB team.	<u>Work functions at problem analysis stage:</u> -Project planning <u>Work functions at solution design stage:</u> -Pitch presentation -Finding a profitable solution -Prototyping <u>Work functions at implementation stage:</u> -Prototyping -Documentation -Pitch presentation
Control tasks/ information-processing activities	<u>Control tasks for the implementation mode:</u> - Pitch presentation -Prototype implementation <u>Information-activity processing for the implementation mode:</u> -Choosing the development approach -Identification of a list of actions for implementing the development plan -Implementation of the prototype and pitch presentation -Feedback collection and an identification of the list of changes -Identification of a list of actions for implement the changes -Prototype update to apply the changes.	<u>Control tasks for the implementation mode:</u> - Pitch presentation -Prototype implementation <u>Information-activity processing for the implementation mode:</u> -Choosing the development approach -Identification of a list of actions for implementing the development plan -Implementation of the prototype and pitch presentation -Feedback collection and an identification

		of the list of changes -Identification of a list of actions for implement the changes -Prototype update to apply the changes.
Inter-team interactions	<u>Intern team-Mentor team:</u> <u>Team members involved: MBA intern, business mentor</u> Description: MBA intern from the intern team presents the pitch deck and the prototype to the business mentor to receive his or her feedback on the delivery of business values. Boundary object: Pitch deck, prototype Type: Synchronous Abstraction level: Physical form <u>Intern team-Mentor team:</u> <u>Team members involved: MBA intern, program manager</u> Description: MBA intern from the intern team presents the pitch deck and the prototype to the program manager to receive his or her feedback on the delivery of business values. Boundary object: Pitch deck, prototype Type: Synchronous Abstraction level: Physical form <u>Intern team-Mentor team:</u> <u>Team members involved: Technical interns, technical mentors</u> Description: Technical interns from the intern team present the pitch deck and the prototype to the technical mentors to receive their feedback on the technical architecture Boundary object: Pitch deck, prototype Type: Synchronous Abstraction level: Physical form	None.

Intra-team interactions	<u>Intern team:</u> <u>Team members involved: Technical interns, MBA intern</u> Description: The intern team establishes the requirements for developing the business solution and chooses the development approach Boundary object: Project plan Type: Synchronous Abstraction level: Generalized function <u>Technical interns:</u> <u>Team members involved: UX designer, Front-end developer</u> Description: UX designer shares the initial design concept with the front-end developer to implement. The front-end developer provides feedback on the design Boundary object: Prototype (design concept and mock-ups) <u>Technical interns:</u> <u>Team members involved: UX designer, Back-end developer</u> Description: UX designer shares the initial design concept with the back-end developer to implement. The back-end developer provides feedback on the design Boundary object: Prototype (design concept, design mock-ups, data model) <u>Technical interns:</u> <u>Team members involved: Front-end developer, Back-end developer</u> Description: Front-end developer shares the design mock-ups with the back-end developer to see what infrastructures are required to support the user interface. The back-end developer provides feedback on the design. Boundary object: Prototype (design mock-ups, data model)	None.

While the decision wheels are a good representation to show how different EB participants interact on a single control task, the CAT is a good representation to show how individuals are involved in multiple control tasks in various situations. However, the basic CAT does not convey information about team structures, team interactions, or the boundary objects shared. As shown in Figure 57, the extended CAT for the team analysis represents the team functions in the EB team and identifies the contribution of each team member in various situations.

In the following section, I will explore the collaborative requirements of the EB team at the strategy level.

4.5 Comparison between Strategies Analysis and Team Strategies Analysis

In this section, I will compare the findings of a regular StA and the extended Team StA for the analysis of the collaborative requirements of the EB team. While ConTA is concerned with what tasks are needed, StA deals with the question of how those tasks can be done. The Team StA expands this objective to identify (1) the range of strategies possible; (2) viable and effective strategies with respect to the work-domain constraints; (3) the sequence of actions in a strategy and how different team members contribute to execution of the strategy; and (4) strategy pathways are and contribution of the team members to each pathway. In the following section, I will start with conducting a basic StA to identify the strategy constraints for the EB team and, then, compare the findings with the results of the Team StA.

4.5.1 Basic Strategies Analysis

In this section, I use information flow maps as a modeling tool to conduct a strategies analysis for the EB team. In a typical StA (Vicente, 1999), the strategies associated with the information-processing activities are identified. During the basic ConTA (Table 28), six different information-processing activities were identified: (1) choosing the development approach, (2) identification of a list of actions for implementing the development plan, (3) implementation of the prototype and pitch presentation, (4) feedback collection and an identification of the list of changes, (5) identification of a list of actions for implement the changes, and (6) prototype update to apply the changes. For the sake of clarity, I focus on only one of those activities and present the strategies for the third activity: prototype implementation.

To implement the prototype, the intern team adopted an agile software development method with regular stand-up scrum sessions every day. There are different methods to implement an agile software development (Cockburn, 2006). In a scrum method, every day the team sets the plan for the day in a very quick, usually early in the morning, scrum sessions.

The basic unit of development in scrum is called sprint. Each sprint begins with a planning meeting, where the goal of the sprint is set and a list of tasks with an estimated time to commit to them is identified for each team member. Figure 58 shows a snapshot of the sprint planning for the technical team.

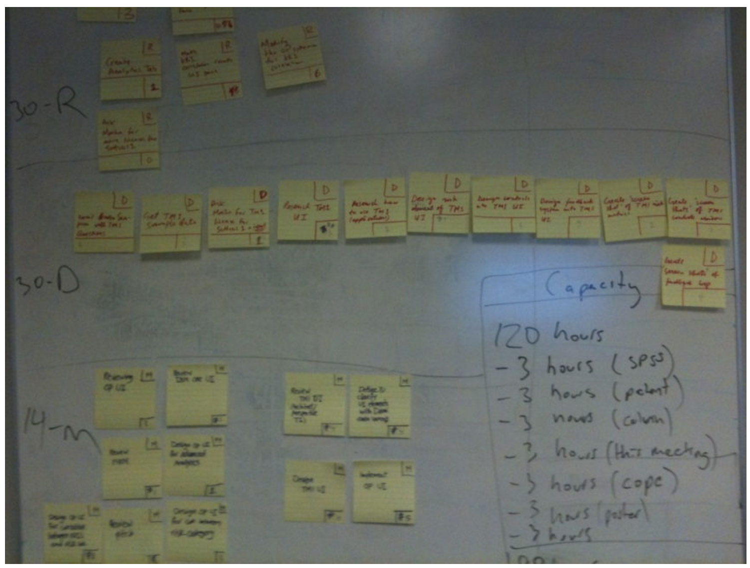


Figure 58. Sprint Planning for the Extreme Blue Team.

At the end of the sprint, the intern team presents the deliverables of that sprint to the mentors and receive feedback to plan for the next sprint. Figure 59 shows the information flow map of a typical weekly sprint for the EB team.

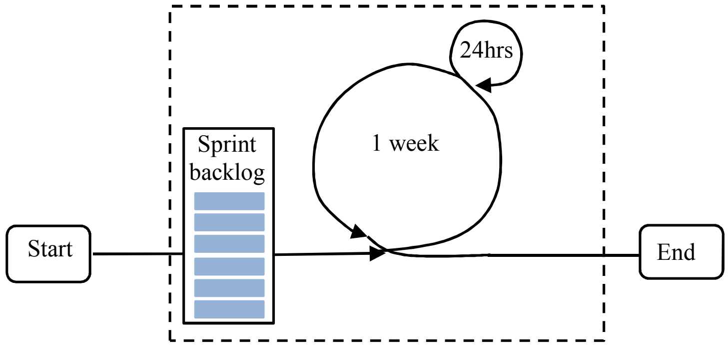


Figure 59. Information Flow Map for the Agile Development Approach.

A second strategy for the software development could be a traditional waterfall approach. In the waterfall approach, the intern team starts with a complete analysis of the problem, identifies all the requirements for implementations and, then, moves to develop the design concepts. When the design specifications are carefully identified, the intern team starts building the prototype. At the end of the project, the final prototype would be presented to the mentor team for feedback. Figure 60 shows the information flow map for this approach.

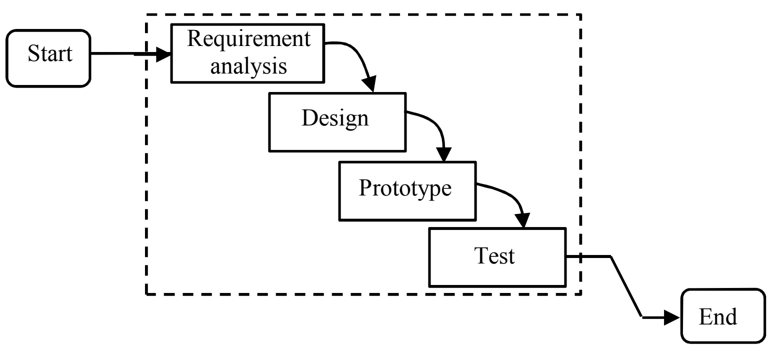


Figure 60. Information Flow Map for the Waterfall Approach.

The strategies at this level are categories. Vicente (1999) argues that the strategies identified at this stage should be instantiated by an operator for a particular situation. These instantiations, then, would represent a sequence of actions for each strategy. Although StA identifies various strategies that can be used by operators to perform the required control tasks, it leaves open the issue of who is responsible for performing the sequence of actions in each strategy. In the following section, I will demonstrate how the extended models of the Team StA can be used to identify the sequence of actions in a strategy and how different team members contribute to the execution of the strategies.

4.5.2 Operational Strategies

The Team StA methods and models examine strategies within four categories of (1) operational strategies, (2) coordination strategies, (3) team development strategies, and (4) structural strategies. The value added by the operational strategies lies in understanding different ways to carry out the shared control tasks. Although the basic StA identifies various strategies that can be used by operators to perform the required control tasks, it leaves open the issue of who contributes to an execution of a strategy. Team StA models leverage the IFM representation to identify a descriptive characterization of strategies and reveal how an experienced team of operators may perform a shared task. In addition to the IFMs, an extended CAT is suggested to describe various strategies in terms of the factors, such as resource access, task priority, expertise level, and time constraints, that may influence strategy selection in a variety of situations.

As discussed in the basic StA, the intern team adopts an agile software development method for the prototype implementation. In daily scrum sessions, the team sets the plan for the day. Daily scrum contains sets of predefined roles (Schwaber & Sutherland, 2011). The intern team in this study had adopted a weekly sprint planning with the following scrum roles: (1) the *scrum master* (MBA intern), who maintains the planning process and manages the scrum sessions, (2) the technical *team,* who do the actual design and implementation. At the end of the sprint, the technical deliverables get confirmed with the technical mentors and the business related deliverables get the business mentor approval. While the technical team is mostly responsible for implementing the prototype, the MBA intern is responsible for the identification of the business values and driving the project to the right direction. Figure 61 shows a typical weekly sprint for the EB team.

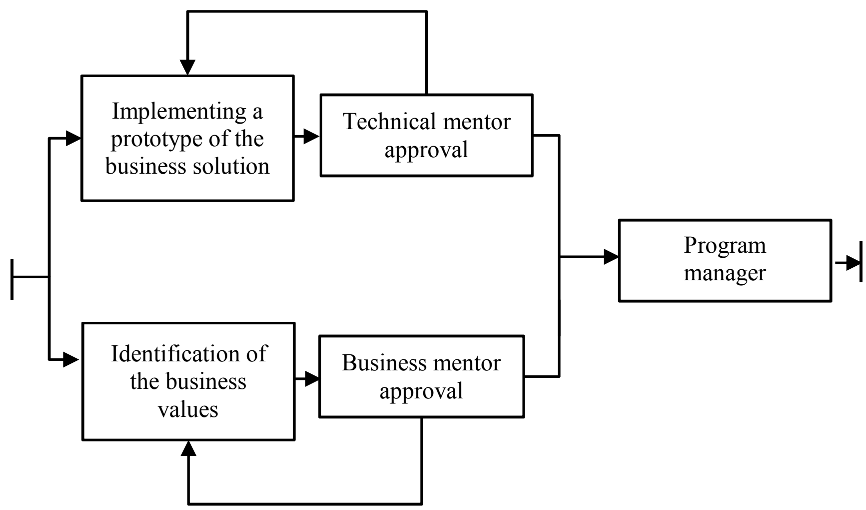


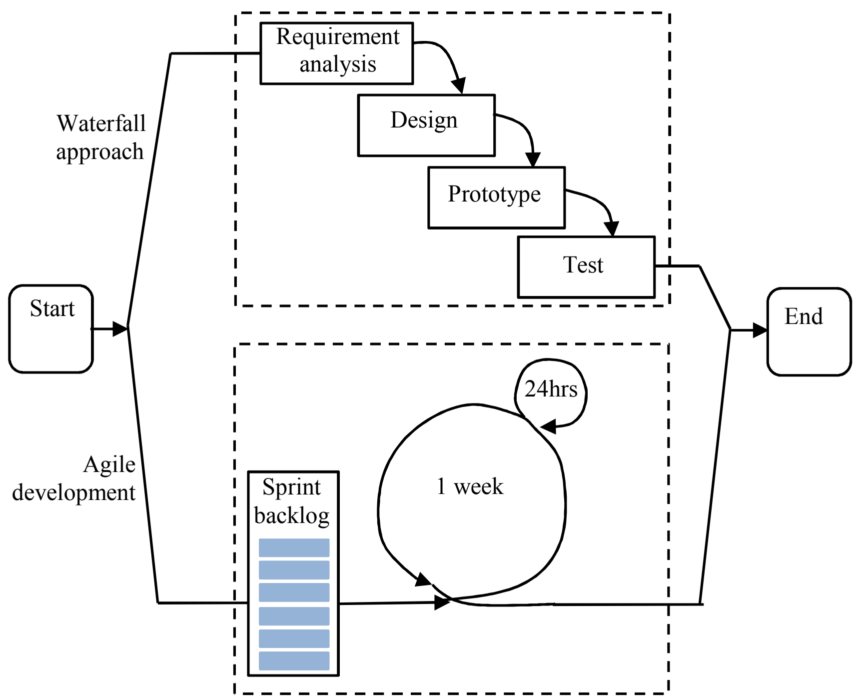
Figure 61. A Typical Weekly Sprint Plan for the Extreme Blue Team.

The EB program is fairly straight forward, the deadlines are pre-set and there are no major operational risks involved. Tables 32 and 33 show the sample strategies for two selected team activities: prototype implementation and pitch presentation.

Table 32. Strategy Analysis for Prototype Implementation.

Team Function: Prototype implementation			
Team Structure	Expertise level	Procedures	Systems used
Intern team: - MBA intern - Technical interns Mentor team: - People manager - Technical staff - EB alumni	Novice interns, experienced mentors	- The intern team implements a prototype to showcase the business value - The mentor team verifies the quality of the prototype	Internal code sharing applications, existing collaborative technologies and services

Information flow map:



Strategy description:

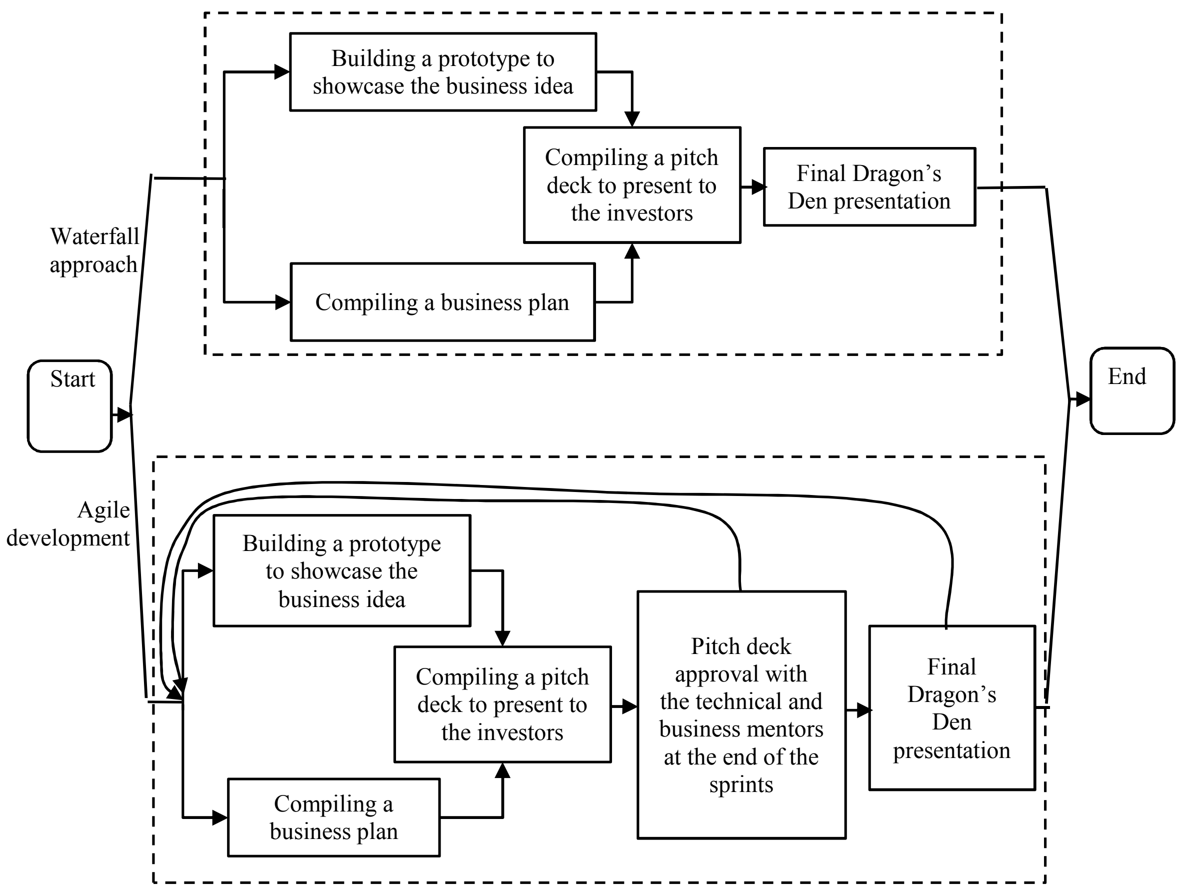
In the waterfall approach, the team starts with an examination of the problem state followed by designing a business solution and implementing a prototype to showcase the business value. However, the agile development framework is an iterative approach that starts with the weekly sprint planning, setting the goals for each week, and daily scrum stand-up sessions to plan the list of activities every day to achieve the sprint goals.

Table 33. Strategy Analysis for Pitch Presentation.

Team Function: Pitch presentation

Team Structure	Expertise level	Procedures	Systems used
Intern team: - MBA intern - Technical interns Mentor team: - Business mentor - Technical mentors - Program Manager	Novice interns, experienced mentors	Three monthly Dragon's Den presentations are planned to evaluate the quality of the presentation delivery, the depth of the analysis, and the practicality of the business solution	Internal presentation system

Information flow map:



Strategy description:

In the waterfall approach, the EB team develops a business plan before creating the pitch deck for the Dragon's Den presentation. But, in the agile development framework, the team confirms the pitch updates with the mentor team at the end of the sprints (end of the weeks) and gradually builds upon the slides as they progress through the development process.

4.5.3 Coordination Strategies

While operational strategies revolve around different ways to carry out control tasks, coordination strategies focus on an identification of the coordination structures, interaction patterns, and the management style. Figure 62 shows the coordination structure for the EB team. The EB participants are represented with solid black circles and the links between the circles represent interactions between the members. Inter-team interactions are shown with the dashed lines, and inter-team interactions are shown with the solid black lines. Different teams are represented by the dashed circles.

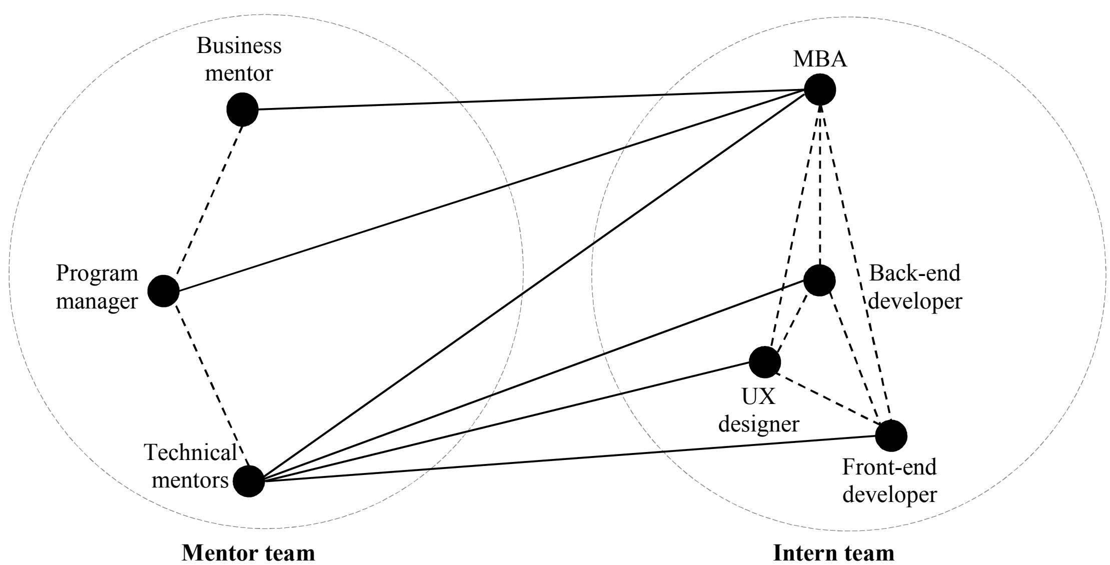


Figure 62. Coordination Structure for the Extreme Blue Team.

The coordination structure at this point is a combination of different structures in the Rasmussen's (1989) explanation of the coordination structures. Within the intern team, the MBA intern, as the scrum master, is responsible for managing the scrum sessions and coordinating activities in the intern team. Consequently, the coordination structure for the intern team can be seen as the autocratic structure.

The coordination structure inside the technical team is different. In the technical intern team, coordination is more similar to a democratic structure, which involves interaction among all the technical interns.

At the higher level, the coordination structure within the EB team can be examined as a diplomatic structure as the individual decision makers negotiate with only the neighbours' involved. For example, the technical interns are responsible for reaching out to the technical mentors to ask for the feedback; whereas, the MBA intern is responsible for verifying the validity of the business value with the business mentor and the quality of the visual representations of the pitch deck with the program manager. This observation provides a good example of a variety of coordination structures for the sub-teams of a hierarchal team structure.

4.5.4 Structural Strategies

Structural strategies inherit, and build on, the work-domain constraints and can be revealed by the Team StA. An analysis of the structural strategies can help to identify what strategies are feasible when the work-domain constraints have been considered. By mapping the strategies to the work-domain model, Team StA can be used for examining which WDA elements are involved in each strategy, what the various strategy pathways are, and how different team members contribute to the execution of that strategy. In the previous three sections, I discussed different strategies for the prototype implementation and pitch presentation. In this section, I discuss the strategy pathways and examine the feasibility of different strategies for these two activities. Figure 63 shows the strategy pathways for pitch presentation. Discussion of the shared work-domain elements for each strategy can be used for determining team member contributions to the strategy pathways. At the physical level, any strategy for pitch presentation requires using the pitch deck. Since the pitch deck is the boundary object shared between everyone in the EB team, all the EB participants should contribute to review and evaluate the pitch deck. Strategy pathways for pitch presentation can be used to identify (1) which technical interns contributes to the pathway and (2) what strategies for prototype implementation are feasible when the work-domain constraints have been considered. Figure 64 shows the strategy pathways for the prototype implementation.

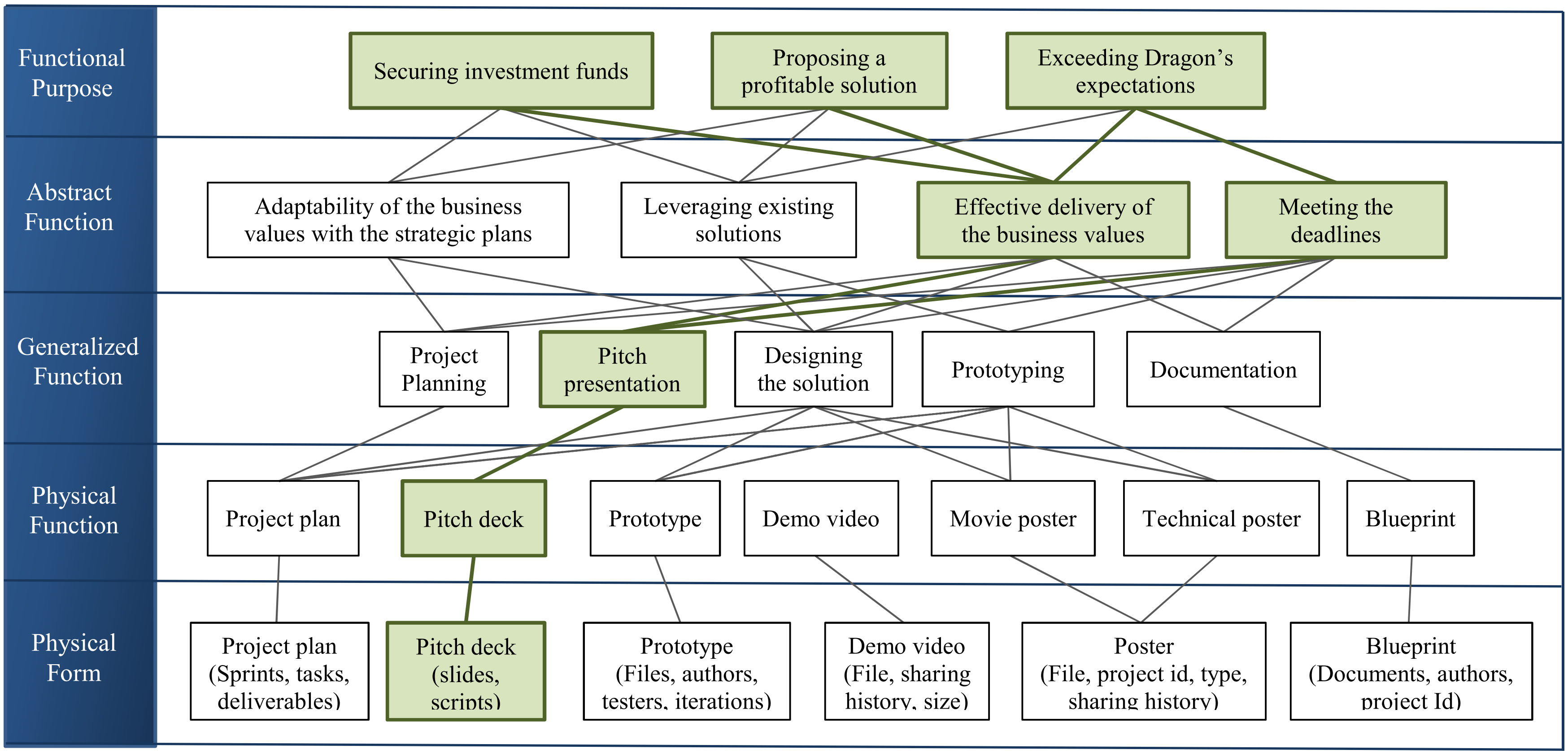


Figure 63. The Strategy pathway for Pitch Presentation.

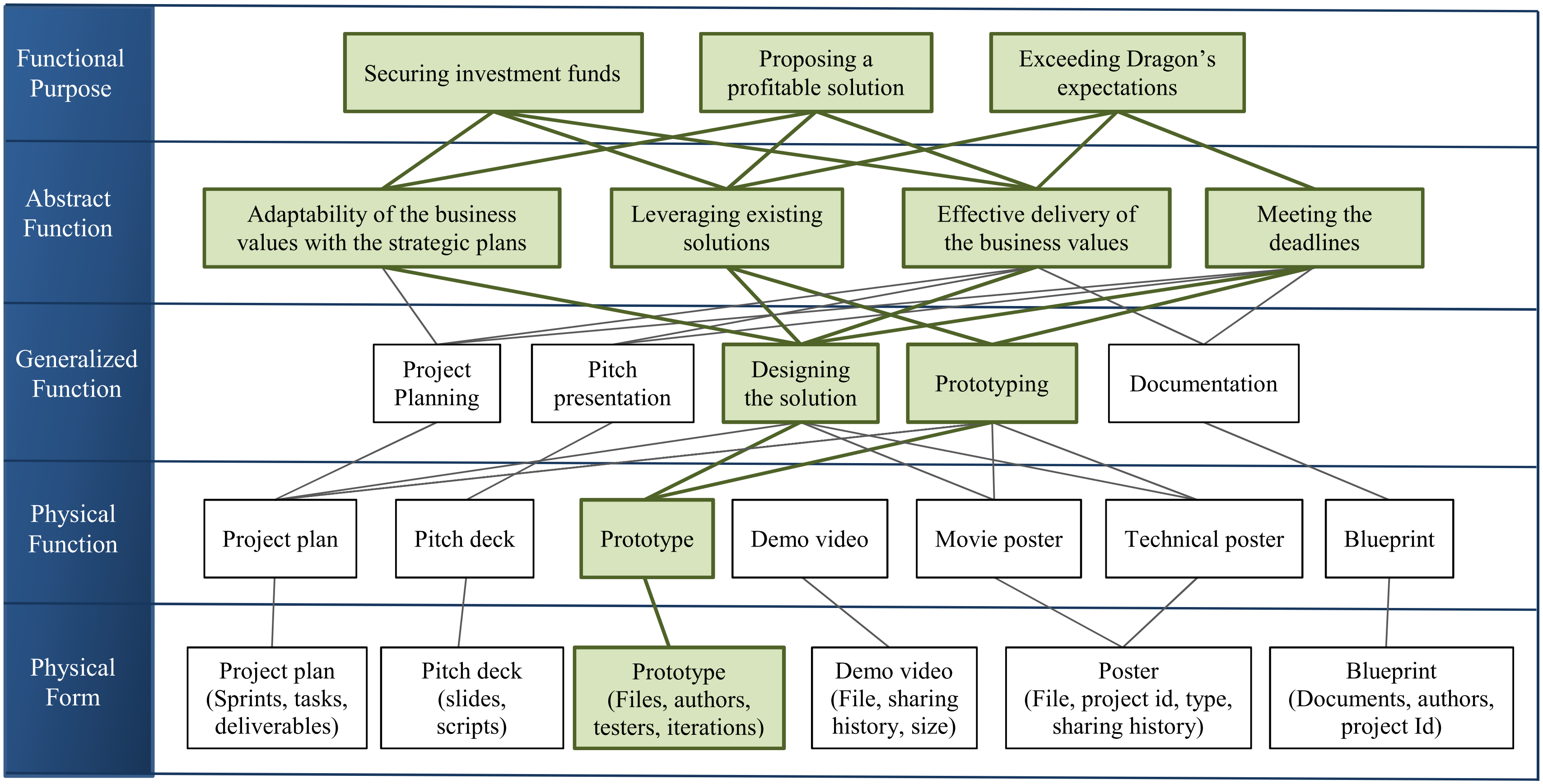


Figure 64. The Strategy Pathway for Prototype Implementation.

Similar to pitch presentation, at the physical level, any strategy for prototype implementation requires using the prototype object. Since prototype is the boundary object shared between everyone on the EB team, all the participants are required to review and evaluate the prototype. At the generalized-function level, the prototyping process is shared only between the technical interns. This means, the technical interns are the only team members contributing to a strategy for building the prototype.

To summarize, with an examination of the strategy pathways and the physical work-domain constraints, the EB participants can identify (1) what strategies are feasible to implement, (2) which WDA elements are involved in each strategy, (3) who contributes to each strategy and what WDA elements are shared, (4) what the various strategy pathways are, and (5) how different team members contribute to the strategy pathways. Then, decide on the feasible strategies and take the best strategy to implement.

In the following section, I will explore the team development strategies for understanding the collaborative requirements of the EB team.

4.5.5 Team Development Strategies

As discussed earlier, Tuckman's (1956) team development model considers five main stages of progress for a team: (1) forming, (2) storming, (3) norming, (4) performing, and (5) adjourning. The EB participants are assigned to the team of four before the program starts. The interns do not get to choose their team. However, to support the EB team in the forming stage, the program manager organizes a few workshops to discuss the importance of the performance support, teaming, growth and development, work style and strengths, supervision, and management. The forming stage for the EB program is about three days when the team goes through many orientation sessions, meets with the mentors, gets educated about the working environments, rules and guidelines, facilities, and resources. The team is given the opportunity to reach out to the EB alumni from last years to get a better idea of the expectations and deliverables.

At the storming stage, the conflict arises and the team members compete to allocate the team roles. At this point, the intern team needs to know about the social and functional competencies of their team members, their personalities, interests, strengths, weaknesses, and their reactions to a conflict. At the team of my study, the program manager organized a few personality tests to help the EB participants get a better idea of each other competencies and conducted a couple of workshops to teach the team how to face and resolve the conflict situations. At this stage facing with the conflicts is inevitable, but it is important for the team to learn how to resolve the conflict in a peaceful way.

At the norming stage, close relationships develop and the team demonstrates cohesiveness. At this point, the intern team sets the norms for handling conflicts and making group decisions. Team strategies, at the norming stage, involve more of coordination strategies and effective communications. For example, at this stage, the intern team decides to follow an agile team development with weekly sprints and daily scrum session. The team assigns the MBA intern as the scrum master to lead the scrum sessions and manage the weekly sprint planning sessions.

Finally at the fourth stage, performing, the team actually starts being productive. At this point, team members have learned how to work together, manage conflicts, and contribute to meet the team's purpose. Strategies to manage this stage are more focused on the operational strategies and different ways to tackle a task. At this stage, the team needs to know the work load, task interdependencies, and expertise level of the team member to decide on the sequence of actions and assign them to the competent interns to execute.

At the end of the program, the adjourning stage, the team starts wrapping up the project, makes the blueprint of the product, and hands over the documentations to the new development team. The individual strategies at this point revolve around maintaining the network and reaching out to the company Staff to build and explore further opportunities.

4.5.6 Summary of the Findings

In this section, I started with conducting a basic StA and developing the information flow maps for prototype implementation. Table 34 shows a summary of the comparison between StA and Team StA for the EB team.

The findings from the basic StA identified two potential categories of strategies for the EB team to implement the prototype: (1) agile approach and (2) waterfall approach. To implement the prototype, the intern team adopted an agile software development method with daily stand-up scrum sessions and weekly sprint planning.

Table 34: Summary of the Comparison between StA and Team StA for the Extreme Blue Team.

Constraints	Team StA	Basic StA
Operational strategies	Prototype implementation strategies Strategies: Agile development method, waterfall approach Team Structure: Intern team: - MBA intern - Technical interns Mentor team: - People manager - Technical staff - EB alumni Expertise level: Novice interns, experienced mentors Procedures: - The intern team implements a prototype to showcase the business value - The mentor team verifies the quality of the prototype Systems used: -Internal code sharing applications, -Existing collaborative technologies and services Pitch presentation strategies Strategies: Agile development method, waterfall approach Team Structure: Intern team: - MBA intern - Technical interns Mentor team: - People manager - Technical staff - EB alumni Expertise level: Novice interns, experienced mentors Procedures: Three monthly Dragon's Den presentations are planned to evaluate the quality of the presentation delivery, the depth of the analysis, and the practicality of the business solution Systems used: Internal presentation system	Prototype implementation strategies -Agile development method -Waterfall approach Pitch presentation strategies -Agile development method -Waterfall approach
Coordination strategies	Coordination structure for the implementation stage: (prototype implementation and pitch presentation) -Intern team: autocratic structure -Technical interns: democratic structure -EB team: diplomatic structure	None.

Structural strategies	Strategy pathways for pitch presentation: Physical constraint: Pitch deck (People involved: the EB team) Processes involved: Pitch presentation (People involved: the EB team) Strategy selection criteria: Effective delivery of the business values and meeting the deadlines (People involved: the EB team) Strategy pathways for prototype implementation: Physical constraint: Prototype (People involved: the EB team) Processes involved: Prototyping (People involved: technical interns) and designing the solution (People involved: interns, technical mentors, and business mentors) Strategy selection criteria: Effective delivery of the business values and meeting the deadlines (People involved: the EB team), leveraging existing solutions and adaptability of the business values with the strategic plans (People involved: interns, technical mentors, and business mentors)	None.
Team development strategies	Needs attached to the forming stage: -Understanding the importance of the performance support, teaming, growth and development, work style and strengths, supervision, and management -Meeting with the mentors -Getting educated about the working environments, rules and guidelines, facilities, and resources Needs attached to the norming stage: -Information about the social and functional competencies of the team members, their personalities, interests, strengths, weaknesses, and their reactions to a conflict Needs attached to the storming stage: -Norms for conflict resolution and group decision making Needs attached to the performing stage: Similar to the operational strategies	None.

The strategies identified with a basic StA are categories. Vicente (1999) argues that these strategies should be instantiated by an operator for a particular situation. These instantiations, then, would represent a sequence of actions for each strategy. Although StA identifies various strategies that can be used by the EB team to implement the prototype, it leaves open the issue of who is responsible for performing the sequence of actions in each strategy.

By conducting the Team StA, I examined the team strategies for the EB team within four categories of (1) operational strategies, (2) coordination strategies, (3) team development strategies, and (4) structural strategies. The findings from the analysis of the operational strategies provides an understanding of different prototype implementation strategies in terms of the required team structure, expertise level of the team members, information flow maps, and the sequence of actions for each strategy. The value added by the analysis of operational strategies lies in understanding different ways to implement a prototype and contribution of the EB team to the sequence of actions.

With an analysis of the coordination strategies, Team-StA provided an understanding of the coordination structures in the EB team when they work together on implementing the prototype. The intern team may switch between several coordination strategies to deal with the changing interdependencies between the tasks. In the analysis of coordination strategies, I examined the coordination structure for prototype implementation. For a different activity, such as the project planning, the team might adopt a different coordination structure. The EB participant might switch between different strategies depending on the situation. A complete analysis of the coordination strategies for all of the activities identified during the ConTA can provide a good understanding of the interaction patterns in different situations. Poor coordination structures for the EB team can be identified, and the team can have a more informed sprint planning for the rest of the project.

An analysis of the structural strategies for the EB team helped to identify (1) the feasible strategies, (2) the WDA elements involved in each strategy, (3) the EB participants that contribute to that strategy, and (4) how different team members contribute to the strategy pathways.

An examination of team development strategies for the EB team indicates how the behaviours of the EB participants may change during the team lifecycle. I had a chance to stay with the EB team from the first day that the team met for the first time to the last day at work to wrap up the documentation and leave the office. It was a great opportunity to examine different stages of Tuckman’s (1965) team development model for the EB team and understand the needs of the intern team at different stages of the forming, norming, storming, performing, and adjourning stages.

By understanding the needs attached to each stage of the team development model, the program coordinators may be able to design and present the supplement trainings tailored to the team members' needs at each stage. A good understanding of the team development models can inform the design specifications to adapt to the changing teamwork requirements as the interns grow within the company.

In the following section, I will explore the collaborative requirements of the EB team at worker competency level.

4.6 Comparison between Worker Competencies Analysis and Team Worker Competencies Analysis

In this section, I conduct a traditional WCA and compare the analysis with the findings of a Team WCA. Much of the previous attempts to use WCA for an examination of competencies have focused on an identification of the skill-set required for the operators to take over their functional roles. It leaves open the issue of social competencies and the desired behaviours that operators should exhibit for effective interaction with another. The overall objective of Team WCA is to allow the determination of a series of desirable attributes for operators based on the requirements of the application domain instead of a general assumption of the operator requirements.

In the following section, I will start with conducting a basic WCA to identify the functional competencies required for the EB participants and, then, analyze the findings of a Team WCA for an examination of team roles and social competencies.

4.6.1 Functional Competencies

Functional competencies define the job-specific competencies that directly reflect the requirements of the application domain. Much of the previous work to use the basic WCA for an identification of functional competencies has used the SRK taxonomy to analyze the skill-, rule-, and knowledge-based behaviours of the operators.

Team WCA consolidates all the requirements imposed by the preceding phases for examining the functional competencies required for effective teamwork. At the Team ConTA, I identified three main team functions for the implementation mode: (1) pitch presentation, (2) prototyping, and (3) documentation. For the sake of clarity, in the StA section, I explored different strategies for two of these three main functions (i.e., prototype implementation and pitch presentation). In this section, I explore the functional competencies for effective pitch presentation and prototype implementation.

Team WCA consolidates all requirements imposed by the preceding Team CWA phases for examining functional and social requirements that the EB participants should possess in order to effectively contribute to pitch presentation and prototype implementation. At the work-domain level, a representation of functional competencies may lead to a more informed task allocation. By describing the required skill-set for pitch presentation and prototype implementation, it is possible to identify the competent interns to participate in each process and determine which processes are more suited to which interns. At the control-task level, Team WCA may be used for an examination of a series of context-dependent situation-specific behaviours that are required for effectively performing the control tasks. At the strategy level, Team WCA identifies what strategies are available for prototype implementation in terms of experience, ability, and knowledge of the team members.

Table 35 shows the SRK inventory for the two team functions of pitch presentation and prototype implementation. The first column of the SRK inventory represents the team functions. The rest of the columns indicate the skill-, rule-, and knowledge-based behaviours that apply to those team functions. As shown in Table 35, the experienced participants gravitate naturally towards demonstrating skill-based behaviours, but may switch to rule-based behaviours when an appropriate rule set or a best practice is available. By comparing the qualifications of the EB participants and the description of the functional competencies required to perform a process, the program manager can identify whether extra training is necessary. Team WCA is useful for the design of the training programs that are tailored to the responsibilities and competencies of the EB participants.

Table 35: Partial SRK Inventory for the Extreme Blue Team.

Team function	Participants	Skill-based behaviour	Rule-based behaviour	Knowledge-based behaviour
Pitch presentation	Intern team: - MBA intern - Technical interns Mentor team: - Technical mentors - Business mentor - Program manager	An experienced mentor team should understand the business context and provide appropriate feedback and direct guidance for the intern team. The experienced intern team should be able to effectively present the idea and identify a list of changes based on the mentors' feedbacks.	The mentor team should be able to look up the business guidelines to effectively challenge the intern team. The intern team should be able to look up the fact sheets, best practices, business guidelines, and company's documents to identify the requirements for an effective presentation of the business ideas.	The mentor team should be able to do a deep research on the market challenge and available opportunities to guide the team in the best way to implement the best possible approach to effectively showcase the value of the business solution. The technical intern should be able to explore the resources available to learn how to effectively present the business ideas, how to interpret the feedback from the business professionals, and how to map them to an action plan for the rest of the project.
Prototyping	Technical interns	The experienced technical interns must possess proven strong programming skills to quickly start implementing the prototype.	The technical interns should be able to identify the existing solutions and design the technical architecture in such a way that is feasible to implement.	The technical interns should be able to quickly learn and adapt to different software development methodologies. The y should be able to effectively go through the sprint planning sessions, evaluate their performance on the last spring, and set the appropriate goals for the following sprint. They should be able to analyze the situation, pick up new technologies, identify the risks in the development cycle, and revise the plans based on the situation.

While functional competencies describe the skill-set required for the operators to take over their functional roles, social competencies indicate the desired behaviours that operators should exhibit for effective interaction with each other. In the following section, I will describe the discussion of the social competencies for the EB team.

4.6.2 Social Competencies

Social competencies focus on interpersonal skills required for effective teamwork. As discussed the intern team adopted an agile software development and decides to have the MBA mentor as the scrum master. As the scrum master, the MBA intern should be able to effectively manage the daily scrum stand-ups and the weekly sprint planning sessions. Consequently, the MBA is expected to demonstrate significant contributions in a team based environment, both as a team player and a leader. The technical team in an agile development approach are expected to possess the ability to work collaboratively in a team and demonstrate passion for technology, business, or community. Figure 62 shows the coordination structure for the implementation stage. The MBA intern as the scrum master can be seen as the coordinator at the Belbin's model. He or she should be strong project manager and be able to ensure that the technical interns would fulfill the weekly spring goals. The technical interns, as the technical team in the scrum roles, play the workers at the Belbin's model. The business mentor and the technical mentors should be the specialists to criticize the work. The program manager is the coordinator between the EB team, the Dragon's Den committee, and the internal IBM stakeholders. He or she can be seen as the coordinator in the Belbin's model. Table 36 shows the functional and team roles allocated to the EB participants when they follow an agile development to implement and refine the prototype.

Table 36: Team-role Summary for the Extreme Blue Team.

Team	Functional role		Team role	Social skills required (Belbin,1981)	Functional skills required (Extreme Blue, 2011)
Intern team	MBA		Coordinator	Confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	The MBA intern should demonstrate previous participation in a new product development initiative and the ability to work business issues in a highly dynamic, technology based environment
	Technical interns		Team-worker	Cooperative, mild, perceptive, and diplomatic. Should be able to listen, build, and avert friction	The technical interns must possess proven strong programming skills. They should have the ability to take ownership of an idea and turn it into reality
Mentor team	Technical mentors	People manager	Specialist	Single-minded, self-starting, dedicated to provide knowledge and skills in rare supply	People manager should be a specialist in his field. -The technical member is usually a senior technical employee, who works on the related products or services to the EB project
		Technical staff	Specialist		Expertise level varies depending on the number of years working on a particular product
		EB alumni	Specialist		The EB alumni should demonstrate a prior participation to the EB program
	Business mentor		Specialist		The business mentor should be a specialist in business planning, consulting, and services.
	Program manager		Coordinator	Confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	The program manager is the coordinator for the whole program and responsible for the recruiting process, bringing the interns to the IBM lab, train them sufficiently, and accompany the Canada EB teams to the IBM's global head office for the final pitch. He or she should have a good understanding of the business needs as well as the technical requirements of the EB projects and work closely with the people managers to recruit competent people for the team.

4.6.3 Summary of the Findings

In this section, I explored the functional and social competencies for the EB team. Table 37 shows a summary of the comparison between a basic WCA and the Team WCA for the EB team.

Table 37: Summary of the Comparison between WCA and Team WCA for the Extreme Blue Team.

Constraints	Team WCA	Basic WCA
Functional competencies	Similar to a basic WCA.	<u>Function roles:</u> - MBA intern - Technical interns - People manager - Technical staff - EB alumni - Business mentor - Program manager Functional skills: The skill-, rule-, knowledge- behaviour are examined within the SRK inventory in Table 35
Social competencies	<u>Team roles for the implementation stage:</u> - MBA intern: coordinator - Technical interns: team-worker - People manager: specialist - Technical staff: specialist - EB alumni: specialist - Business mentor: specialist -Program manager: coordinator <u>Social skills:</u> -Specialist: single-minded, self-starting, dedicated to provide knowledge and skills in rare supply -Team-worker: cooperative, mild, perceptive and diplomatic. Should be able to listen, build, and avert friction -Coordinator: confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	None.

With respect to the functional competencies, the SRK inventory for the two team functions of pitch presentation and prototype implementation was identified. The SRK inventory explores a range of job-specific competencies required for effective contribution to pitch presentation or prototype implementation. While functional competencies described the skill-set required for the EB team to take over their functional roles, social competencies indicated the desired social behaviours of the EB participants. Depending on the coordination structure, the EB participants may switch between different team roles. I identified the team role of the EB participants when they contribute to pitch presentation and implementing the prototype. In spite of the dynamic nature of team-role allocation, the EB team is not flexible to switch between the functional roles. For example, the UX designer in the technical team is specialized in the UX design and the front-end developer is specialized in web programming. Specializing in different skill-sets, the UX designer cannot replace a front-end developer when implementing the prototype, but they can both take over the coordination of the technical interns in the sprint planning sessions.

Team WCA is also useful for the design of the training programs that are tailored to the responsibilities and competencies of the EB participants. By comparing the qualifications of the EB participants and the description of the functional competencies required to perform a process, the program manager can identify whether extra training is necessary.

In this section, I conducted a basic CWA for the analysis of the collaborative requirements for the EB team and compared the results with the findings of the Team CWA. In the next chapter, I will explore the Team CWA for the second observation at the Ottawa hospital to analyze the team interactions in the operating room.

Chapter 5

Observational Study 2: Collaboration in the Operating Room

Figure 65 provides an overview of thesis structure with the highlighted chapter material for Chapter 5. In this chapter, I will review the applicability of my extended models to analyse the collaborative requirements of a surgical team at the Labour and Delivery Department of The Ottawa Hospital.

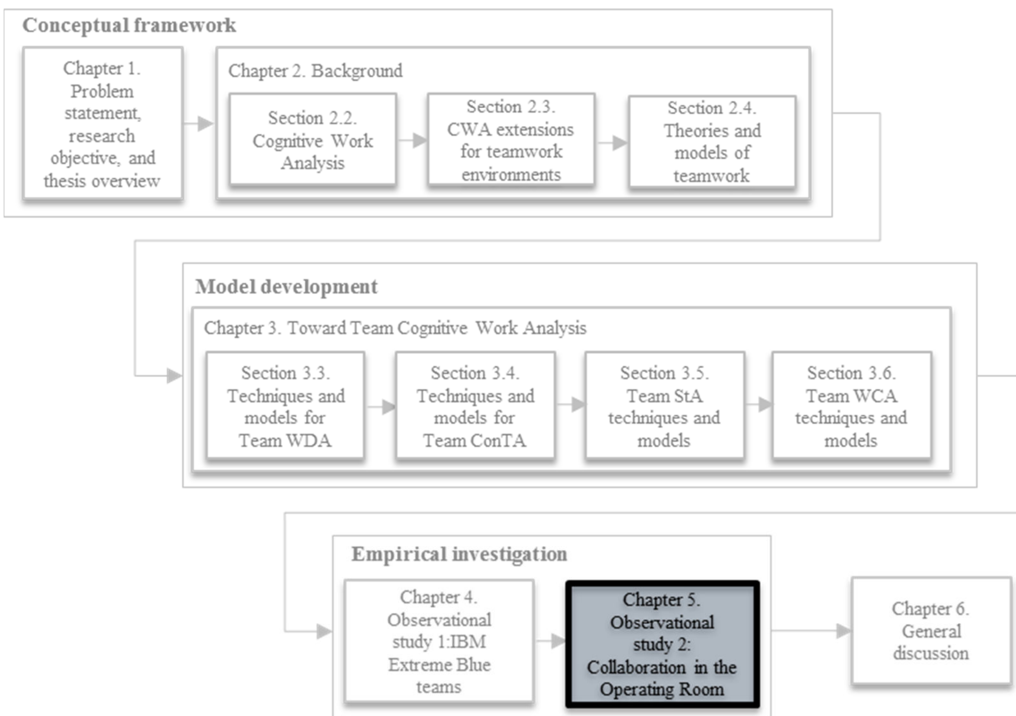


Figure 65. Chapter 5 Overview.

5.1 Introduction

Effective communication enhances the delivery of patient care and develops cohesion within the healthcare team. However, teams often do not perform to their potential due to inadequate awareness of team goals, conflicts between team members, mismatched individual goals, and breakdowns in coordination between team members. While there are reasonably good measures in the literature that gauge team performance in an operating room (e.g., Davies, 2005; Guerlain et al., 2005; Hajdukiewicz, 1998; Parush et al., 2010), very few studies use these benchmarks to design proper technologies to improve team performance. In this chapter, I explore the applicability of Team CWA methods and models to an analysis of the collaborative decision-making of a surgical team. I spent two weeks at the Labour and Delivery Department of The Ottawa Hospital to study the interactions within the surgical team of a Cesarean section surgery (C-section). In the next sections, I will review the results of conducting a traditional CWA and a Team CWA to analyze the collaborative requirements of a surgical team during a C-section surgery.

5.2 Setting

A surgical team in a typical C-section consists of a nursing team (two circulating nurses and one scrub nurse), a pediatric team (one pediatrician and assistant), an anesthesia team (an anesthesiologist sometimes with an assistant), and an obstetrical team (one obstetrician, one obstetrical resident, and one medical student). Figure 66 shows the hierarchical structure of the surgical team.

Nursing responsibilities revolve primarily around managing operating room activities. The scrub nurse ensures the safe use of surgical equipment and monitors the sterile field. The first circulating nurse (circ-1) is responsible for assisting everyone in the Operating Room (OR) to create a safe and comfortable environment. The second circulating nurse (circ-2) monitors the patient's emotional and physical status, assists the anesthesiologist in pain management, and the pediatricians in newborn evaluation. The obstetrician is the surgical lead on the team.

In this chapter, I summarize the findings of my 31 hour observations at the birthing unit from the time that a patient was admitted to the birthing unit to the time that she was transferred to the recovery room with her baby. This includes three hours of observation of two non-emergency C-section surgeries. Observational data collected from the OR has been verified by the nurses of the Labour and Delivery Department. Table 38 summarizes characteristics of the C-section surgical teams of my observation.

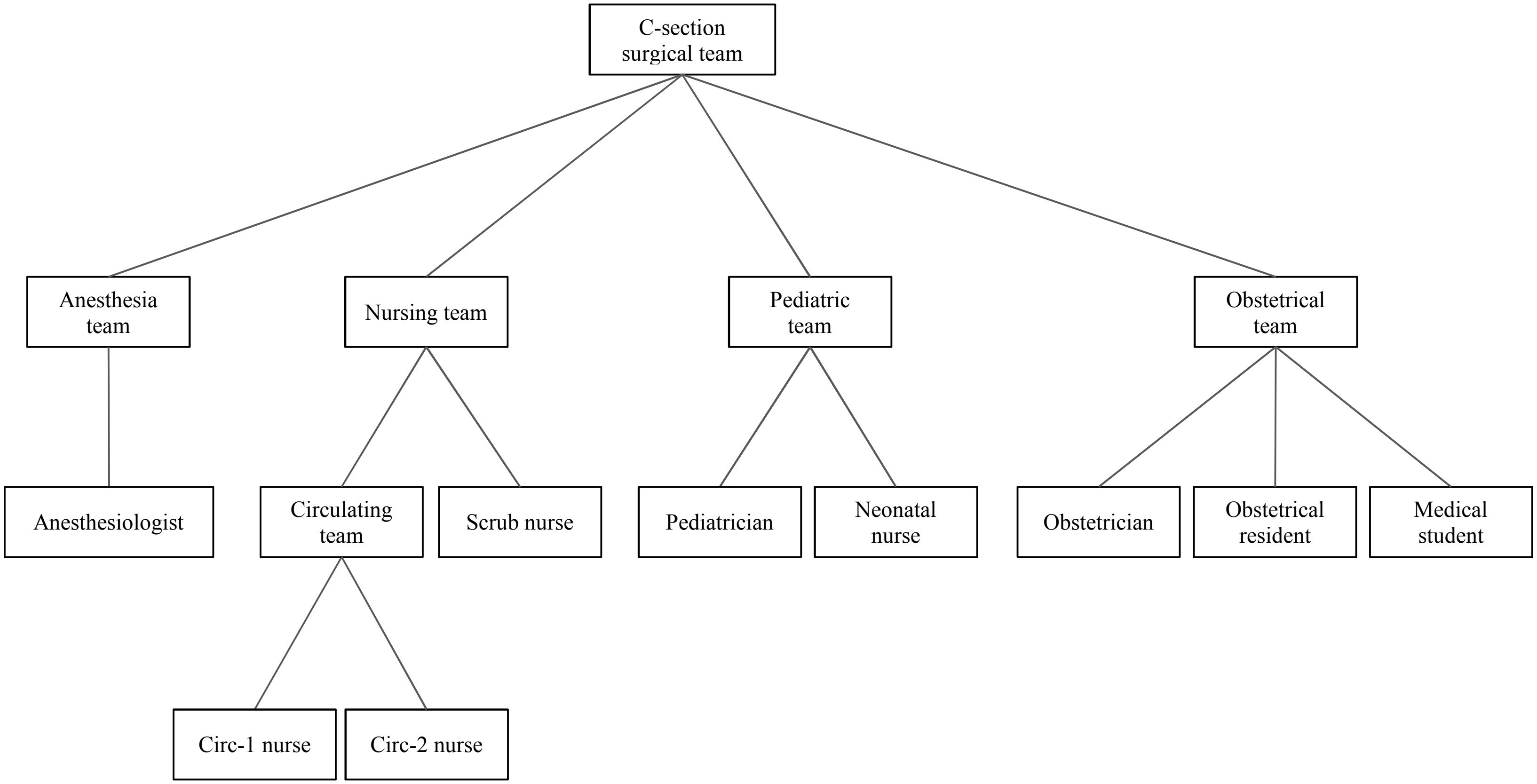


Figure 66. Team Structure for the Surgical Team.

Table 38: Application Characteristics.

Characteristics	C-section surgery at The Ottawa Hospital
Observation period	Team lifecycle: 45-90 min in the OR Observation period: 2 weeks (November and December 2010)
Team size	Small OR team (team size: 7-10). Different surgical teams, but with the same set of roles and responsibilities.
Team structure	The OR team includes four sub teams of anesthesia, obstetrical, pediatric, and nursing team.
Team lifecycle	This surgical team was at the performing stage of Tuckman's (1965) team development model.
Expertise level	Highly skilled physicians in an emergency. Novice to expert professionals in a normal surgery.

5.3 Comparison between Work Domain Analysis and Team Work Domain Analysis

In this section, I conduct a traditional WDA and compare the analysis with the findings of a Team WDA. My focus, in this section, is on the analysis of the OR interactions at the work-domain level. To demonstrate the value of the extended models, I will examine the abstraction hierarchy of the surgical team and will discuss how the hierarchy can be extended to the collaboration tables and abstraction wheels.

5.3.1 Basic Work Domain Analysis

Figure 67 shows the basic work-domain model for the C-section surgical team. A typical WDA examines fundamental behaviour-shaping constraints, such as the purpose of the work, values, priorities, processes, and resources.

At the functional-purpose level, the AH elements correspond to the work-domain purposes. There are four purposes identified for the surgical team: (1) maintaining patient's health, (2) maintaining baby's health, (3) pain management, and (4) baby delivery.

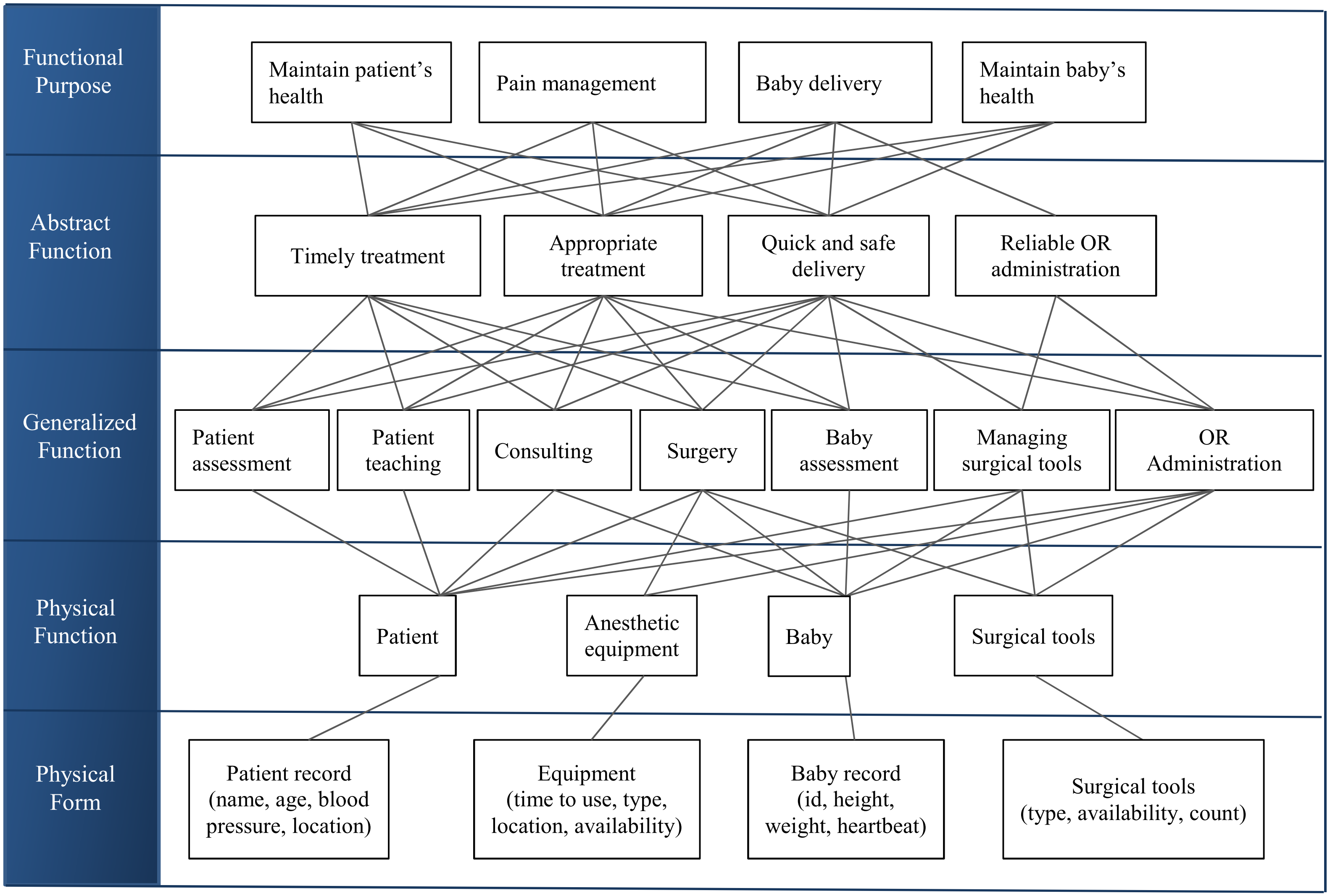


Figure 67. Basic Work-Domain Model for the Surgical Team.

The AH elements at the abstract-function level correspond to the values, priorities, and principles. There are four main values and priorities that the surgical team should provide: (1) timely treatment, (2) appropriate treatment, (3) quick and safe delivery, and (4) reliable OR administration. The structural links of the AH going from the abstract-function level to the level above correspond to the why-how relation between the purposes of the work domain and the values and priorities.

The main processes for the surgical team are described at the generalized-function level. The seven main processes in the C-section may include: (1) patient assessment, (2) patient teaching, (3) consulting, (4) surgery, (5) baby assessment, (6) managing surgical tools, and (7) OR administration. The structural links of the AH going from the generalized-function level to the level above indicate the work-domain processes to meet the priorities.

The physical work-domain resources are identified at the physical-function level. The patient, baby, surgical tools, and anesthetic equipment, are examples of the physical elements of the work domain. The structural connections of the AH going from the physical-function level to the generalized-function level indicate the physical resources that are involved in completing the processes.

The physical characteristics of the work-domain resources are identified at the final level of the AH. The structural links of the AH going from the physical-form level to the physical-function level correspond to the physical characteristic of the work-domain resources. Although the basic work-domain model can be used to identify the work-domain elements, it does not provide guidance on identifying which work-domain elements are shared and by whom.

5.3.2 Responsibility Maps and the Corresponding Collaboration Tables

Figure 68 shows the responsibility maps for the surgical team. The complexity of the overlap is managed by replacing individuals' decision spaces with the decision spaces of the sub-teams.

As discussed in Chapter 3, the overall objective of the Team WDA is to provide models and techniques for understanding the shared or individual purposes; values, priorities, and principles; processes; as well as the boundary objects. While this information can be derived from the responsibility maps, a table format may be clearer. The Collaboration Tables (CTs) provide a table format for examining the overlaps between the decision spaces of the team members. Tables 39-42 show the CTs for the surgical team.

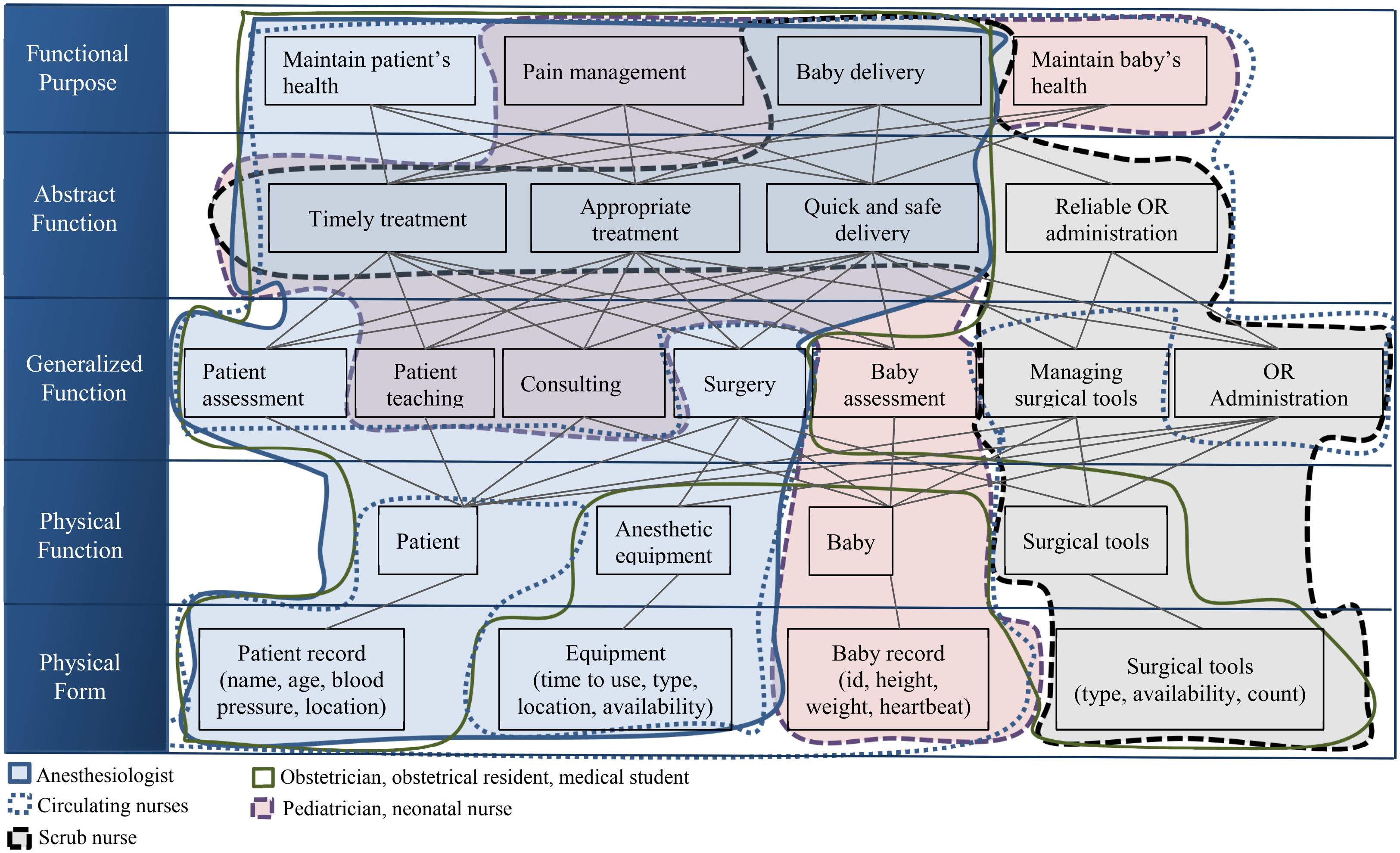


Figure 68. Responsibility Maps for the Surgical Team.

Table 39: Collaboration Table at the Functional-Purpose Level for the Surgical Team.

	Anesthesia team	Nursing team		Obstetrical team			Pediatric team	
Functional purpose	Anesthesiologist	Circulating nurses	Scrub nurse	Obstetrician	Obstetrical resident	Medical student	Pediatrician	Neonatal nurse
Maintaining patient's health	X	X		X	X	X		
Pain management	X	X		X	X	X	X	X
Baby delivery	X	X	X	X	X	X	X	X
Maintaining baby's health		X					X	X

Table 40: Collaboration Table at the Generalized-Function Level for the Surgical Team.

	Anesthesia team	Nursing team		Obstetrical team			Pediatric team	
Generalized function	Anesthesiologist	Circulating nurses	Scrub nurse	Obstetrician	Obstetrical resident	Medical student	Pediatrician	Neonatal nurse
Patient assessment	X	X		X	X	X		
Patient teaching	X	X		X	X	X	X	X
Consulting	X	X	X	X	X	X	X	X
Managing surgical tools			X					
OR Administration		X	X					
Surgery	X		X	X	X	X		
Baby assessment		X					X	X

Table 41: Collaboration Table at the Abstract-Function Level for the Surgical Team.

	Anesthesia team	Nursing team		Obstetrical team			Pediatric team	
Abstract function	Anesthesiologist	Circulating nurses	Scrub nurse	Obstetrician	Obstetrical resident	Medical student	Pediatrician	Neonatal nurse
Timely treatment	X	X	X	X	X	X	X	X
Appropriate treatment	X	X	X	X	X	X	X	X
Quick and safe delivery	X	X	X	X	X	X	X	X
OR Administration		X	X					

Table 42: Collaboration Table at the Physical-Function Level for the Surgical Team.

	Anesthesia team	Nursing team		Obstetrical team			Pediatric team	
Physical function	Anesthesiologist	Circulating nurses	Scrub nurse	Obstetrician	Obstetrical resident	Medical student	Pediatrician	Neonatal nurse
Patient	X	X	X	X	X	X		
Surgical tools			X	X	X	X		
Anesthetic equipment	X							
Baby		X					X	X

As in the AH, a typical CT examines the work-domain elements in five different levels: (1) functional purpose, (2) abstract function, (3) generalized function, (4) physical function, and (5) physical form. At the functional-purpose level, Table 39 indicates the roles and responsibilities that contribute to the work-domain purposes. In the OR, the responsibilities of the pediatric team revolve around taking care of the baby right after delivery; whereas, the obstetrical team and the anesthesiologist are mostly responsible for maintaining the mother's health.

At the abstract-function level, Table 41 identifies the shared or individual values, principles, and priorities. The surgical team is expected to quickly and safely take the baby out and provide an appropriate timely treatment for both the patient and the newborn. The nursing team provides a smooth surgery by facilitating the OR administration.

At the generalized-function level, Table 40 describes the overlap between the processes that each team member is responsible for. Everyone on the surgical team contributes to the patient teaching and consulting. The pediatric team is responsible for baby assessment and the obstetrical team is responsible for the surgery. A detailed understanding of the shared processes in the team may lead to a better understanding of the boundary objects and the way the OR crew exchange information during a C-section surgery. The corresponding physical-function level CT, shown in Table 42, indicates the boundary objects for the surgical team.

5.3.3 Abstraction Wheels

Figure 69 shows a graphical illustration of the shared work-domain elements within the sub-teams of the C-section scenario. Each team is represented by a wheel with each team member comprising a portion of the wheel. The inner circles of each wheel represent the corresponding AH level in a WDA. The most inner circle represents the functional-purpose level and the outer circle represents the physical-form level.

While the collaboration tables provide a representation of the shared work-domain elements, the abstraction wheel offers a tool for visualizing the shared elements. To manage the complexity of the wheels, the individual circulating nurses are replaced with the circulating team.

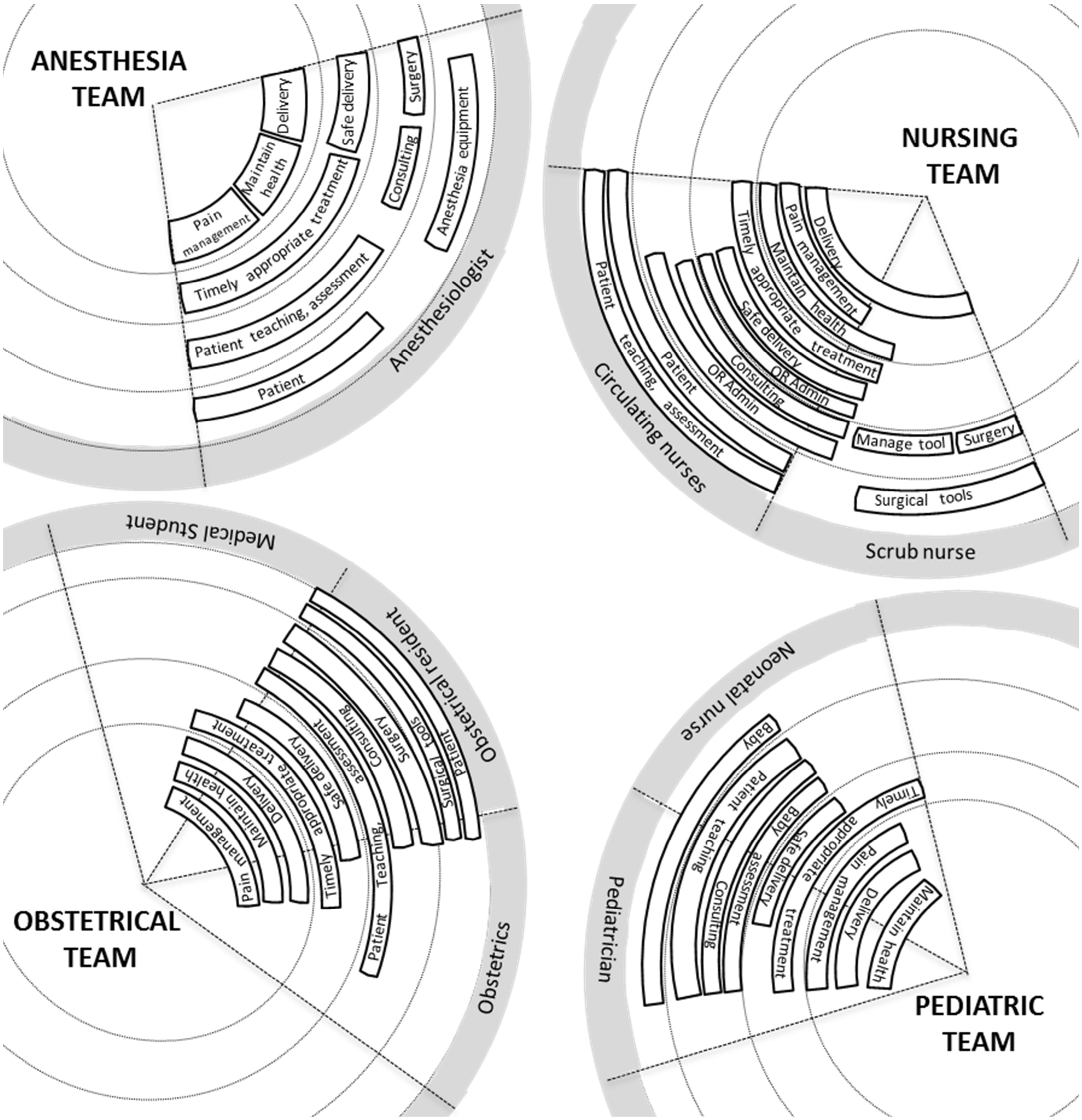


Figure 69. The Abstraction Wheel for the Surgical Team.

As in Figure 69, the abstraction wheel provides a graphical illustration of the team structures and the shared work-domain elements. In an emergency, the team structure may be changed and additional people may join the OR team. Later, in the strategies section, I will discuss team behaviours in a variety of situations. Table 43 describes the characteristics of the inter-team interactions at the work-domain level.

Table 43: The Abstraction-Wheel Table for the Surgical Team.

Teams involved	Abstraction level	Shared element	Type
- Anesthesia team - Nursing team - Obstetrical team - Pediatric team	Functional purpose	- Pain management - Baby delivery	Shared purpose
- Anesthesia team - Circulating team - Obstetrical team	Functional purpose	Maintaining patient's health	Shared purpose
- Circulating team - Pediatric team	Functional purpose	Maintaining baby's health	Shared purpose
- Anesthesia team - Nursing team - Obstetrical team	Abstract function	- Timely treatment - Appropriate treatment - Safe delivery	Shared value
- Nursing team	Abstract function	Reliable OR administration	Shared value
- Anesthesia team - Circulating team - Obstetrical team	Generalized function	Patient assessment	Shared process
- Anesthesia team - Circulating team - Obstetrical team - Pediatric team	Generalized function	Patient teaching	Shared process
- Anesthesia team - Nursing team - Obstetrical team - Pediatric team	Generalized function	Consulting	Shared process
- Nursing team	Generalized function	OR administration	Shared process
- Nursing team - Obstetrical team	Generalized function	Surgery	Shared process
- Circulating team - Pediatric team	Generalized function	Baby assessment	Shared process
- Anesthesia team - Nursing team - Obstetrical team	Physical function	Patient record	Boundary object
- Nursing team - Obstetrical team	Physical function	Surgical tools	Boundary object
- Circulating team - Pediatric team	Physical function	Baby assessment equipment	Boundary object
- Pediatrician - Neonatal resident	Physical function	Baby record	Boundary object

5.3.4 Summary of the Findings

As discussed, the basic WDA does not provide sufficient guidance for the discussion of the shared work-domain elements. The responsibility map as an extension to the basic WDA provides a visualization of the overlaps between the decision spaces of the surgical team. The complexity of the overlap can be managed by replacing individuals' decision spaces with the decision spaces of the sub-teams. Table 44 provides a summary of the shared work-domain elements resulted from conducting the basic WDA and the Team WDA.

From a teamwork perspective, the goal in using a WDA is to create a set of models for the team that describe the shared values, purposes, and priorities of teamwork. However, the basic WDA may not provide sufficient guidance on extracting which work-domain elements are shared and by whom. Team WDA could address this challenge and provide models and techniques for analyzing shared or individual purposes; values, priorities, and principles; processes; and physical work-domain resources. For example, the discussion of the shared or individual processes in Team WDA can identify the interdependencies between the processes, a view that has not been addressed in WDA. Shared processes during a C-section surgery require tight coordination between the OR crew. Thereby, the design specification should suggest an effective solution to support this tight coordination. For example, shared displays may be one solution for exchanging information in the OR.

In the following section, I will explore the collaborative requirements of the surgical team at the control-task level.

Table 44: Summary of the Shared Work-Domain Elements for the Surgical Team.

Comparison factors	Team WDA	Basic WDA
Functional-purpose level	Shared purposes: - Maintaining patient's health is the shared purpose between the anesthesiologist, circulating nurse, and the obstetrical team. - Maintaining baby's health is the shared purpose between the circulating nurses and the pediatric team. - Pain management is shared by everyone except the scrub nurse. As the scrub nurse is only responsible for managing surgical tools in the OR. -Everyone on the tea m contribute to baby delivery.	Purposes: - Maintaining patient's health - Maintaining baby's health - Pain management - Baby delivery
Abstract-function level	Shared values, priorities, and principles: - Reliable OR administration is the shared value between the nursing team. - Everyone on the EB team is expected to contribute in a timely treatment, appropriate treatment, and quick and safe delivery.	Values, priorities, and principles: - Timely treatment - Appropriate treatment - Quick and safe delivery - Reliable OR administration
Generalized-function level	Shared processes: - Patient assessment is the shared process between the obstetrical team, anesthesiologist, and the circulating nurses. - Everyone in the OR except the scrub nurse share the patient teaching process. Since the scrub nurse is responsible for managing the surgical tools, he or she often does not have interactions with the patient. - Surgery is the shared process between the obstetrical team, the scrub nurse, and the anesthesiologist. - Everyone on the surgical team contributes to the consulting process. - Baby assessment is the shared process between the pediatric team and the circulating nurses. - Managing surgical tools is an individual process performed by the scrub nurse. - OR administration is the shared process in the nursing team.	Processes: - Patient assessment - Patient teaching - Consulting - Surgery - Baby assessment - Managing surgical tools - OR administration
Physical-function level	Boundary objects: - Patient is the boundary object shared between the anesthesiologist, nursing team, and obstetrical team. - Surgical tools are shared by the scrub nurse and the obstetrical team. - Anesthetic equipment is not shared. The anesthesiologist is the only person in the OR that uses that.	Physical work-domain resources: - Patient - Baby - Surgical tools - Anesthetic equipment

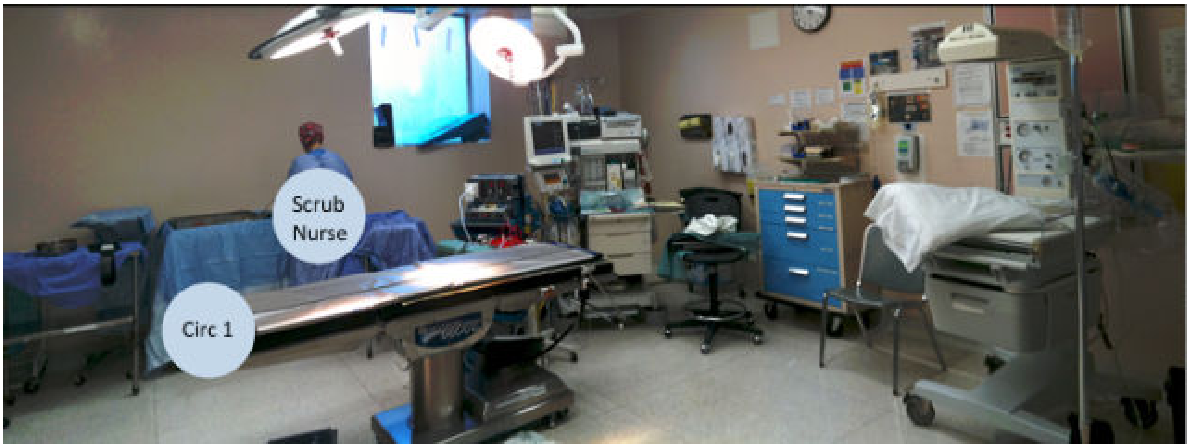
5.4 Comparison between Control Task Analysis and Team Control Task Analysis

In this section, the results of conducting a traditional ConTA and a Team ConTA for the analysis of the collaborative requirements of the surgical team are discussed. In the following section, I will start with exploring the decision ladders to identify the control tasks for the surgical team and, then, I will compare the findings with the results of decision wheels and the extended CATs for teams.

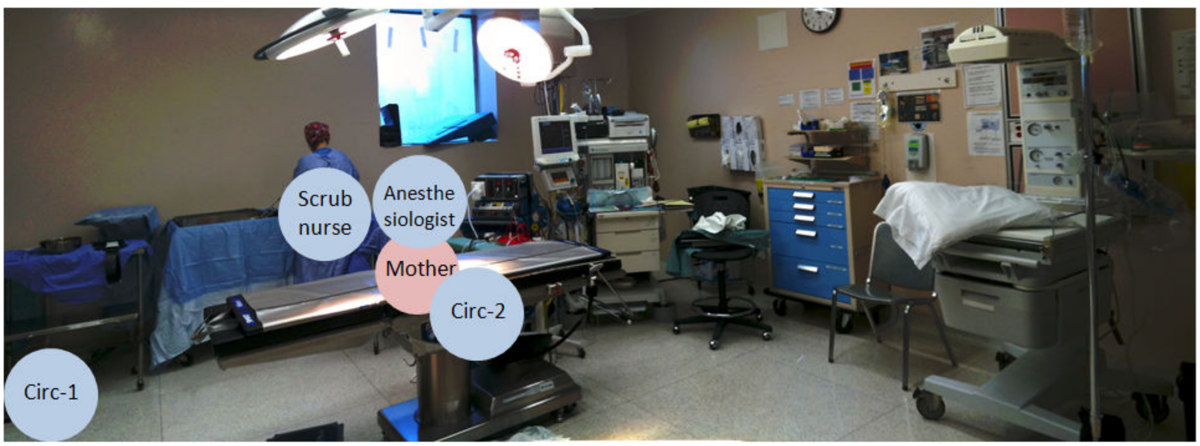
5.4.1 Basic Control Task Analysis

The overall objective in using a regular ConTA is to identify the constraints on what needs to be done. The regular ConTA suggests using the decision ladder as a template of generic information-processing activity to identify the control requirements for each application domain. Vicente (1999) analyzes activities as a set of control tasks at different operating modes. These operating modes correspond to different situations in Naikar et al.'s (2006) explanation of ConTA.

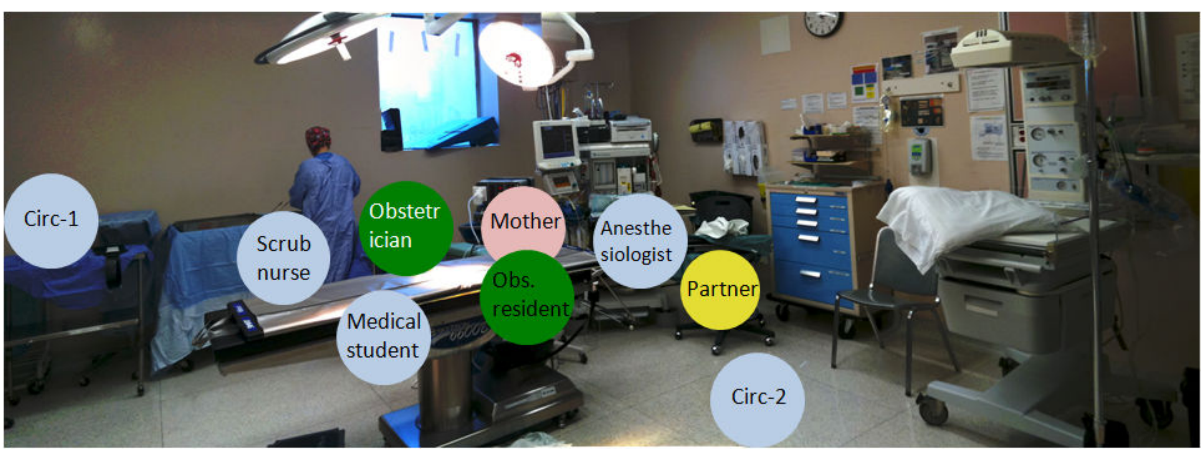
In the surgical team of my observation, activities could be analyzed within six situations: (1) final OR setup, (2) patient preparation before the operation, (3) pre-delivery operation, (4) newborn evaluation, (5) post-delivery operation, and (6) patient transfer to the recovery room. During the final OR setup, the nursing team finishes the final checking in the OR to make sure everything is ready for the surgery. The scrub nurse prepares the surgical tools and the circulating nurses check the OR forms, and the required equipment for the surgery. During the patient preparation, the patient is transferred to the OR and the circulating team with the help of the anesthesiologist prepares the patient for the operation. The scrub nurse continues to prepare the surgical tools; the circulating nurses explain the operation process to the patient; and the anesthesiologist is available to sedate and anesthetize the patient (i.e., epidural injection). Since I was not authorized to take pictures and record videos in the OR, I recorded the location of the OR crew every few minutes to keep track of what was going on during the surgery. Figure 70 shows the location of the OR crew during different situations. This approach may not provide an accurate analysis of the events, but for the purpose of this work, it is sufficient to represent who was involved with different stages of the surgery.



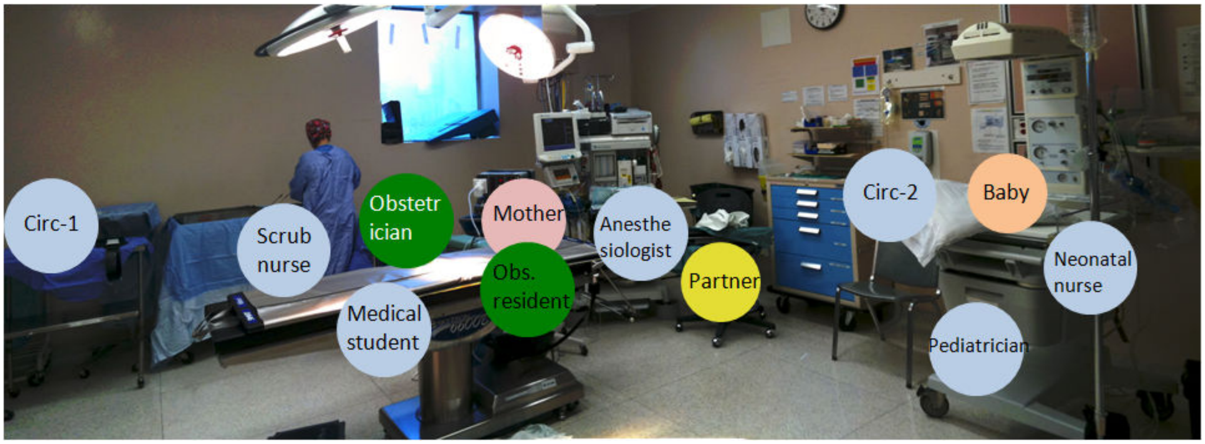
(a) Final OR setup



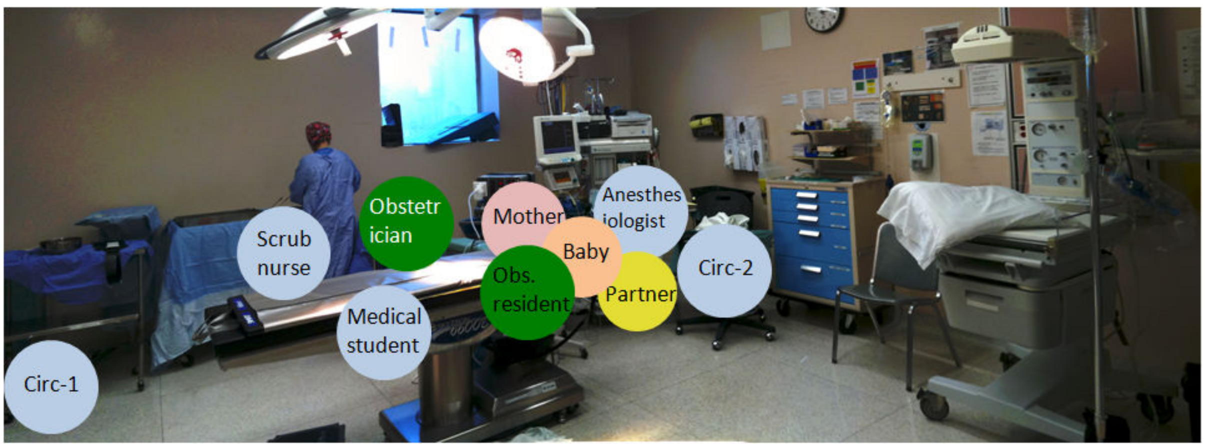
(b) Patient preparation before the operation



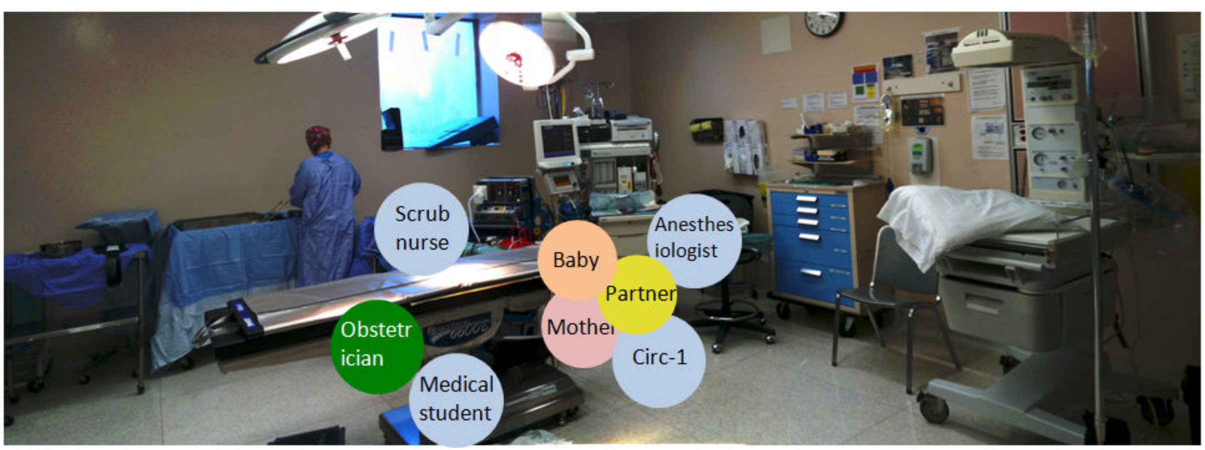
(c) Pre-delivery operation



(d) Newborn evaluation



(e) Post-delivery operation



(f) Patient transfer to the recovery room

Figure 70. Various Collaborative Situations Observed within the Operating Room.

Once the patient is ready for the operation, the obstetrical team arrives. At this point, the circulating nurses help the obstetrical team to get ready for the operation. The scrub nurse continues to work on the preparation of the surgical tools. The anesthesiologist talks to the patient and constantly monitors the heartbeat, consciousness, and blood pressure of the patient. Once the obstetrical team is ready, they start the surgery with a vertical incision on the skin. One of the circulating nurses fills out the OR forms and calls the nursing station to report the start of the surgery. This situation is the pre-delivery operation.

A few minutes after the start of the surgery, the pediatric team arrives. Once the baby is out, the pediatric team starts evaluating the newborn to make sure that the baby is healthy and does not need special care. This situation remarks newborn evaluation.

During the post-delivery operation, the pediatric team leaves the OR and the obstetrical resident finishes the surgery.

When the operation is done, the patient with her baby is transferred to the recovery room. This is the last situation, the patient transfer.

Vicente (1999) recommends conducting a separate ConTA for each of these situations (i.e., modes) to identify the information requirements associated with that situation. For the sake of clarity, I conducted a regular ConTA for one of these situations, newborn evaluation. The reason I chose this situation for the analysis of the findings is that the newborn evaluation situation is the only period that the whole surgical team is available in the OR.

The control tasks during the newborn evaluation can be discussed with respect to the patient and the newborn. After the baby delivery, the responsibilities the obstetrical team and the anesthesiologist revolve around patient care and finishing the surgery; whereas, the pediatric team is responsible for ensuring that the newborn does not need special care. Two main control tasks can be identified here: (1) surgery for the obstetrical team, anesthesiologist, and scrub nurse; (2) baby assessment for the pediatric team and circulating nurses. In this section, I explore a regular ConTA for baby assessment. The decision ladder for baby assessment is shown in Figure 71. Table 45 shows a tabular summary of the analysis and describes the content of the information-processing activities, states of knowledge, and shortcuts identified in the decision ladder in Figure 71.

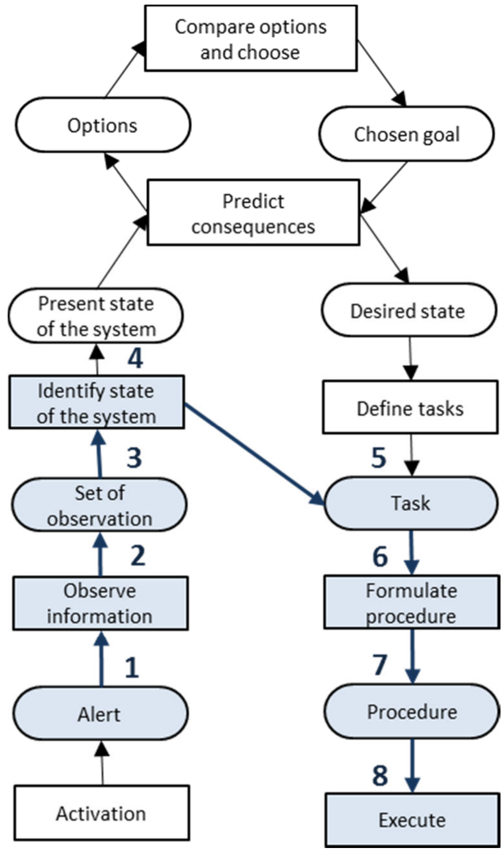


Figure 71. Decision Ladder for Baby Assessment in a Normal Situation.

The baby's arrival is a signal for the pediatric team to immediately start the assessment process (Step #1 in Table 45). The pediatric team takes the baby to conduct a set of initial measurements and collect the required information for baby assessment (Step #2). The outcome of this activity is the results of the set of measurements (Step #3). Based on the collected information, the pediatric team needs to identify whether the baby is healthy or the baby needs special care (Step #4).

In a normal situation, baby assessment is fairly straightforward. When the baby is healthy, the experienced pediatric team is aware of the set of tasks to document the results of baby assessment. This shortcut is represented with a shunt from the state identification to the task state (Step #5) followed by a procedure formulation to identify a sequence of actions to perform those tasks (Step #6). For example, the pediatric team is expected to fill out and sign the OR forms in order to report the baby's information. The outcome of this activity is a sequence of actions to perform (Step #7). After that, the pediatric team and the circulating nurses are ready to implement the actions (Step #8).

Table 45. A Summary of the ConTA for Baby Assessment in a Normal Situation.

Step #	Description	Ladder code	Abstraction level
1	Baby has arrived	Alert	Physical function
2	Collect the required information for baby assessment	Observe	Generalized function
3	A set of measurements	Set of observation	Physical form
4	Identify whether the baby needs special care	Identify state of the system	Generalized function
5	What needs to be done in order to document the baby's health status	Task	Generalized function
6	Formulate a sequence of actions to document the baby's health parameters	Formulate	Physical function
7	A list of steps	Procedure	Physical function
8	Complete the steps, such as filling out the OR forms	Execute	Physical form

In an emergency situation, there is no direct link between the state identification and the list of tasks. Figure 72 shows the decision ladder in case of an emergency. Table 46 shows a tabular summary of the analysis and describes the content of the information-processing activities, states of knowledge, and shortcuts identified in the decision ladder in Figure 72.

In the birthing unit of my observation, *Code 222* indicates the emergency situation for the baby. *Code 222* in an emergency code in the hospital that indicates the breathing problem for the baby right after the birth. In case of a *Code 222*, all of the on call pediatricians are expected to be present in the OR within two minutes.

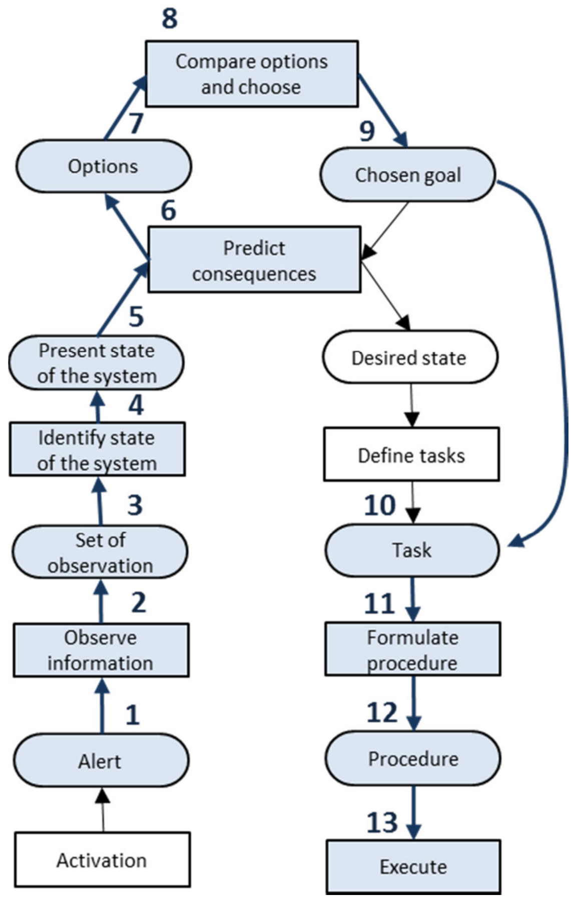


Figure 72. Decision Ladder for Baby Assessment in Emergency.

The pediatric team should identify the reason for the emergency call (Step #5) and, then, identify a set of options to deal with the situation (Step #6). The outcome of this activity is a set of options to deal with the situation (Step #7). For example, in some situations, the baby needs to be immediately transferred to the MRI unit.

When the emergency pediatric team is available in the OR, the pediatric team compares the options with the emergency crew and decides on the required special care for the baby (Step #8). The outcome for this activity is the final decision on the required special care (Step #9). The experienced pediatric team knows how to provide that special care. This direct link is shown as a leap between the chosen goal and the task state (Step #10). The rest of the steps to perform the tasks are similar to the decision ladder in a normal situation.

Table 46. A Summary of the ConTA for Baby Assessment in Emergency.

Step #	Description	Ladder code	Abstraction level
1	Baby is out	Alert	Physical function
2	Collect the required information for baby assessment	Observe	Generalized function
3	A set of measurements	Set of observation	Physical form
4	Identify whether the baby needs special care	Identify state of the system	Generalized function
5	The reason that the baby requires a special care	Present state of the svstem	Abstract function
6	Identify what sort of special care is required	Predict consequences	Abstract function
7	A set of options	Options	Abstract function
8	Consulting among the emergency crew and decide on the best option	Compare options and choose	Abstract function
9	The special care needed	Chosen goal	Abstract function
10	What needs to be done to provide that special care	Task	Physical function
11	Formulate a list of actions for that special care	Formulate	Physical function
12	A list of actions	Procedure	Physical function
13	Complete the actions and provide the special care	Execute	Physical form

The pediatricians in the emergency pediatric team are often experienced pediatricians to ensure an immediate reliable response to the emergency situation. In the worker competencies section, I will discuss the expertise level of the surgical team.

Naikar et al. (2006) recommend the use of CAT for analyzing work functions in various situations. They suggest an analysis of activities in terms of a set of recurring work situations to deal with and a set of work functions to perform. Naikar et al. (2006) argue that the work situations can be mapped to the Vicente's definition of operating modes. With respect to this approach, the activities in the surgical teams can be discussed in six situations: (1) final OR setup, (2) patient preparation before the operation, (3) pre-delivery operation, (4) newborn evaluation, (5) post-delivery operation, and (6) patient transfer to the recovery room. Figure 73 shows the basic CAT for the surgical team. Work situations are shown along the horizontal axis and work functions are shown along the vertical axis. The circles indicate the work functions and the horizontal lines connected to the circles indicate all of the work situations in which a work function can occur. Depending on the granularity of the analysis, different work functions at different levels of details may be identified for this analysis. In order to be consistent with the work-domain processes identified in a basic WDA, I discuss the activities within the five functions of (1) patient assessment, (2) baby assessment, (3) surgery, (4) managing surgical tools, and (5) patient teaching.

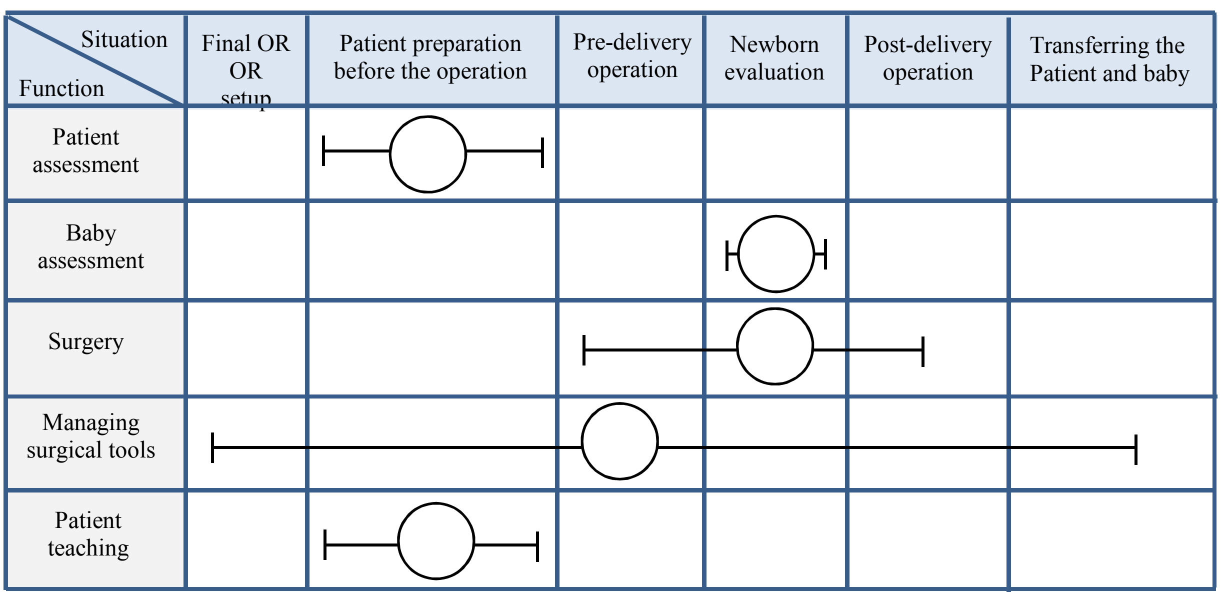


Figure 73. The Contextual Activity Template for the Surgical Team.

While the basic CAT provides a good illustration of the work functions in various situations, it does not represent the distribution of the shared work among the OR crew. In the discussion of Team ConTA models, I will demonstrate how an extended CAT can be used to understand the distribution of work functions in the surgical team.

5.4.2 Decision Wheels

While a decision ladder represents an examination of the control task for the whole team, a decision wheel may be used for an examination of the team interactions. In a decision wheel, the shared work flow and interactions between the team members are shown by the arrows that connect the decision ladders together. Figure 74 shows the decision wheels for newborn evaluation in a normal situation. The summary of the information-processing activities in baby assessment is already explained in Table 45. In this section, I focus on an examination of the connections between the ladders to explain where interaction happens. The decision-wheel table, shown in Table 47, represents the characteristics of the team interactions. Links are numbered and correspond to the numbers in Figure 74. For the sake of simplicity, the inactive decision ladder boxes, which are not involved within the decision making of the control task, are deleted from the diagram.

The wheel represents a team with each team member comprising a portion of the wheel. The decision ladder of each team member is drawn within the slices and the connections between the ladders represent the interactions between team members.

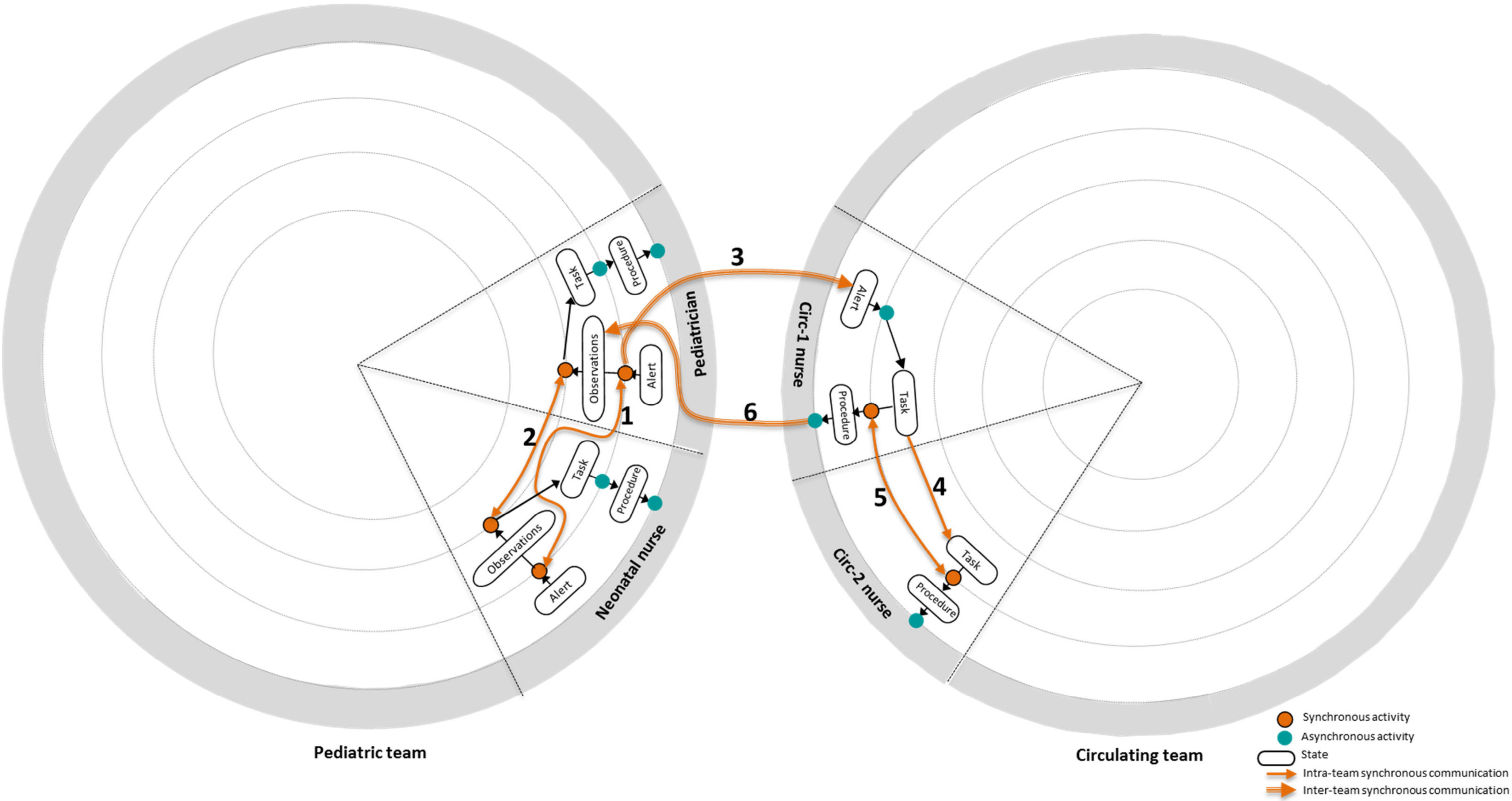


Figure 74. The Decision Wheel for Newborn Evaluation in a Normal Situation.

Table 47. The Decision-Wheel Table for Newborn Evaluation in a Normal Situation

					CSCW criteria (Reinhard et al, 1994)		
	Team members involved	Description	Abstraction level	Boundary Objects	Synchronicity	Communication channel	Distribution
1	- Pediatrician - Neonatal nurse	Baby assessment: collecting the required information for baby assessment	Generalized function	-Baby	Synchronous	Verbal, visual	-Pediatric team
2	- Pediatrician - Circ1 nurse	The pediatrician asks the circ-1 nurse to help the pediatric team in baby assessment	Physical function	-Baby -Patient	Synchronous	Verbal, visual, text	- Pediatric team - Circulating team
3	- Circ1 nurse - Circ2 nurse	Baby assessment: as part of the observation and baby assessment, the circ-1 nurse may ask for the help from the other circulating nurse	Generalized function	-Baby	Synchronous	Verbal, visual	- Circulating team
4	- Circ1 nurse - Circ2 nurse	The circulating nurses help each other to formulate a sequence of actions to complete the observations	Generalized function	-Baby	Synchronous	Verbal, visual, text	- Circulating team
5	- Circ1 nurse - Pediatrician	The Circ-1 nurse updates the pediatrician with the collected information	Physical function	-Baby	Synchronous	Verbal, visual, text	- Pediatric team - Circulating team
6	- Pediatrician - Neonatal nurse	Based on the results of the observations, the pediatric team identifies whether the baby needs a special care	Generalized function	-Baby	Synchronous	Verbal, visual, text	- Pediatric team
7	- Pediatrician - Neonatal nurse	The pediatric team works together to formulate a sequence of actions to document the baby's health parameters	Physical function	-Baby	Synchronous	Verbal, visual	- Pediatric team

Once the baby is arrived, the pediatric team starts the initial observation to make sure the baby is healthy (Link #1). For example, they check if the baby is comfortable with breathing. In some cases, the pediatrician asks the circulating nurses available in the OR to complete some measurements (Link #2), such the heartbeat, blood pressure, height, and weight of the baby. The pediatric team may also ask for some information about the history of the mother's health parameters. The circulating nurses share the observation task with the each other (Link #3) and, then, they plan the sequence of actions to complete that task (Link #4).

After completing the observation, the circ-1 nurse updates the pediatrician with the requested information (Link #5). Based on the results of the observation, the pediatric team needs to identify if the baby needs some special care (Link #6). In a normal situation, when the baby does not need special care, the pediatrician informs the neonatal nurse about what needs to be done (Link #7) and they plan for the sequence of actions for documenting the results of baby assessment.

In an emergency situation, more people are involved and the decision-making process, as summarized in Table 46, is different. In the strategies section, I will come back to this discussion to examine the team strategies and identify the team structure in an emergency situation. Table 48 provides a comparison between the control tasks identified by ConTA and Team ConTA.

Table 48: A Summary of the Comparison between ConTA and Team ConTA for the Surgical Team.

Comparison factors	Team ConTA	Basic ConTA
Operating modes/Situations	Operating mode/ situation: - Final OR setup - Patient preparation before the operation - Pre-delivery operation - Newborn evaluation - Post-delivery operation - Patient transfer to the recovery room	Operating mode/ situation: - Final OR setup - Patient preparation before the operation - Pre-delivery operation - Newborn evaluation - Post-delivery operation - Patient transfer to the recovery room
Control tasks/ information-processing activities	Control tasks for the Newborn evaluation mode: - Surgery - Baby assessment Information-activity processing for patient assessment (normal situation): - Collecting the required information for baby assessment. The pediatric team and both circulating nurses contribute to this activity - Identifying whether the baby needs special care. The pediatric team is responsible for performing this activity. - Formulating a list of steps for documenting the baby's health parameters. The pediatric team is responsible for performing this activity. - Completing the actions, such as filling out the forms	Control tasks for the Newborn evaluation mode: - Surgery - Baby assessment Information-activity processing for patient assessment (normal situation): - Collecting the required information for baby assessment - Identifying whether the baby needs special care - Formulating a list of steps for documenting the baby's health parameters - Completing the actions, such as filling out the forms

To summarize, I demonstrated how the decision wheels along with the corresponding tables could be used to understand the distribution of control tasks in the surgical team. The decision wheel provides an examination of team structure; inter-team and intra-team interactions; and the boundary objects. In the following section, I will explore the extend CAT for the analysis of the collaborative requirements of the surgical team.

5.4.3 Team Contextual Activity Template

While the decision wheels are a good representation to show how different parties interact on a single control task, the CAT is a good representation to show how individuals are involved in multiple control tasks in various situations. The basic CAT does not convey information about the team structure, team interactions, or boundary objects. In the following section, I will demonstrate how the extended CAT for teams can be used to understand the distribution of the work functions in the surgical team. Figure 75 shows the modified CAT for the surgical team.

Work situations are shown along the horizontal axis and roles and responsibilities are shown along the vertical axis. The ovals indicate the teamwork functions and the small solid circles attached to the teamwork functions indicate the surgical team members that contribute to that function. The extended CAT can be used to identify the team functions at each situation. For example, at the newborn evaluation situation, two team functions can be identified: (1) baby assessment, which is a shared function between the pediatric team and the circulating nurses; and (2) surgery, which is the shared function between the scrub nurse, anesthesiologist, and the obstetrical team. Table 49 shows a summary of the work functions between ConTA and Team ConTA. While the basic CAT does not convey information about the distribution of work functions in the surgical team, the extended CAT for teams can provide a representation of how individuals are involved in multiple control tasks in various situations.

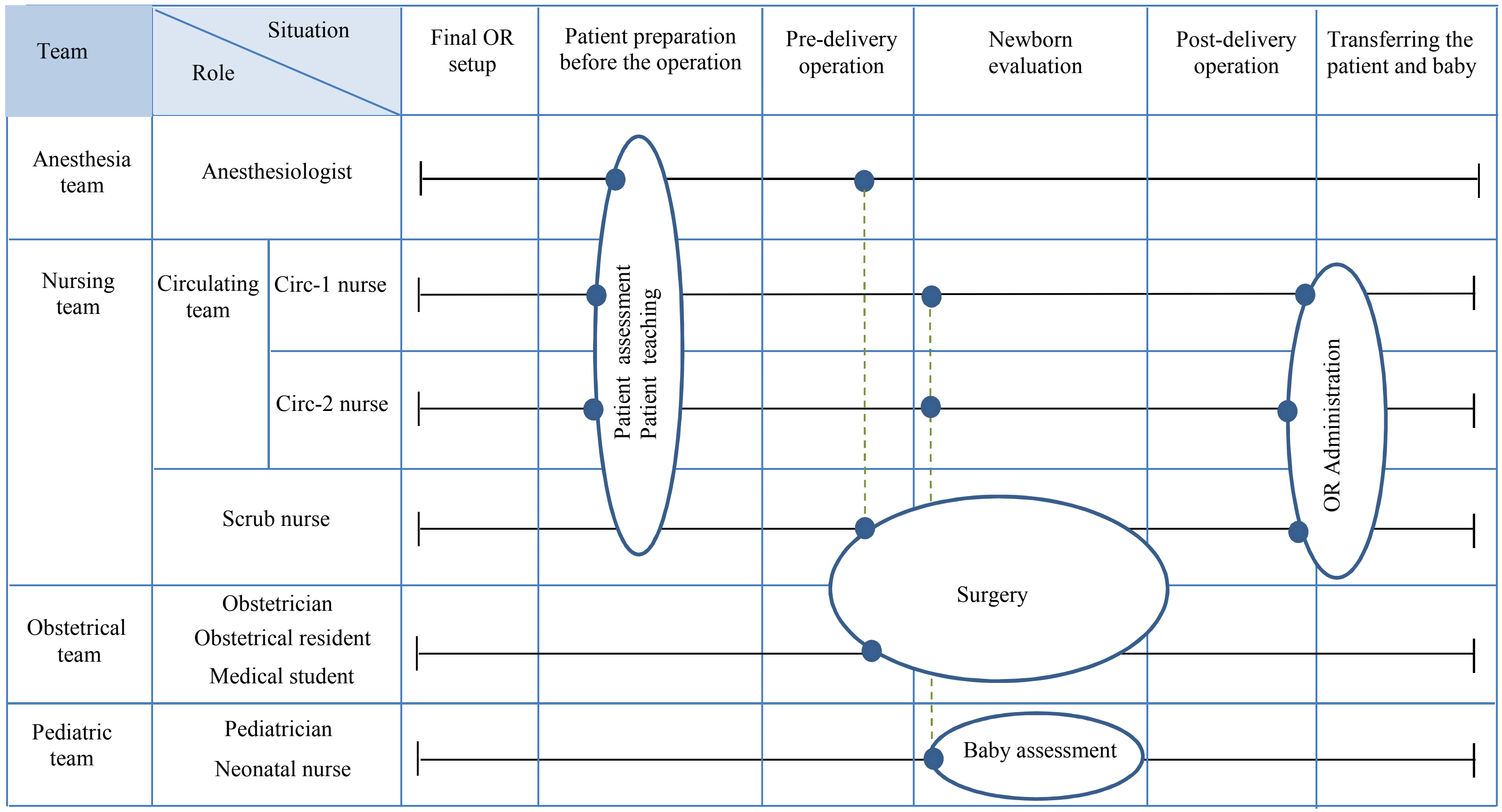


Figure 75. The Modified Contextual Activity Template to Represent Work Distribution in the Surgical Team.

Table 49: A Summary of the Work Functions Identified for the Surgical Team.

Comparison factors	Team ConTA	Basic ConTA
Work functions	<u>Team functions at the final OR setup situation:</u> At this situation, the scrub nurse manages the surgical tools and the circulating nurse checks the OR equipment. All the work functions at this situation are individual work functions. <u>Team functions at the patient preparation situation:</u> - Patient assessment is the shared function between the anesthesiologist and circulating nurses. - Patient teaching is the shared function between the anesthesiologist and the circulating nurses. - Managing surgical tools is the individual work function for the scrub nurse. <u>Team functions at the pre-delivery operation situation:</u> - Surgery is the shared function between the scrub nurse, anesthesiologist, and the obstetrical team. - Managing surgical tools is the individual work function for the scrub nurse. <u>Team functions at the newborn evaluation situation:</u> - Baby assessment is shared between the pediatric team and the circulating nurses. - Surgery is the shared function between the scrub nurse, anesthesiologist, and the obstetrical team. - Managing surgical tools is the individual work function for the scrub nurse. <u>Team functions at the post-delivery operation situation:</u> - Surgery is the shared function between the scrub nurse, anesthesiologist, and the obstetrical team. - Managing surgical tools is the individual work function for the scrub nurse. <u>Team functions at the patient transfer situation:</u> - Managing surgical tools is the individual work function for the scrub nurse. The rest of the team help to transfer the patient to the recovery room. Operation is done at this point.	<u>Work functions at the final OR setup:</u> - Managing surgical tools <u>Work functions at the patient preparation situation:</u> - Patient teaching - Patient assessment - Managing surgical tools <u>Work functions at the pre-delivery operation situation:</u> - Surgery - Managing surgical tools <u>Work functions at the new-born evaluation situation:</u> - Surgery - Managing surgical tools - Baby assessment <u>Work functions at the post-delivery operation situation:</u> - Surgery - Managing surgical tools <u>Work functions at the patient transfer situation:</u> - Managing surgical tools

5.4.4 Summary of the Findings

In this section, I explored a basic ConTA and the extended models of the Team ConTA for understanding the collaborative requirements of the surgical team. The goal of the basic ConTA is to identify the individual control tasks in the surgical team. However, it does not provide sufficient explanation of a team view, the shared cognitive processes, the shared control tasks, and the interdependencies between the tasks. The Team ConTA expands this objective to identify the team structure, team interactions, shared workflows, and boundary objects. Team ConTA models expand decision ladders into decision wheels and provide suggestions to revamp the CAT for the team analysis. Decision wheels leverage the analysis of control tasks in a basic ConTA to identify the required team interactions for the completion of the shared task. Table 50 provides a summary of the comparison between the team interactions that are identified by a regular ConTA and a Team ConTA. This information provided in Table 50 demonstrates the team interactions for patient assessment in a normal situation.

While the decision wheels are a good representation to show how the surgical team collaborate on a single control task, the CAT is a good representation to show how individuals are involved in multiple control tasks in various situations. The extended CAT can be used to identify the distribution of the work functions to different team members in a variety of the situations. Table 49 shows a summary of the work function identified for ConTA and Team ConTA.

In the following section, I will explore the collaborative requirements of the surgical team at the strategy level.

Table 50: A Summary of the Comparison between the Team Interactions Identified by ConTA and Team ConTA.

<table>
<tr><th>Comparison factors</th><th>Team ConTA</th><th>Basic ConTA</th></tr>
<tr><td>Inter-team interactions</td><td><u>Teams involved:</u>
Pediatric team- Circulating team

<u>Team members involved:</u>
Circ-1 nurse, pediatrician, neonatal nurse

<u>Description:</u>
To complete baby assessment, The pediatrician asks the circ-1 nurse to help the pediatric team in baby assessment. The pediatric team may also ask about some information about the history of the mother's health parameters. Once the circulating nurse finishes the baby assessment, the circ-1 nurse updates the pediatrician with the collected information

<u>Boundary object:</u>
Baby, patient

<u>Synchronicity:</u>
Synchronous

<u>Abstraction level:</u>
Physical function

<u>Communication channel:</u>
Verbal, visual, text</td><td>None.</td></tr>
<tr><td>Intra-team interactions</td><td><u>Pediatric team</u>
<u>Team members involved: Pediatrician, Neonatal nurse</u>
Description: To complete baby assessment, they help each other in collecting the required information for baby assessment. Then, based on the results of the observations, the pediatric team identifies whether the baby needs a special care. After that, they works together to formulate a sequence of actions to document the baby's health parameters
Boundary object: Baby
Type: Synchronous
Abstraction level: Generalized function, physical function

<u>Circulating team:</u>
<u>Team members involved: Circ-1 nurse, Circ-2 nurse</u>
Description: As part of the observation and baby assessment, the circ-1 nurse may ask for the help from the other circulating nurse. Then, they help each other to formulate a sequence of actions to complete the observations
Boundary object: Baby
Type: Synchronous
Abstraction level: Generalized function</td><td>None.</td></tr>
</table>

5.5 Comparison between Strategies Analysis and Team Strategies Analysis

In this section, I use information flow maps as a modeling tool to conduct a basic strategies analysis. In a typical StA, a strategies analysis is conducted to identify different ways to carry out the information-processing activities identified during a basic ConTA. In the basic ConTA section, I explored the decision ladders for baby assessment. In this section, I explore different strategies and the sequence of actions to perform a baby assessment.

5.5.1 Basic Strategies Analysis

During the basic ConTA, discussed in Table 45, two different control tasks were identified for a newborn evaluation: surgery, and baby assessment. For the sake of clarity, I focused on one of the control tasks and developed the ConTA and Team ConTA models for baby assessment. By following a basic ConTA, I identified four information-processing activities for baby assessment in a normal situation: collecting information for baby assessment, identifying whether the baby needs special care, formulating a sequence of actions for documenting the results of baby assessment, and completing the sequence of actions before leaving the OR. I described in the decision wheels that the pediatric team starts the initial observation to make sure the baby is healthy. Based on the results of the initial observations, the pediatric team identifies whether the baby needs some special care. In some cases in a normal situation, the pediatrician may ask the circulating nurses available in the OR to complete some baby assessments, such as measuring the heartbeat, blood pressure, height, and weight of the baby. The pediatric team may also ask some information about the history of the mother's health. The circulating nurses share the observation task with each other and plan for the sequence of actions to complete the measurements. Once the measurement is done, thecirc-1 nurse, as the coordinator in the circulating team, informs the pediatrician with the results of the measurements.

In an emergency situation, more people are involved and the decision-making process is different. In case of an emergency, all the on call pediatricians are expected to be present in the OR within two minutes. The pediatric team should identify the reason for the emergency call and, then, identify a set of options to deal with the situation. With the help of the emergency pediatric team, the paediatrician compares the options and decides about the required special care for the baby. Figure 76 shows the information flow map of the surgical team of my observation for baby assessment.

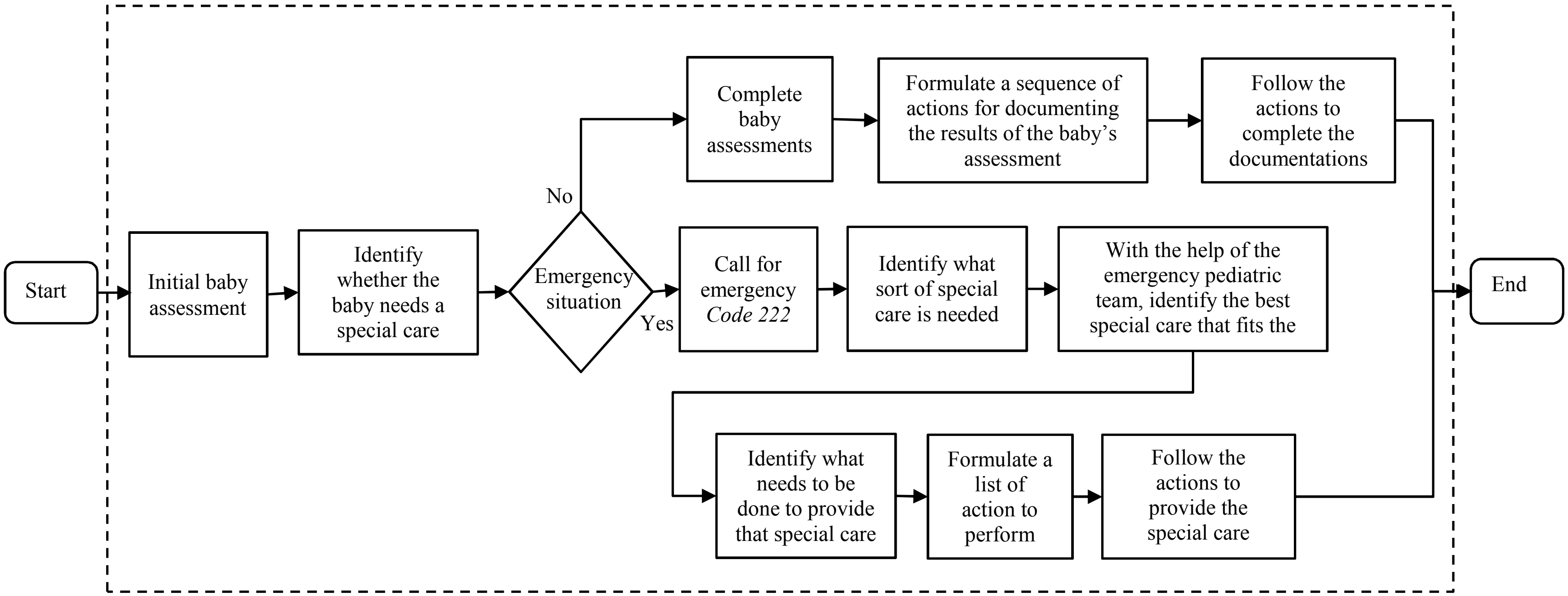


Figure 76. Information Flow Map for Baby Assessment.

The strategies at this level are categories. Vicente (1999) argues that the strategies identified at this stage should be instantiated by an operator for a particular situation. These instantiations, then, would represent a sequence of actions for each strategy. Although StA identifies various strategies that can be used by operators to perform the required control tasks, it leaves open the issue of who is responsible for performing the sequence of actions in each strategy. In the following section, I will demonstrate how the extended models of the Team StA can be used to identify the sequence of actions in a strategy and how different team members contribute to the execution of the strategies.

5.5.2 Operational Strategies

The value added by the operational strategies lies in understanding different ways to carry out the shared control tasks. Although the basic StA identifies various strategies that can be used by operators to perform the required control tasks, it leaves open the issue of who contributes to an execution of a strategy. An examination of the operational strategies can be used to reveal how an experienced team of operators work together into performing a shared task. In addition to the IFMs for an analysis of the operational strategies, an extended CAT is suggested to describe various strategies in terms of the factors, such as resource access, task priority, expertise level, and time constraints, that may influence strategy selection in a variety of situations.

As discussed in the Team ConTA, in a normal situation, the pediatric team and the circulating nurses contribute to baby assessment. In an emergency situation, instead of the circulating nurses, an experienced team of pediatricians come to the OR to help the pediatric team in baby assessment. Tables 51 and 52 show some sample strategies for baby assessment in a normal and emergency situation. The discussion of the operational strategies in Team StA is very similar to a regular StA, but the distribution of the actions to the team members is identified. Tables 53 and 54 summarize the operational strategies for baby assessment.

Table 51: The Modified Contextual Activity Template for Baby Assessment in a Normal Situation.

Team Function: Baby assessment							
Factors / Situation	Team Structure	Access to resources	Expertise level	Task priority	Procedures	Duration	Systems used
Normal	- Circ-1 nurse - Circ-2 nurse - Pediatrician - Neonatal resident	Limited access	Novice and expert	Medium	Once the baby is born, the pediatric team starts the initial observation to make sure the baby is healthy. In some cases, the pediatrician may ask the circulating nurses available in the OR to complete some baby assessments. Once the measurement is done, one of the circulating nurses updates the pediatrician with the collected data. Then, the pediatric team decides on the sequence of actions to finish the process.	It took around 10 minutes in my observations	Electronic patient record

Information flow map:

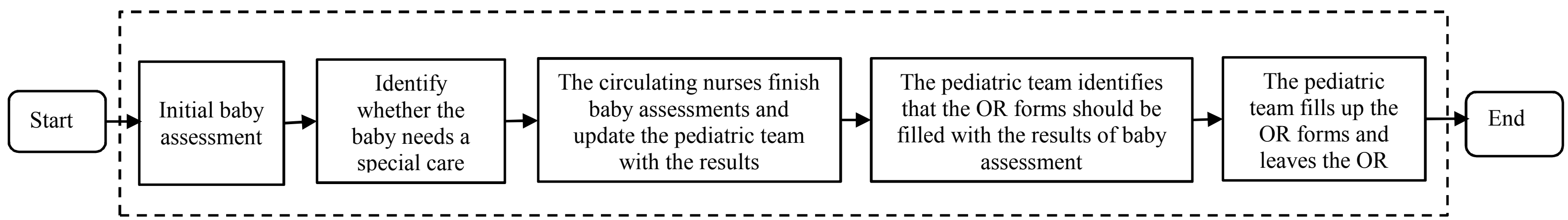


Table 52: The Modified Contextual Activity Template for Baby Assessment in Emergency.

Team Function: Baby assessment							
Factors / Situation	Team Structure	Access to resources	Expertise level	Task priority	Procedures	Duration	Systems used
Emergency *Code 222*	- Circ-1 nurse - Circ-2 nurse - Pediatrician - Neonatal resident - Emergency pediatric team	Full access to the resources	Mostly experienced	High	In case of an emergency, all the on call pediatricians are expected to be present in the OR within two minutes. The pediatric team should identify the reason for the emergency call and, then, identify a set of options to deal with the situation. With the help of the emergency pediatric team, the paediatrician compares the options and decides about the required special care for the baby.	Rapid response is required	Electronic patient record and the internal systems as needed

Information flow map:

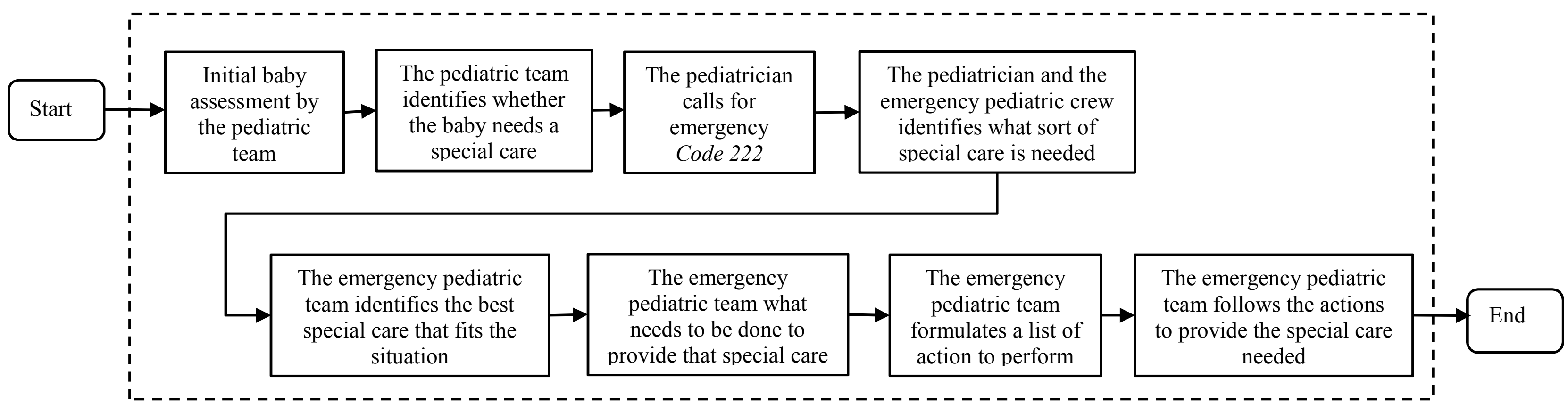


Table 53: A Summary of the Comparison between the Operational Strategies Identified by StA and Team StA in a Normal Situation.

Comparison factor	Team StA	Basic StA
Operational strategies	Team Structure: Circulating team: - Circ1 nurse - Circ2 nurse Pediatric team: - Pediatrician - Neonatal resident Expertise level: Experienced pediatrician, novice nurses Systems used: - Electronic patient record Duration: Around 10 minutes Category of actions: - Initial baby assessment - Identify whether the baby needs a special care - The circulating nurses finish the baby assessments and update the pediatric team with the results - The pediatric team identifies that the OR forms should be filled with the results of baby assessment - The pediatric team fills up the OR forms and leaves the OR	Procedure: Once the baby is born, the pediatric team starts the initial observation to make sure the baby is healthy. In some cases, the pediatrician may ask the circulating nurses available in the OR to complete some baby assessments. Once the measurement is done, one of the circulating nurses updates the pediatrician with the collected data. Then, the pediatric team decides on the sequence of actions to finish the process.

Table 54: A Summary of the Comparison between the Operational Strategies Identified by StA and Team StA in Emergency.

Comparison factor	Team StA	Basic StA
Operational strategies	Team Structure: Circulating team: - Circ1 nurse - Circ2 nurse Pediatric team: - Pediatrician - Neonatal resident Emergency pediatric team Expertise level: Experienced pediatricians, experienced and novice nurses Systems used: - Electronic patient record -Internal systems as needed Duration: Very quick Category of actions: - Initial baby assessment by the pediatric team - The pediatric team identifies whether the baby needs a special care - The pediatrician calls for emergency Code 222 - The pediatrician and the emergency pediatric crew identifies what sort of special care is needed - The emergency pediatric team identifies the best special care that fits the situation - The emergency pediatric team what needs to be done to provide that special care - The emergency pediatric team formulates a list of action to perform - The emergency pediatric team follows the actions to provide the special care needed	Procedure: In case of an emergency, all the on call pediatricians are expected to be present in the OR within two minutes. The pediatric team should identify the reason for the emergency call and, then, identify a set of options to deal with the situation. With the help of the emergency pediatric team, the paediatrician compares the options and decides about the required special care for the baby.

5.5.3 Coordination Strategies

Coordination strategies focus on an identification of the coordination structures, interaction patterns, and the management style. In the ConTA section, I reviewed the interactions for a baby assessment at the control-task level and, then, in the operational strategies section, I provided a sequence of actions for performing baby assessment. In this section, I will use the findings of the prior phases to identify the collaboration structures for baby assessment. As discussed in the Team ConTA, the pediatric team and the circulating team work together to complete baby assessment. Figure 77 shows the coordination structure of the surgical team for baby assessment in a normal situation. The OR crew are represented with solid black circles and the links between the circles represent interactions between the members. Inter-team interactions are shown with the dashed lines, and inter-team interactions are shown with the solid black lines. Different teams are represented by the dashed circles.

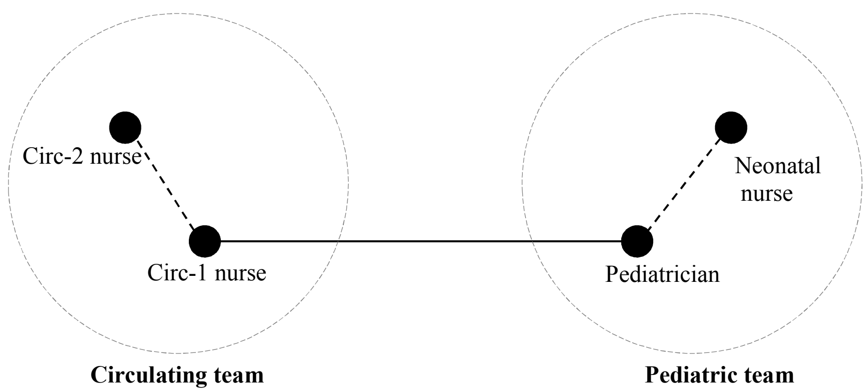


Figure 77. Coordination Structure for Baby Assessment in a Normal Situation.

The coordination structure for baby assessment in a normal situation is similar to the autocratic structure in the Rasmussen's (1989) explanation of the coordination structures. The circ-1 nurse is responsible for coordinating the activities of the circulating team and the pediatrician is responsible for coordinating the activities of the pediatric team.

In an emergency situation, the coordination structure is a combination of different structures. While the coordination structure inside the pediatric team and the circulating team can be interpreted as an autocratic structure, the interactions between the emergency pediatric team and the rest of the team is totally distributed. Figure 78 shows the coordination structure for baby assessment in case of an emergency. In case of an emergency, the pediatrician is the lead for the team. Thereby, at a higher level, the coordination structure for the whole baby assessment team in an emergency situation can be examined as an autocratic structure. This observation provides a good example of a variety of coordination structures for the sub-teams of a hierarchal team structure.

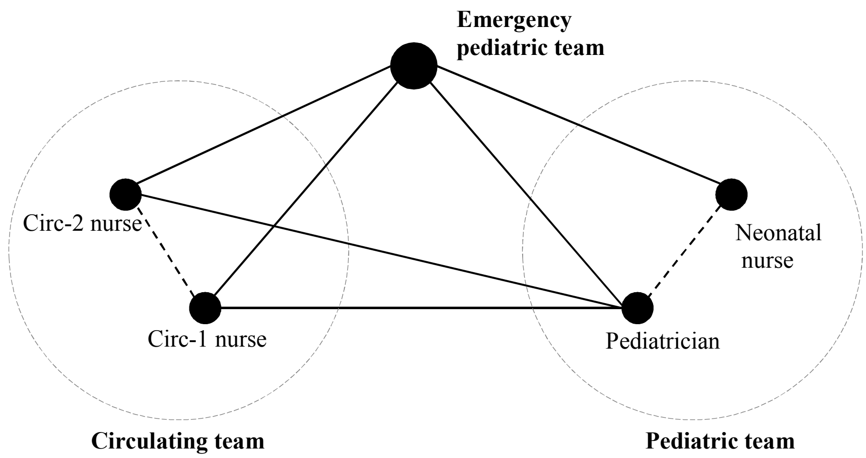


Figure 78. Coordination Structure for Baby Assessment in Emergency.

The hierarchical structure of the surgical team is shown in Figure 66. Although the team structure is relatively fixed, depending on the nature of the control task, the team may adapt different team structures. An analysis of the coordination structures within Team StA can be used to identify poor coordination structures and provides guidelines for redesigning the coordination structure and the management style. Table 55 provides a summary of the comparison between the coordination strategies identified by StA and Team StA.

Table 55: A Summary of the Comparison between the Coordination Strategies Identified by StA and Team StA.

Comparison factor	Team StA	Basic StA
Coordination strategies	Coordination structure for the newborn assessment at the newborn evaluation situation: Normal situation: - Pediatric team: autocratic structure - Circulating nurses: autocratic structure An emergency: - Pediatric team: autocratic structure - Circulating nurses: autocratic structure - Considering the pediatric as the team lead, the whole team can be examined as an autocratic structure - Considering the emergency pediatric team and connections with every other team members, it is a distributed structure.	None.

5.5.4 Structural Strategies

Structural strategies inherit, and build on, the work-domain constraints and can be revealed by the Team StA. By mapping the strategies to the work-domain model, Team StA can be used for examining the work-domain elements involved in each strategy, the various available strategy pathways, and team member contribution to the execution of that strategy. In the previous three sections, I discussed the operational strategies and the coordination structure for performing baby assessment in the newborn evaluation state. In this section, I discuss the strategy pathways for baby assessment to identify which WDA elements are involved in baby assessment. Figure 79 shows the strategy pathways for baby assessment. Discussion of the shared work-domain elements for the baby assessment strategies can be used to determine how different team members contribute to the strategy pathways. At the abstract-function level, the values and priorities in the strategy pathway indicate the team members' criteria to evaluate different strategies. At the physical-function level, the physical objects involved in the strategy pathways can be used to indicate if a strategy is feasible to perform.

To summarize, with an examination of the strategy pathways and the physical work-domain constraints, the OR crew can identify (1) what strategies are feasible to implement, (2) which WDA elements are involved in each strategy, and (3) how different team members contribute to the strategy pathways. Then, decide on the feasible strategies and take the best strategy to implement.

In the following section, I will explore the team development strategies for understanding the collaborative requirements of the surgical team.

5.5.5 Team Development Strategies

As discussed earlier, Tuckman's (1956) team development model considers five main stages of progress for a team: (1) forming, (2) storming, (3) norming, (4) performing, and (5) adjourning. During the C-section surgery, the surgical team is at the performing stage. At this point, the surgical team has learned how to work together, manage conflicts, and contribute to meet the team's purpose. Strategies to manage this stage are more focused on the operational strategies and different ways to tackle the tasks in a C-section surgery. At this stage, the team needs to know the work load, task interdependencies, and expertise level of the team members to decide on the sequence of actions. Specially, in case of an emergency, the team should have a good understanding of each other's strength and weaknesses. Table 56 provides a summary of the comparison of the structural and team development strategies identified in StA and Team StA.

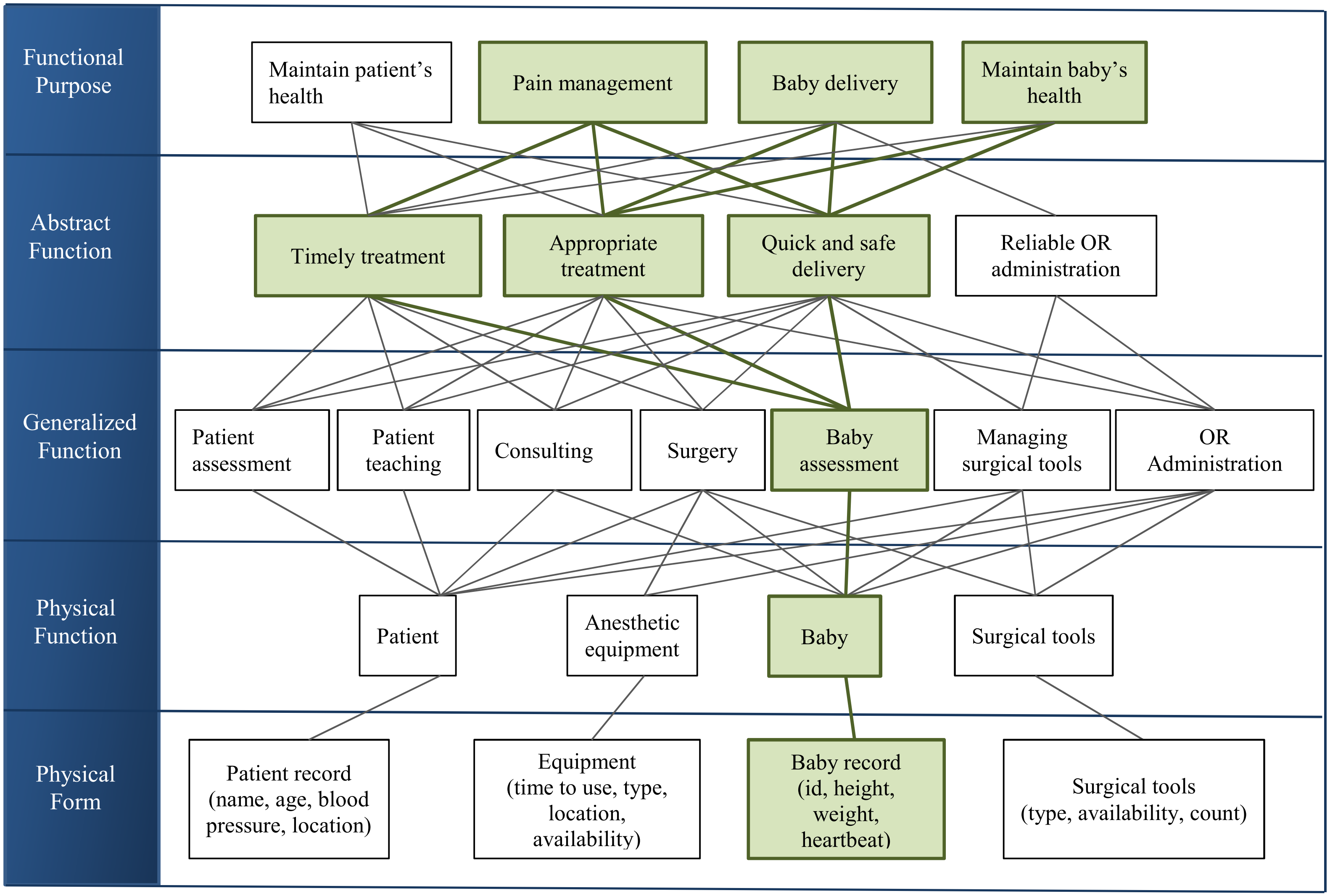


Figure 79. Coordination Structure for Baby Assessment in Emergency.

Table 56: A Summary of the Comparison between the Structural and Team Development Strategies Identified with StA and Team StA.

Constraints	Team StA	Regular StA
Structural strategies	Strategy pathways for baby assessment in newborn evaluation mode: Physical constraint: Baby Processes involved: Baby assessment (People involved: the pediatric team, circulating nurses) Strategy selection criteria: Timely treatment, appropriate treatment, quick and safe delivery	None.
Team development strategies	Needs attached to the forming stage: It was not part of the observation. Needs attached to the norming stage: It was not part of the observation. Needs attached to the storming stage: It was not part of the observation. Needs attached to the performing stage: Similar to the operational strategies.	None.

5.5.6 Summary of the Findings

The value added by the Team StA lies in understanding different ways to carry out the shared OR tasks. While the basic IFM discusses different operational strategies for the individuals' control tasks, it falls short in extracting the team strategies. Team StA considers team strategies and allows for an identification of potential categories of generic team strategies for the OR team. An examination of the operational strategies may enable practitioners to get a better understanding of the team strategies in various situations and help the OR team to evaluate how well the OR team reacts to the changing demands of an emergency situation. The extended CATs for the strategies analysis in the Team StA provides a tool to describe various strategies in terms of the factors, such as resource access, task priority, expertise level, and time constraints, that may influence strategy selection in a variety of situations.

While a basic StA does not include discussion of coordination strategies, Team StA delivers an examination of the OR coordination structures in both emergency and normal situations. This information may be used to identify poor coordination structures or inappropriate leadership styles.

5.6 Comparison between Worker Competencies Analysis and Team Worker Competencies Analysis

In this section, I conduct a traditional WCA and compare the analysis with the findings of a Team WCA. The overall objective of Team WCA is to allow the determination of a series of desirable functional and social attributes for team members based on the requirements of the application domain. In the following section, I will start with conducting a basic WCA to identify the functional competencies required for the surgical participants and, then, analyze the findings of a Team WCA for an examination of team roles and social competencies.

5.6.1 Functional Competencies

Functional competencies define the job-specific competencies that directly reflect the requirements of the application domain. Team WCA consolidates all the requirements imposed by the preceding phases for examining the functional competencies required for effective teamwork. At the Team ConTA section, I identified two main team functions for the newborn evaluation situation: (1) baby assessment, (2) and (2) surgery. For the sake of clarity, in the Team StA section, I explored different strategies for one of the functions (i.e., baby assessment). In this section, I explore the functional competencies for baby assessment.

At the work-domain level, a representation of functional competencies may lead to a more informed task allocation. By describing the required skill-set for baby assessment, it is possible to identify the competent nurses, obstetricians, anesthesiologists, and pediatricians for baby assessment.

At the control-task level, Team WCA may be used for an examination of a series of context-dependent situation-specific behaviours that are required for effectively performing the control tasks.

At the strategy level, Team WCA identifies what strategies are available for baby assessment in terms of experience, ability, and knowledge of the team members. Table 57 shows the SRK inventory for baby assessment in a normal situation. The first column of the SRK inventory represents the team functions. The rest of the columns indicate the skill-, rule-, and knowledge-based behaviours that apply to those team functions.

Table 57: Partial SRK Inventory for Baby Assessment.

Participants	Skill-based behaviour	Rule-based behaviour	Knowledge-based behaviour
Pediatric team: - Pediatrician - Neonatal nurse Circulating team: - Circ1 nurse - Circ2 nurse	An experienced pediatric team should be able to quickly identify the emergency situations and if the baby requires special care. The experienced nurses should be aware of the set of measurements required for baby assessment in the OR	The pediatric team should be able to look up the factsheet available in the OR to interpret the observations and decides if the baby is healthy. The circulating team should be able to look up the fact sheets available in the OR to decide on the required measurements.	Once the required information is collected, the pediatric team should be able to analyze supplementary information and make a decision about the criticality of the situation. The circulating team should be able to identify a list of signs and symbols to observe.

As in Table 57, the experienced participants gravitate naturally towards demonstrating skill-based behaviours, but may switch to rule-based behaviours when an appropriate rule set or a best practice is available. As with many team situations, there is a chain of command during C-sections. The obstetrician is the surgical lead on the team. They have graduated from medical school and have completed their residency, much of it in obstetrics. The obstetrical resident is second in command. There are four or five years of residency after graduation from medical school to become specialized in obstetrics. The further the obstetrical residents are in residency, the more experience they have in obstetrics. It is similar for the pediatric and the neonatal nurse as the assistant to the experienced pediatric. Circulating nurses have the basic knowledge of the anesthesia, obstetrical, and pediatric team's knowledge, rule, and skills. They are not expert in those field but they need to be able to provide sufficient assistance to every other single role in the OR during an emergency situation when needed. The scrub nurse is trained to predicate and prepare the surgical instruments that the obstetrical team might ask for during a surgery.

5.6.2 Social Competencies

While functional competencies describe the skill-set required for the surgical team to take over their functional roles, social competencies indicate the desired behaviours that the team members should exhibit for effective interaction with each other. Figure 77 shows the coordination structure for baby assessment in a normal situation. The coordination structure for baby assessment in a normal situation is similar to the autocratic structure in the Rasmussen's (1998) explanation of the coordination structures. The circ-1 nurse is responsible for coordinating the activities of the circulating team and the pediatrician is responsible for coordinating the activities of the pediatric team. Table 58 shows the functional and team roles allocated to the surgical team when they perform baby assessment. While the circ-1 nurse and the pediatricians are the coordinators, the circ-2 nurse and neonatal can be considered as team-workers. The pediatrician as the experience person in the pediatric team plays the role of the specialist in the Belbin's (1965) team role model.

Table 58: Functional and Team-Roles for the Surgical Team.

Team	Functional role	Team role	Social skills required (Belbin,1981)	Functional skills required
Pediatric team	Pediatrician	- Coordinator - Specialist	Single-minded, self-starting, dedicated to provide knowledge and skills in rare supply Confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	Expert, four or five years of residency after graduation from medical school is required
	Neonatal nurse	- Team-worker	Cooperative, mild, perceptive and diplomatic. Should be able to listen, build, and avert friction	A neonatal student might be a trained nurse or a resident medical student completing her or his training to become a pediatrician
Circulating nurse	Circulating nurse 1	- Coordinator	Confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	The trained nurse who has passed the training period required for participating in a C-section surgery
	Circulating nurse 2	- Team-worker	Cooperative, mild, perceptive and diplomatic. Should be able to listen, build, and avert friction	The trained nurse who has passed the training period required for participating in a C-section surgery

5.6.3 Summary of the Findings

In this section, I explored the functional and social competencies for the surgical team involved with the baby assessment in a normal situation. Table 59 shows a summary of the comparison between a basic WCA and the Team WCA for the pediatric and circulating teams.

With respect to the functional competencies, the SRK inventory for the baby assessment in a normal situation was identified. The SRK inventory explores a range of job-specific competencies required for effective contribution to baby assessment. While functional competencies described the skill-set required for the functional roles, social competencies indicated the desired social behaviours of the surgical team.

Table 59: A Summary of the Comparison between WCA and Team WCA for Baby Assessment in a Normal Situation.

Constraints	Team WCA	Basic WCA
Functional competencies	Similar to a basic WCA.	Function roles: - Pediatrician - Neonatal nurse - Circ1 nurse - Circ2 nurse Functional skills: The skill-, rule-, knowledge- behaviour are examined within the SRK inventory in Table 57
Social competencies	Team roles for baby assessment: - Pediatrician: coordinator, specialist - Neonatal nurse: team-worker - Circ1 nurse: coordinator - Circ2 nurse: team-worker Social skills: -Specialist: single-minded, self-starting, dedicated to provide knowledge and skills in rare supply -Team-worker: cooperative, mild, perceptive and diplomatic. Should be able to listen, build, and avert friction -Coordinator: confident, a good chairperson, should be able to clarify goals, promote decision making, and delegate well	None.

Chapter 6
Summary and Future Work

Figure 80 provides an overview of thesis structure with the highlighted chapter material for Chapter 6. The detailed discussion and specific conclusions for each part of the current thesis were presented in the relevant chapters. Here, the value of the extended models of each phase is summarized and the limitations and areas for future research are discussed.

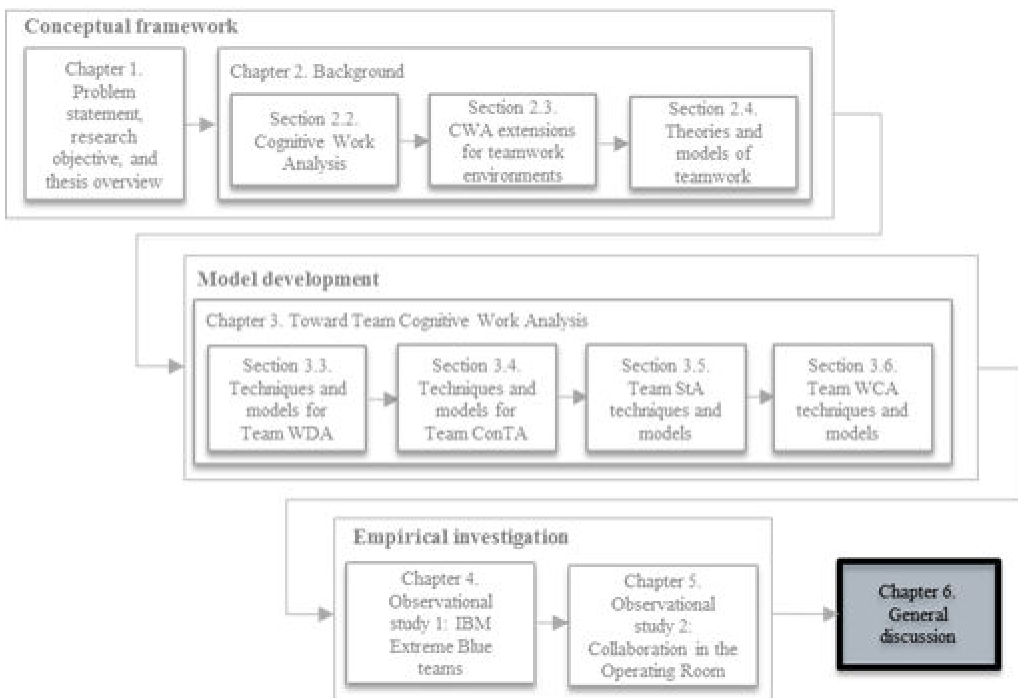


Figure 80. Chapter 6 Overview.

6.1 Significant and Original Outcomes of Research

There were several original outcomes of this research which are given in the sections that follow. The most important outcomes are the identification of shared constraints, team strategies, and social competencies of team players.

6.1.1 Discussion of the Shared Constraints

While the previous attempts to use WDA for teamwork environments show how the work-domain space can be used by teams, they can fall short in an identification of which work-domain elements are used by which team members. Team WDA may identify shared or individual purpose; values, priorities or principles; purposes; and boundary objects. The collaboration table can be used to identify the Team SA requirements at different levels of purposes, values, processes, and physical work-domain resources. Team SA requirements remark the degree to which team members know which information needs to be shared. When higher-level aspects of the work-domain are shared, one can expect various team members to be collaborative and likely to work well together. By identifying areas where higher-level elements are not shared, one may be able to identify where conflicts or counterproductive actions could arise. This discussion could present a good opportunity for providing display of the other team members' actions and their purpose, to support Team SA and make sure that collaboration remains effective.

Team WDA could be also used for an identification of the shared elements of the information space (i.e., boundary objects) in CSCW. Boundary objects often present unique design challenges in that they must be designed to be compatible for different team members or for different teams entirely. Boundary objects are a critical, but understudied, theoretical construct in CSCW (Lutters & Ackerman, 2002). At the work-domain level, the collaboration tables could be used to identify boundary objects and shared elements of the information space in a cooperative work.

Team WDA has potential to be used for designing new teams or identifying poor team structures. By organizing along shared purpose and values, or shared process and objects, more effective team structures may be built.

While the collaboration table may provide a clear table format to represent work-domain elements, the abstraction wheel may offer a graphical illustration of team structure and shared work-domain elements both within a team and across multiple teams.

Schmidth and Bannon (1992) discuss the core issues for CSCW and describe that a CSCW should support the management of workflows and the management of a common information space. At the control-task level, Team CWA could be used to identify the shared workflows and discuss the distribution of the workflow to different team members. The decision wheels could also identify boundary objects and information space elements shared in a team interaction.

At the strategy level, Team StA could be used to examine the work-domain elements involved in each strategy, the various available strategy pathways, and team member contribution to the pathways. This discussion may contribute to identify how different team members in a CSCW use the shared information space when they work together on implementing a strategy.

6.1.2 Discussion of the Team Structure and Inter-team Interactions

The goal of the basic ConTA is to identify the constraints on what needs to be done. Team ConTA expands this objective to identify team structure, team interactions, shared workflows, and boundary objects. ConTA has been successfully used to extract control-task requirements and examine changing demands in various situations. However, ConTA falls short in explaining team interactions, shared workflows, and boundary objects. Team ConTA models expand chained ladders (Rasmussen et al., 1994) into decision wheels (Ashoori & Burns, 2011) and provide suggestions to revamp the CAT for teams (Ashoori & Burns, 2012). For each team interaction, Team ConTA carefully identifies the type of interaction (i.e., synchronous vs. asynchronous), the scope of interaction (i.e., intra-team vs. inter-team interaction), and the boundary objects. When designing a CSCW system to facilitate data sharing, it is essential to examine information flows, boundary objects, synchronicity of communications, shared workflow, and interdependencies between the tasks (Reinhard et al, 1994).

The regular ConTA suggests using the decision ladder to identify control-task requirements for each application domain. While the decision ladder lacks the discussion of inter-team and intra-team communications, the decision wheel provides a graphical illustration of team interactions. The discussion of inter-team interactions in Team ConTA could result in a better understanding of interdependencies between teams, which has not been addressed in ConTA. This understanding can also be used for designing new teams and identifying poor team structures. By organizing along inter-team interactions, more effective team structures may be built.

The decision wheel along with the corresponding decision-wheel tables could be used to extract collaborative work requirements and gain insight into operators' behaviours in relation to another. A serendipitous feature of this structure is that high-level cognitive tasks become focused in the centre "bulls-eye" of the wheel. While the decision-making activities are mapped to the inner circles, observations and actions tend to filter to the outside of the wheel, making it easier to examine team interactions at different levels. With respect to Team SA mechanisms and mental models, the decision wheels show when teams must collaborate on knowledge-based tasks together (the centre of the wheel), where shared mental models might be most needed.

While the decision wheel is a good representation to show how different team members interact on a single control task, the CAT is a good representation to show how individuals are involved in multiple work functions in various situations. However, the basic CAT does not convey information about team structures, team interactions, or boundary objects. The extended CAT for the team analysis provides discussion of team functions in various situations and represents the distribution of team functions to team members. The extended CAT for teams could be used to identify what needs to be done in various situations and examine team interactions over time.

6.1.3 Discussion of Team Strategies

Team StA supplements traditional StA with methods to analyze various aspects of teamwork or team requirements. Team StA emphasizes both formative and descriptive approaches to strategies analysis. With respect to the formative approach, Team StA provides four general categories for examining individual and team strategies: (1) operational, (2) coordination, (3) team development, and (4) structural strategies. The value added by Team StA lies in understanding different ways to carry out shared tasks. While operational strategies focus on different ways of performing control tasks, coordination strategies examine coordination structures and the processes underlying coordination. Team development strategies are used to analyze how operators' behaviours change during the team lifecycle. Structural strategies inherit and build on the work-domain constraints and indicate what is feasible and how to evaluate different strategies.

In a formative approach, strategies are defined as categories; therefore, they accommodate many different action sequences. In a descriptive approach, Team StA focuses on identifying the sequence of actions for different categories of strategies. A description of strategies as a sequence of actions can result in compatible information systems with the knowledge of actual domain practitioners.

Several key requirements are identified by Team StA: coordination structure; feasible strategies; evaluation criteria to select the best strategy; process constraints for each viable and effective strategy; operator behaviour changes during the team lifecycle; Team SA processes; strategy pathways; and team member contributions to each pathway.

Team StA provides a better understanding of the processes underlying effective coordination. With a high-level analysis of interaction patterns, poor coordination structures may be identified. By organizing along the connections between team members and removing any unnecessary interaction, more effective team structures may be built.

6.1.4 Discussion of Social Competencies

The overall objective of Team WCA is to allow the determination of a series of desirable attributes for operators based on the requirements of the application domain instead of a general assumption of qualification requirements. Much of the previous attempts to use WCA for an examination of competencies have focused on examining the skill-set required for operators to take over their functional roles. It leaves open the issue of social competencies and the desired behaviours that operators should exhibit for effective interaction with another. In Team WCA, I consolidate both approaches to analyze operator competencies with respect to (1) functional competencies and (2) social competencies. While functional competencies look at the cognitive skills of individuals, such as problem solving or analytical reasoning, social competencies focus on interpersonal skills required for effective teamwork.

Team WCA adopts Rasmussen’s (1983) SRK taxonomy to evaluate operators’ behaviours in three different levels of interaction with system: skill-based, rule-based, and knowledge-based. Discussion of SRK behaviour at the work-domain level may lead to an identification of the functional competencies required for performing work-domain processes. At the control-task level, Team WCA may be used for an examination of a series of context-dependent situation-specific behaviours that are required for effective teamwork. At the strategy level, Team WCA identifies what strategies are available in terms of experience, ability, and knowledge. Indeed, Team WCA consolidates all requirements imposed by the preceding Team CWA phases for examining functional and social requirements that an operator should possess in order to effectively perform a task in a team. An analysis of SRK behaviours in a team may inform interface design such that both novice and expert behaviours are supported. The socio-technical systems should encourage the use of skill- and rule-based behaviours whenever possible, while at the same time, allowing for operator's seamless transition to knowledge-based reasoning in unanticipated circumstances or when operator is not completely familiar with the task.

Team WCA can draw attention to skill gaps. By comparing the qualifications of team members with the description of the functional competencies required to perform a process, one may design the training programs that are tailored to responsibilities and competencies of team members. Team WCA can be used for examining the social and functional competencies that are required for designing new teams, redesigning poor team structures, and hiring new people. An analysis of the skill gaps between operator competencies and the set of skills required for effective teamwork may be used to identify if extra training or recruitment is necessary. By allocating appropriate team roles to the social competent people, more effective coordination structures may be built.

Team WCA adopts Belbin's (1981) team-role theory for examining how individuals interact in a team and describe a set of social skills for different team roles. By comparing the social skills of individuals and the description of social skills required for each team role, Team WCA can be used to identify which team roles are more suited to which team members. In spite of the dynamic nature of team-role allocation, operators may or may not have flexibility to switch between functional roles. Organizations often hire new employees for specific functional roles and, later, assign different team roles to them based on the coordination structure or the social competencies of the new hires. The functional role of operators usually does not change as each role requires a certain specialties and level of expertise; whereas, team roles and social responsibilities might change based on the scenario, business process, or coordination structure.

6.2 Limitations

There are seven areas that limit the results from this thesis:

1. Designing for extremely large teams. At the work-domain level, the goal of Team CWA is to identify which work-domain elements are shared, and by whom, and which elements only influence individuals. While this information can be derived from joint work-domain models or responsibility maps, with larger teams and more complex interactions, a table format can be clearer. The previous attempts to use CWA for teamwork environments can suffer from a scaling issue, being better suited to environments with two or three clear team roles. Collaboration tables provide a table format for examining the overlaps between decision spaces of team members and can be used for extremely large teams. At the control-task level, the decision wheel allows larger teams to be analyzed. However, it still suffers from scaling issues such that extremely large teams could not be studied with this model.

2. Guidelines. Team CWA provides some guidelines for identifying various operating modes or different situations, but lacks a discussion of how to identify control tasks. A discussion of other task analysis approaches might lend insight into enriching the extended models. As an example, it might be helpful to provide general categories of control tasks such as monitoring or maintenance for the human factors practitioner as a guideline for identifying control tasks in a teamwork environment.

3. Limited software support. The second limitation is the challenge of developing the large number of graphical representations with limited software support. The CWA process is often criticised for being complex and time consuming (Cummings, 2006). Jenkins et. al (2007) has implemented a software tool to expedite the documentation process in a regular CWA and can be used for developing the abstraction hierarchy, decision ladders, and information flow maps. But, there is no software support to date for the responsibility maps, decision wheels, coordination structures, and abstraction wheels.

4. Exploratory not quantified. The Team CWA approach is still exploratory. The applicability of the Team CWA models needs to be quantified. It is valuable to analyze a before and after comparison on the outcomes of applying Team CWA approach to various application domains. Another way to evaluate the applicability of the approach is to characterize the

work domain before applying the Team CWA approach, then make some changes such as CSCW changes or team reorganization and redo the analyses after to evaluate the differences.

5. Consideration of other team models. Team CWA does not necessarily consider all team models. Other aspects, such as macro cognition, community building models, or social networking analysis might be relevant. In the following section, I will expand on this item.

6. Failure factors. When designing a socio-technical system, it is essential to identify failure factors and a team and explore how a socio-technical system can contribute to minimize them. It is observed that teams often do not perform to their potential due to an inadequate awareness of team goals, conflicts between team members, mismatched individual goals, and breakdowns in process and coordination between team members. Although Team CWA provides supports for examination of general failure factors in a team, it does not provide sufficient guidance to identify the application-specific failure factors and explore how the design requirements can be re-examined to accommodate the failure factors.

7. Applicability of the extended models. Team CWA approach might not be applicable to all teams and all domains. In this work, I demonstrated the applicability of the approach to two different application domains. The first observation at the IBM Software Group was characterized as a participatory observation to analyze the team lifecycle for an agile software development team. In the second set of observations at The Ottawa Hospital, I was observing team interactions without interrupting the team tasks. The results of both observations were utilized to enrich the extended models. However, in other application domains, depending on the application, the nature of teamwork may require further extensions to the current approach. For example, in rapid changing teams where the work-domain constraints change quickly, time should be considered as the basis for analysis. Although Team CWA provides an examination of time as a constraint in the work domain, neither CWA nor Team CWA provides a guideline for examination of rapidly changing work domain constraints. Gaining access to other opportunities to conduct other analyses would lend further insight into enriching the current models for various teamwork applications.

6.3 Recommendations for Future Work

Further research in the influence of the organization and individual competencies on how people work together in a team, team strategies, shared tasks, shared mental models, and collaborative tools and devices would nurture the current models toward extending CWA to Team CWA.

A couple of relevant fields that merit detailed investigation in the future are suggested as follows:

1. Team Cognition: To scope this work, I have decided not to explore models of team cognition. Although they certainly describe how well a team works together, these models focus on internal macro-cognitive processes. The focus of this work is to develop CWA models that describe team coordination and collaboration, primarily the external processes of how teams work together and interact with their work domain. Discussion of shared mental models and Team SA mechanisms would nurture the current Team CWA models.

2. Community building models: There is a wealth of information on community building models. While this is also relevant for social organizational analysis, this level of analysis is beyond the team level. It should be noted, however, that Euerby and Burns (in press) have applied the Communities of Practice framework to CWA. The methods examined in this thesis are those that explicitly look at the coordination activities of teams and how teams collaborate.

3. Social Networking Analysis: Social Network Analysis (SNA) has emerged as an analytic approach in modern psychology and has now moved to being a paradigm with its own theoretical statements, methods, and tools. SNA studies the underlying patterns of social structures, how they affect the behaviour of network members, the density and clustering of network, and how patterns of different types of relationships interrelate. Pfautz and Pfautz (2009) have applied the social networks to CWA (Pfautz & Pfautz 2009) to identify the social structure of teamwork. The SNA can be used in CWA to analyze and map social networks but social networks are at a much larger scale than teams.

4. Artificial Intelligence: The focus of this thesis is on human collaboration. However, a CSCW in the future can bring the discussion of intelligent systems and hybrid human-agent teamwork (Sycara & Sukthankar, 2006). Software agents can support either individual team members, or play as a teammate (Ashoori, Miao, & Cai, 2007). The design of a socio-technical system that can make decisions on its own and play as one of the team members

will open a new avenue for research and understanding design requirements in hybrid human-agent teams.

6.4 Conclusions

CWA as an analytical approach for examining complex socio-technical systems can be used to analyze teamwork. However, CWA techniques and models do not yet provide sufficient guidance on identifying shared constraints, team strategies, or social competencies of team players. There has not been a concerted effort to study how CWA can be used for teams. The CWA approach allows room for social and team interactions, but a more explicit analysis of team aspects can reveal more information for systems design. In this thesis, I explored whether a team approach to CWA could yield more information than a typical CWA. I propose that it can be useful to modify the traditional five-level CWA approach to a 2x4 approach, where there is a parallel set of social or team models. Team CWA suggests techniques and models that leverage the synergy between social organization analysis and the available guidelines of CWA for individual work analysis.

Team CWA can make a methodological contribution by extending the CWA framework to support teamwork and should make a practical contribution by demonstrating the usefulness of the framework in a real collaboration context. These developments should enable human factors practitioners to understand the cognitive work of teams better, and to design better systems to support teamwork and collaboration.

Bibliography

Ahlstrom, U. (2005). Work domain analysis for air traffic controller weather displays. *Journal of Safety Research,* 36(2), 159-169.

Ashoori, M., Miao, C., & Cai, Y. (2007). Socializing Pedagogical Agents for Personalization in Virtual Learning Environments, In the *IEEE Proceedings of 2007 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology*, Silicon Valley, CA, USA.

Ashoori, M., & Burns, C. M. (2010). Reinventing the wheel: Control Task Analysis for Collaboration. *Proceedings of the Human Factors and Ergonomics Society's 54th Annual Meeting*, San Francisco, CA, United States.

Ashoori, M., & Burns, C. M. (2011). Control Task Analysis in Action: Collaboration in the Operating Room. In the *Proceedings of the Human Factors and Ergonomics Society's 55th Annual Meeting*, Las Vegas, NV, United States.

Ashoori, M., & Burns, C. M. (2012). Team Cognitive Work Analysis: Structure and Control Tasks. *Journal of Cognitive Engineering and Decision Making.*

Ball, C. T., Langholtz, H. J., Auble, J., Sopchak, B. (1998), Resource-Allocation Strategies: A verbal protocol analysis, *Organizational Behaviour and Human Decision Processes*, 76(1), 70-88.

Belbin, R. M. (1981), *Management teams: Why they succeed or fail.* Oxford: Butterworth-Heinemann.

Bannon, L., & Schmidt, K. (1989). CSCW: Four Characters in Search of a Context. *In Proceedings of the First European Conference on Computer Supported Cooperative Work,* Gatwick, London, 358-372.

Bannon, L., & Bodker, S. (1997). Constructing common information spaces. *In the proceedings of the fifth conference on European Conference on Computer-Supported Cooperative Work*, Norwell, MA.

Beyer, H., Holtzblatt, K. (1998). *Contextual Design: Defining Customer-Centered Systems*. Academic Press.

Bisantz, A. M. & Mazaeva, N. (2009). Work Domain Analysis Using the Abstraction Hierarchy: Two Contrasting Cases. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis* (pp. 15-47). CRC Press, Boca Raton, FL.

Bodker, S. (1991). Activity theory as a challenge to systems design. In H. E. Nissen, H. K., Klein, & R. Hirschheim (Eds.), *Information systems research arena of the 90's* (pp. 551-564). Amsterdam: Elsevier.

Brannick, M. T., Salas, E., Prince, C. (1977). *Team performance assessment and measurement: theory, methods, and applications.* Lawrence Erlbaum Associates.

Burns, C. M. & Hajdukiewicz, J. R. (2004). *Ecological Interface Design*. CRC Press.

Burns, C. M., & Vicente, K. (1995). A framework for describing and understanding interdisciplinary interactions in design. *Proceedings of the 1st conference on Designing interactive systems: Processes, practices, methods, & techniques,* Ann Arbor, MI, United States, 97 – 103.

Burns, C. M., Bryant, D., & Chalmers, B. A. (2005). Boundary, purpose, and values in work-domain models: Models of naval command and control. *Systems and Humans*, *IEEE Transactions on Systems, Man and Cybernetics, 35*(5), 603 – 616.

Burns, C. M., Enomoto, Y., & Momtahan, K. (2009). A Cognitive Work Analysis of cardiac care nurses performing teletriage. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis* (pp. 149-174). CRC Press, Boca Raton, FL.

Burns, C. M., Torenvliet, G., Chalmers, B., & Scott, S. (2009). Work domain analysis for establishing collaborative work. *Proceedings of the Human Factors and Ergonomics Society's 53rd Annual Meeting*, San Antonio, United States.

Cary, M. & Reder, L.M. (2002). Metacognition in strategy selection: Giving consciousness too much credit. In Izaute, M., Chambres, P., & Marescaux, P.J. (Eds.), Metacognition: Process, Function, and Use. New York, NY: Kluwer, pp. 63-78.

Christiansen, E. (2005). Boundary objects, please rise! On the role of boundary objects in distributed collaboration and how to design for them. *Paper presented at 2005 workshop of 'Cognition and Collaboration'*, Portland, Oregon.

Cockburn, A. (2006). *Agile software development: the cooperative game* (agile software development series). Addison-Wesley Professional

Cooke, N. J. (2005). Measuring Team Knowledge. *Handbook on Human Factors and Ergonomics Methods*, Boca Raton, FL: CLC Press, LLC, 49-1- 49-6.

Cornelissen, M., Salmon, P. M., Jenkins, D. P., Lenné, M. G. (2011). How can they do it? A structured approach to the strategies analysis phase of Cognitive Work Analysis. In the *Proceedings of the Human Factors and Ergonomics Society's 55th Annual Meeting*, Las Vegas, CA, United States.

Crone, D. J. (2011). *Selecting Measures to Evaluate Complex Sociotechnical Systems: an Empirical Comparison of a Task-based and Constraint-based Method.* PhD thesis, School of Psychology, University of Queensland.

Crowston, K., Kammerer, E. E. (1998). Coordination and collective mind in software requirements development, *IBM Systems Journal*, 37(2), 227-245.

Cummings, M.L. (2006). Can CWA inform the design of networked intelligent systems. *In the proceedings of Moving Autonomy Forward Conference,* Lincoln, UK.

Davies, J. M. (2005). Team communication in the operating room. *Acta Anaesthesiologica Scandinavica*, 49(7), 898 - 901.

Duck, S. (1989). Socially Competent Communication and Relationship Development. In B. H. Schneider, G. Attili, J. Nadel, & R. P. Weissberg (Eds.), *Social Competence in Developmental Perspective* (pp. 91-106). Kluwer Academic Publishers.

Effken, J. A., Brewer, B. B., Logue, M. D., Gephart, S. M., & Verran, J. A. (in press). Using Cognitive Work Analysis to fit decision support tools to nurse managers' work flow. *International Journal of Medical Informatics.*

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement, *Proceedings of the 32nd Annual Meeting of Human Factors and Ergonomics Society,* Anaheim, CA, United States, 97-101.

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems, *Human Factors*, 37(1), 32-64.

Endsley, M.R. & Robertson, M.M. (2000). Training for situation awareness in Endsley, M.R. and Garland D.J. (Eds.). *Situation Awareness Analysis and Measurement*. Lawrence Erlbaum Associates: Mahwah, NJ.

Endsley, M. R., Bolte, B., & Jones, D. G. (2003). *Designing for Situation Awareness: an approach to user-centered design*. Boca Raton, FL: Taylor & Francis.

Epidural blood patch. (n.d.). In *Wikipedia*. Retrieved November 4, 2011, from http://en.wikipedia.org/wiki/Epidural_blood_patch

Euerby, A. & Burns, C.M. (in press). Designing for social engagement in online social networks using communities of practice theory and cognitive work analysis: A case study. *Journal of Cognitive Engineering and Decision Making.*

Extreme Blue, IBM Extreme Blue internship experience. (2011). Retrieved December 19, 2011 from http://www.ibm.com/extremeblue

Fidel, R. & Pejtersen, A. M. (2004) From information behaviour research to the design of information systems: the Cognitive Work Analysis framework. *Information Research*, 10 (1) paper 210.

Flach, J. M., & Amelink, M. (2003). A search for meaning: A case study of the approach-to-landing. In E. Hollnagel (Ed.), *Handbook of cognitive task design* (pp. 171-191). Mahwah, NJ: Lawrance Erlbaum Associstes.

Gersick, C. J. (1988). Time and Transition in Work Teams: Toward a New Model of Group Development. *The Academy of Management Journal*, 31(1), 9-41.

Gorman, J. C., Cooke, N. J., & Winner, J. L. (2006). *Measuring team situation awareness in decentralized command and control systems. Ergonomics*, 49, 1312-1325.

Gray, W. D., & Kirschenbaum, S. S. (2000). Analyzing a novel expertise: An unmarked road. In J. M. C. Schraagen, S. F. Chipman, & V. L. Shalin (Eds.), *Cognitive Task Analysis* (pp. 275-290). Mahwah, NJ: Lawrence Erlbaum Associates.

Groppe, M., Pagliari, R., & Harris, D. (2009). Applying Cognitive Work Analysis to study airport collaborative decision making design. *Proceedings of the ENRI International Workshop on ATM/CNS.*

Guerlain, S., Adams, R. B., Beth Turrentine, F. F., Shin, T., Guo, H., Collins, S. R., & Calland, J. F. (2005), Assessing team performance in the operating room: Development and use of a “black-box” recorder and other tools for the intraoperative environment. *Journal of the American College of Surgeons*, 200(1), 29-37.

Guzzo, R. A., Salas, E., & Associates (1995). *Team Effectiveness and Decision Making in Organizations.* J-B SIOP Frontiers Series.

Hager, P. & Gonczi, A. (1996). What is competence? *Medical Teacher,* 18(1), 15-18.

Hajdukiewicz, J. (1998). Development of a structured approach for patient monitoring in the operating room. *National Library of Canada*.

Hajdukiewicz, J. R., Vicente, K. J., Doyle, D. J., Milgram, P., & Burns, C. M. (2001). Modeling a medical environment: An ontology for integrated medical informatics design. *International Journal of Medical Informatics*, 62, 79-99, 2001.

Hauland, G. (2002). Measuring Team Situation Awareness in Training of En Route Air Traffic Control: Process Oriented Measures for Experimental Studies, Ph.D. Thesis, Risø National Laboratory.

Heinemann, G. D., Zeiss, A. M. (2002). *Team Performance in Health Care: Assessment and Development (Issues in the Practice of Psychology).* Kluwer Academic/ Plenum Publishers.

Ho, D., & Burns, C. M. (2003). Ecological Interface Design in Aviation Domains: work Domain Analysis of Automated Collision Detection and Avoidance . *Proceedings of the 47th Human Factors and Ergonomics Society's Annual Meeting*, 119-123.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed Cognition: Toward a New Foundation for Human-Computer Interaction Research. *ACM transactions on Computer-Interaction*, 7(2), 174-196.

Hutchins, E. (2000). *Cognition in the Wild*. MIT Press.

Ingram, H., Teare, R., Scheuing, E., & Armistead, C. (1997). *A systems model of effective teamwork.* The TQM Magazine, 9(2), 118-127.

Jenkins, D. P., Stanton, N. A., Salmon, P. M., Walker, G. H., Young., M. S., Whitworth, I., Farmilo, A., Hone, G. (2007). The Development of a Cognitive Work Analysis Tool. In D. Harris (Eds.). *Engineering Psychology and Cognitive Ergonomics*, pp. 504–511. Springer.

Jenkins, D. P., Stanton, N. A., Salmon, P. M., Walker, G. H., & Young., M. S. (2008a). Using Cognitive Work Analysis to explore activity allocation within military domains. *Ergonomics*, 51(6), 798–815.

Jenkins, D. P., Stanton, N. A., Walker, G. H., Salmon, P. M., & Young, M. S. (2008b). Applying Cognitive Work Analysis to the Design of Rapidly Reconfigurable Interfaces in Complex Networks. *Theoretical Issues in Ergonomics Science*. Taylor & Francis.

Jenkins, D.P., Stanton, N. A., Salmon, P. M., & Walker, G. H. (2009). Cognitive work analysis: Coping with complexity. Aldershot: Ashgate.

Kilgore, R. M. & St-Cyr, O. (2006). The SRK Inventory: A Tool for Structuring and Capturing a Worker Competencies Analysis. *Proceedings of the Human Factors and Ergonomics Society's 50th Annual Meeting*.

Kilgore, R. M., St-Cyr, O., & Jamieson, G., A. (2009). From worker domains to worker competencies: A five-phase CWA. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis* (pp. 15-47). CRC Press, Boca Raton, FL.

Lintern, G. (2009a). The Theoretical Foundation of Cognitive Work Analysis. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis* (pp. 15-47). CRC Press, Boca Raton, FL.

Lintern, G. (2009b). *The Foundations and Pragmatics of Cognitive Work Analysis: A Systematic Approach to Design of Large-Scale Information Systems.* Open source book. Retrieved November 7, 2011 from

http://www.cognitivesystemsdesign.net/Downloads/Foundations%20&%20Pragmatics%20of%20CWA%20%28Lintern2009%29.pdf

Lutters, W., & Ackerman, M. (2002). Achieving Safety: A Field Study of Boundary Objects in Aircraft Technical Support. *In proceeding of the 2002 ACM conference on Computer supported cooperative work*, New York, NY, 266-275.

Malone, T. W., Smith, S. A. (1988). Modeling the Performance of Organizational Structures, *Operations Research*, 36(3), 421-436.

Malone, T. W., Crowston, K., (1990). What is Coordination Theory and How It Help Design Cooperative Work Systems?. *Proceedings of the 1990 ACM conference on Computer-supported cooperative work,* 357-370.

Malone, T. W., Crowston, K., (1994). The Interdisciplinary Study of Coordination, Appeared in *ACM Computing Surveys*, 26 (1), 87-119.

McIlroy, R. & Statnton, N. (2011). Getting past first base: Going all the way with Cognitive Work Analysis. *Applied Ergonomics.* 42, 358-370.

Morgan, B. B., Salas, E., & Glickman, A. (1993). An analysis of team evolution and maturation. *The Journal of General Psychology*, 277-291.

Mumford, T. V., Campion, M. A., & Morgeson, F. P. (2006) Situational Judgment in Work Teams: A Team Role Typology, In J. A. Weekley & R. E. Ployhart, *Situational judgment tests: theory, measurement and application* (pp. 319-343). Lawrence Erlbaum Associates, Mahwah, New Jersey.

Naikar, N., Drumm, D., Pearce, B., & Sanderson, M. P. (2000). Designing new teams with Cognitive Work Analysis. In the *Proceedings of the fifth Australian Aviation Psychology Symposium*. Manly, Australia.

Naikar, N., Pearce, B., Drumm, D., & Sanderson, M. P. (2003). Designing teams for first-of-a-kind, complex systems using the initial phases of Cognitive Work Analysis: Case study, human factors. *Human Factors*, *45,* 202-217.

Naikar, N., Hopcroft, R. & Moylan, A. (2005). Work domain analysis; Theoretical concepts and methodology. *DSTO Technical Report, DSTO-TR-1665,* Defence Science and Technology Organisation, Melbourne, Australia.

Naikar, N. (2006). An examination of the key concepts of the five phases of Cognitive Work Analysis with examples from a familiar system. *Proceedings of the Human Factors and Ergonomics Society's 50th Annual Meeting*, 447-451.

Naikar, N., Moylan, A., & Pearce, B. (2006). Analyzing activity in complex systems with cognitive work analysis: Concepts, guidelines, and case study for control task analysis. *Theoretical Issues in Ergonomics Science*, *7*(4), 371-394.

Naikar, N. (2009). Beyond the Design of Ecological Interfaces: Applications of Work Domain Analysis and Control Task Analysis to the Evaluation of Design Proposals, Team Design, and Training. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis* (pp. 15-47). CRC Press, Boca Raton, FL.

Parker, G. M. (2008). *Team Players and Teamwork: New Strategies for Developing Successful Collaboration*, Jossey-Bass, San Francisco, CA.

Parush, A., Kramer, C., Foster-Hunt, T., Momtahan, K., Hunter, A., & Sohmer, B. (2010). Communication and team situation awareness in the OR: Implications for augmentative information display. *Journal of Biomedical Informatics.*

Pfautz, J. D., & Pfautz, S. L. (2009). Methods for the Analysis of Social and Organizational Aspects of the Work Domain. In A. M. Bisantz & C. M. Burns (Eds.), *Applications of Cognitive Work Analysis,* 175-228. CRC Press, Boca Raton, FL.

Pondy, L. R., (2011). Organizational Conflict: Concepts and Models. In Godwyn, G., & Gittell, J. H. (Eds.), *Socialogy of organizations: Structures and Relationships*. SAGE publications, pp. 427-439.

Rasmussen, J. (1980). The Human as a Systems Component. In H.T. Smith & T.R.G. Green (Eds.), *Human Interaction with Computers*. Academic Press, London.

Rasmussen, J. (1981). Models of mental strategies in process plant diagnosis. In J. Rasmussen & W. B. Rouse (Eds.), *Human detection and diagnosis of system failures* (pp. 241-258). New York: Plenum.

Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-13, 257-266.

Rasmussen, J. (1986). A cognitive engineering approach to modeling of decision making and its organization in : process control, emergency management, CAD/CAM office systems, and library systems. In W. B. Rouse (Ed.), *Advances in Man-Machine System Research*, J.A.I. Press Inc.

Rasmussen, J. (1989). Information Technology and Cognitive Work Analysis, *Hand-Out for tutorial workshop on Analysis of Cognitive Work and Design of Ecological Interfaces*, Boston, MA, United States.

Rasmussen, J., Pejtersen, A., & Schmidt, K. (1990). *Taxonomy for cognitive work analysis.* Risø National Laboratory.

Rasmussen, J., Pejtersen, A. M., & Goodstein, L. P. (1994). *Cognitive systems engineering*. New York, NY: Wiley.

Reinhard, W., Schweitzer, J., Volksen, G., & Weber, M. (1994). CSCW Tools: Concepts and Architectures. In *Computer*, pp. 28-36.

Robbins, S. P. & Langton, N. (2005). *Fundamentals of Organizational Behaviour*. Pearson Education Canada Inc.

Rose-Krasnor, L. (1997). The Nature of Social Competence: A Theoretical Review. *Social Development,* 6(1), 111-135.

Rousseau, R., Trembly, S., Brenton, R. (2004). Defining and Modeling Situation Awareness: Acritical Review. In S. Banbury & S. Tremblay (Eds.), *A Cognitive Approach to Situation Awareness: Theory and Application* (pp. 3-21). Ashgate Publishing Company, Burlington, VT.

Salas, E., Dickinson, T. L., Converse, S. A. & Tannenbaum, S. I. (1992). Toward an Understanding of Team Performance and Training. In Swezey, R. W, Salas, E, *Teams: Their Training and Performance*, pp. 3-31. New Jersey: Ablex Publishing Corporation.

Salas, E., Goodwin, G. F., & Burke, C. H. (2008). *Team Effectiveness In Complex Organizations: Cross-Disciplinary Perspectives and Approaches.* SIOP Organizational Frontiers Series.

Schmidt, K., & Bannon, L. (1992). Taking CSCW Seriously: Supporting Articulation Work. *In Computer Supported Cooperative Work (CSCW),* 1(1-2), 7-40.

Schwaber, K., Sutherland, J. (2011). The scrum guide, The Definitive Guide to Scrum: The Rules of the Game, Retrieved January 30, 2012 from http://www.technologyreview.com/business/38486/page2/

Star, S. L., & Griesemer, J. R. (1989). Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkley's Museum of Vertebrate Zoology, *Social Studies of Science,* 1907-1939.

Sycara, K., & Sukthankar, G. (2006). Literature Review of Teamwork Models. *Technical report.* Robotics Institute, Carnegie Mellon University. Retrieved February 7, 2012 from http://www.cs.cmu.edu/~gitars/Papers/CMU-RI-TR-06-50.pdf

Swezey, R. W, & Salas, E. (1992). *Teams: Their Training and Performance, 3-31*. New Jersey: Ablex Publishing Corporation.Vicente, K. J. (1999). *Cognitive Work Analysis, toward safe, productive, and healthy computer-based work*. Lawrence Erlbaum Associates, Mahwah, NJ.

Tuckman, B. M. (1965). Development Sequence in Small Groups. *Psychological Bulletin*, 63(6), 384-399.

Tuckman, B. M., & Jensen, M. A. (1977). Stages of Small-Group Development Revisited. *Group and Organization Studies*, 419-427.

Vicente, K. J. (1997). A history of cognitive engineering research at Risø (1962-1979), *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting*, 210-214.

Vicente, K. J. (1999). *Cognitive Work Analysis, Toward Safe, Productive, and Healthy Computer-based Work*. Lawrence Erlbaum Associates.

Vroom, H. V., Yetton, P., W. (1973). *Leadership and decision-making.* University of Pittsburgh Press.

Wilson, P. (1991). *Computer supported cooperative work: an introduction*. Kluwer Academic Publishers.

Wood, D. J., Gray, B. (1991). Toward a Comprehensive Theory of Collaboration, *Journal of Applied Behavioral Science,* 27 (2), 139-162.