DiCoT Modeling: From Analysis to Design

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ABSTRACT

In this paper we propose an approach called DiCoT (Distributed Cognition for Teamwork) that can be used for contextual analysis and design considerations. We analyse the London Ambulance Service (LAS) control room as a case study. This approach develops five models that guide data gathering, that provide points of reflection, and act as boundary objects between analysts, designers and stakeholders. Through using the method we find that information buffering and situation awareness are important for system performance. We conclude by identifying four ways in which DiCoT can help bridge from analysis to design: understanding the basic mechanics of the system, gaining deeper conceptual insight, recognising incremental design opportunities, and more revolutionary design considerations.

Author Keywords
Distributed cognition, contextual analysis, design.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Contextual analysis and design is challenging because of the amount and variety of data that can be gathered, the potentially wide remit of the design brief, the areas of focus the analysis might take, and communicating this analysis to different people on the design team and other stakeholders. On top of this, relatively simple socio-technical changes in one area may have unanticipated changes elsewhere in the system. We propose DiCoT (Distributed Cognition for Teamwork) as a method for contextual analysis that can help with these issues. The analysis side of DiCoT has been expanded upon elsewhere [3, 6]; here we focus more on how one might use it to move from contextual analysis to design considerations.

BACKGROUND

DiCoT (Distributed Cognition for Teamwork) is an approach to facilitate the application of DC (Distributed Cognition) theory to teamwork settings [3, 5]. DC provides a theoretical lens on an analysis which revolves around the idea of a 'complex computational system' [4]. These systems are complex because they involve physical, social and representational factors that impact on the system's performance; they are computational because they are concerned with the propagation and transformation of information; and they are systems because they involve many different interacting elements. An archetypal example is the bridge of a ship [7]. Here Hutchins [7] makes observations about communication channels, how representations aid navigation e.g. maps, how tools transform information e.g. a compass, and how the social hierarchy on the ship ensures that different goals are met. Hutchins' [7] method was ethnographic and has little in the way of process and structure. In contrast, DiCoT gives guidance on focus, modeling, and the application of DC principles. The case study in this paper focuses on applying DiCoT to the London Ambulance Service (LAS) control room for contextual analysis and design considerations.

DICOT FOR ANALYSIS

It is not uncommon to be overwhelmed with what is happening in a new and unfamiliar context. DiCoT can provide a focus to start to engage with relatively simple tasks to begin data gathering and analysis. For example, drawing a plan of the room or finding out what the main tools and computer systems people use are and what they do. These are part of the five models in DiCoT, which have been inspired and modified from Contextual Design [2]. Each model has some form of visual artefact associated with it, along with DC principles which relate to the propagation and transformation of information. Two key principles that are highlighted by the analysis are 'information buffering' and 'situation awareness'. Buffering is important because information can be held until it is ready to be processed at a convenient time. This information can be held physically e.g. on paper, digitally e.g. in an email inbox, or mentally e.g. by oneself or by a colleague. This small delay in information can keep ongoing decisions and activities from being disturbed. This was observed to work particularly well in the joint working between colleagues. Situation awareness is important for the smooth running of the LAS control room to understand

and anticipate demands of emergency incidents, the location and availability of ambulances, and other colleague's activities so joint working is improved. We introduce the title and focus of the DiCoT models below:
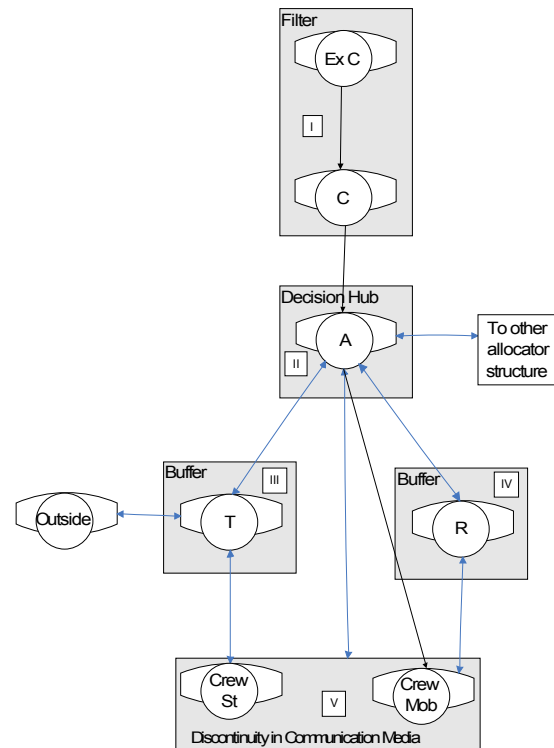
1. Information Flow Model

The information flow model includes how the information is processed, by whom, and by what, from one stage to another. The first stage of analysis is to describe the main function of the system in an input-output style diagram (Table 1). After we break this down into an information flow model. For example, Figure 1 shows an information flow model of the LAS emergency dispatch system. At the top information is filtered from external callers (Ex C) by the call takers (C). This filtered information is passed to the allocator (A) concerned with that area of London and they decide what ambulance to allocate to the incident. The radio operator (R) and the telephone dispatcher (T) contact the mobile ambulance crews (Crew Mob) and the ambulances at stations (Crew St). These ambulance crews might send information back to the allocator via the radio operator and telephone dispatcher, and the telephone dispatcher might contact other outside services e.g. the fire brigade or the police. Although Figure 1 suggests that these people and roles are divided into detached components, analysis shows that joint working and situation awareness are important. Part of this is demonstrated by the buffering activity of the telephone dispatcher and radio operator who will withhold information so it does not unduly disrupt the allocator.

Input	Process	Output
Raw data from an external caller about an incident	-Incident location -Incident priority -Management of resources.	Closest available ambulance crew to a particular site dependent on the priority

Table 1. Input-Output Table of LAS control room system.

2. Physical Model

The physical model concerns itself with the physical layout of the context. This was done at the room level (Figure 2), and the desk level for the LAS control room (Figure 3). For example, Figure 3 shows the arrangement of the sector desks which allow adjacent sectors in London easy communication (a 'sector' is a geographic area of London e.g. NW is the North West sector). Adjacent sectors will have their situation awareness and joint working enhanced due to their co-location. Also, Figure 2 shows the arrangement of a sector desk including the three people that work on a sector and the equipment they use. The 'tray' is a shared resource used by the allocator and radio operator and its position between these two people supports their situation awareness. The people around a desk signify the roles needed to function as an allocating unit. Their co-location means they can process, buffer and filter

Figure 1. Information flow process of LAS emergency dispatch system. Key for letters can be found in Figure 2.

information between themselves more efficiently and so function as a unit better.

3. Artefact Model

The artefact model concerns itself with the artefacts, representations, and tools that are used to store, transform and communicate information. In the LAS control room this includes maps, radio, phones, cards, and computer systems. However, this is not just an inventory but an analysis into the design, use and effectiveness of these artefacts. For example, incident cards are printed at the sector desks for each incident. Decisions and actions are recorded on the incident card, passed between the allocator, radio operator and telephone dispatcher depending on who needs to work on it to progress the incident, and even passed between sector desks in cross-sector working. The incident cards are tangible and persistent so they can be used to buffer information, e.g. instructions can be written and passed between workers and then acted upon at the soonest convenient opportunity. Incident cards are also kept in a tray between the allocator and radio operator in such a way that they can see how many ambulances are allocated from their different stations enhancing their situation awareness of available resources.

4. Social Model

The social model concerns itself with the roles and
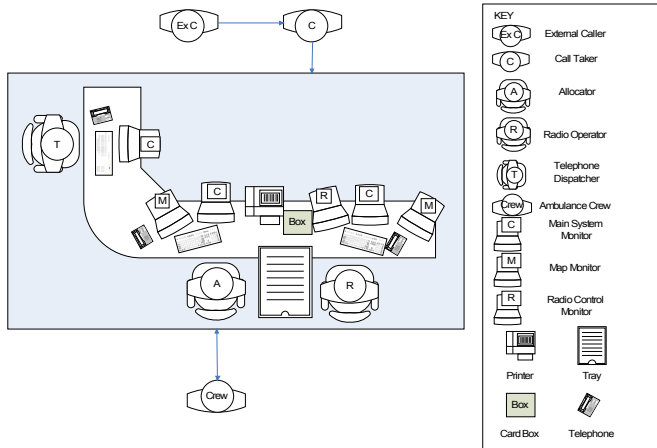
Figure 2. Diagram of a sector desk layout.

responsibilities of the people in the system. The LAS has a chain of command and people with different expertise and experiences in different roles, e.g. as people accumulate experience they will move from being a call taker, to telephone dispatcher, to radio operator, to allocator. Each progressive level of responsibility means more experience, and people at these higher levels will have the necessary experience to appreciate what is happening and needs to happen at the levels beneath them, i.e. they have a greater need and ability for situation awareness in this context.

5. Evolutionary Model

The evolutionary model concerns itself with how the system has evolved over time. There may be important reasons why the system has come to be the way it is. For example, a paper based system for tracking ambulances runs parallel to a computer system because an older computer system once failed leading to much public criticism and controversy [1]. Design recommendations should be understood within this context.

The DiCoT models were developed iteratively in the LAS context, i.e. they were drafted after the initial observation, this highlighted gaps, and then these were addressed in a subsequent round of observations. The DC principles were applied in the analysis but not in a formal way: they were there to inspire reflection, lines of inquiry and data gathering [3, 6]. For example, in terms of 'Arrangement of Equipment', each desk responsible for allocating ambulances for a sector of London was placed next to sectors adjacent to it to facilitate sharing incidents and resources across sectors (Figure 3). Also, in terms of 'Buffering', members of staff would hold-up non-urgent information that might disturb the decision hub (Figure 1).

DICOT FOR DESIGN

Analysis and design are entwined. In moving from analysis to design we identify four ways DiCoT can contribute:
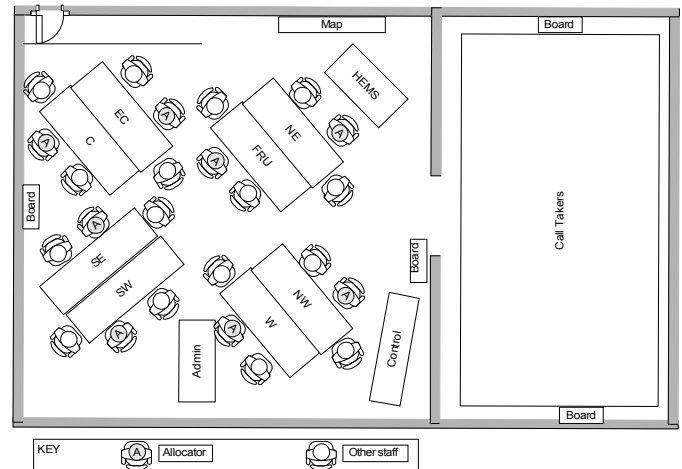
Figure 3. Diagram of the LAS control room.

1. Basic mechanics

At a very basic level people need to understanding the mechanics of the system and what makes it work. This includes the informal and formal nature of work, and how the system actually works rather than how it should work. This also includes the strengths of the system rather than just its weaknesses; i.e. what it is about the system that makes it work well, as these things should not be lost in a redesign. For example, we would be hesitant to move telephone dispatchers away from allocators in a redesign as this may disrupt implicit organisational learning.

2. Deep conceptual insight

Beyond the basic mechanics of the way a system works, the analysis may offer deeper conceptual insight into important elements of the socio-technical system. This might introduce DC related concepts such as 'Buffering'. Buffering information has been associated with people (i.e. the radio operator and telephone dispatcher) and artefacts (i.e. incident cards). These hold information until it can be processed to avoid undue disruption, particularly around the decision hubs.

3. Incremental design considerations

Over the course of an analysis incremental design opportunities may reveal themselves. For example, after some analysis it was proposed that a screen of incident summary details would be more useful than the screen listing incident numbers the LAS staff had. LAS staff liked this suggestion, which was later implemented. The new screen allowed them to have a better overview rather than having to drill down a level to see details of incidents. Design suggestions from analysis might not always be viable but it is an example of recognising issues and bridging from analysis to design.

4. Revolutionary design considerations

Design considerations that are less incremental and more revolutionary require a more dedicated approach to design.
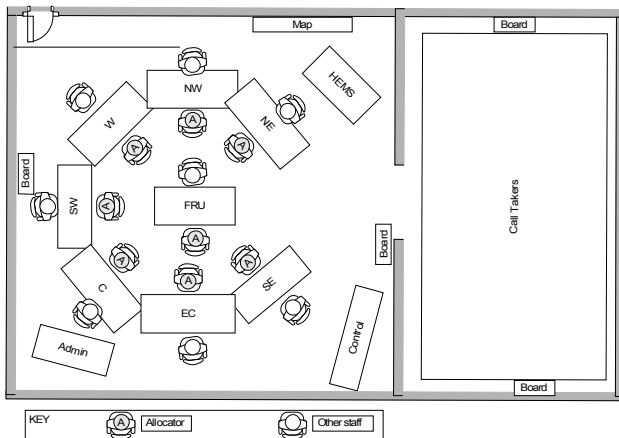
Figure 4. Diagram of a potential LAS control room layout, modified from Figure 3, here all the allocators are sat within an inner circle with radio operators on the outside

For DiCoT this involves using the models as tools for reflection and to play-out the effects of potential design scenarios. For example, Figure 4 shows a potential new room layout for the LAS control room where all the allocators are sat within the inner circle. The motivation for this design was to have the allocators sitting closer together to facilitate better communication between them and better cross-sector working. The radio operators are sat on the outside of the circle and the telephone dispatchers are grouped together somewhere away from this circular formation.

This new design arrangement has inter-dependencies with the way the socio-technical system works which need to be considered across the models. Here we identify design changes and then evaluate this using claims analysis [8]. The pros and cons of the design changes are identified and trade-offs in changes considered. We highlight their pros (+) and cons (-) below:

- Moving allocators closer together.
  + easier communication between allocators , further facilitating cross-sector working, which might be particularly useful in large emergency incidents
  - reorganisation compromises the close working relationship between allocator, radio operator and telephone dispatcher

- Moving telephone dispatchers further away
  + frees room for alternative physical arrangement
  + more telephone dispatchers to support as a group
  - less control over individual telephone dispatchers
  - degradation of telephone dispatcher coupling to allocator as they cannot so easily communicate
  - reduction of implicit learning and the transfer of knowledge between people in different roles

- Moving allocator and radio operator opposite each other rather than working side-by-side
  + allows for alternative arrangements

- reduces peripheral awareness of each other's work as they cannot see what the other is doing

DISCUSSION: FROM ANALYSIS TO DESIGN

We identified different ways that DiCoT can contribute to contextual design. These included understanding the basic mechanics of the system, gaining deep conceptual insight into how the system works (e.g. the roles of buffering and situation awareness), recognising incremental design improvements as the analysis progresses, and finally considering more revolutionary design changes.

Moving from contextual analysis to consider more revolutionary design changes using DiCoT revolved around the models. Following Contextual Design [2], design reconfigurations can be 'played-out' through the models. This 'playing-out' is greatly aided if the person is familiar with the context and the models. For this to be effective, people will have to recognise the consequences of changing part of one model on the others. For example, we reasoned that moving telephone dispatchers away from allocators and radio operators would erode implicit learning between staff in the long term. These changes can be subtle but important.

More broadly, for contextual analysis and design, DiCoT provides a structure for organising information, steps to engage with the context, and a lens in which to view the analysis, i.e. DC. The models provide focus for the analysis; boundary objects for stakeholders, analysts and designers; and points of reflection where design reconfigurations can be played-out.

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